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PRESS TOOLS

Design and Construction

PRAKASH H. JOSHI

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SYSTEM INTERNATIONAL (S.I.) UNITS

Sr. No.	Quantity	S.I. Unit	Symbol	Conversion	
				To Obtain	Multiply by
1.	Length	metre	m	centimetre	100
				millimetre	1000
				inch	39.3708
				foot	3.28084
2.	Area	square metre	m ²	square (Sq) centimetre	10,000
				sq. millimetre	1000,000
				sq. inch	1550.003
				sq. foot	10.76391
3.	Volume	cubic metre	m ³	cubic centimetre	1000,000
				cubic millimetre	1000,000,000
				cubic inch	61023.76
				cubic foot	35.31466
				gallon (U.K.)	219.9692
				gallon (U.S.)	264.172
4.	Force	newton	N	kilogram force	0.1019716
				tonne	0.0001019716
				pound force	0.2248089
5.	Bending Moment or Torque	newton metre	Nm	kilogram metre	0.1019716
				pound foot	0.7375621
6.	Moment of Inertia	metre ⁴	m ⁴	centimetre ⁴	100,000,000
				millimetre ⁴	1000,000,000,000
				inch ⁴	2402510
				foot ⁴	115.8618
7.	Stress and Pressure	Pascal Newton/Meter ²	Pa N/m ²	bar	0.00001
				kilogram/millimetre ²	0.0000001
				pound/inch ²	0.0001450377

Introduction

Sheet metal stampings have now replaced many components which were earlier cast or machined. Material economy and the resultant reduction in weight and cost, high productivity, use of unskilled labour, and a high degree of possible precision have rendered press-work indispensable for many mass produced goods such as electronic appliances, steel furniture, utensils and vehicles. The entire top of a car can be finished to size from a single metal sheet. There is no need for further machining as for castings or forgings.

When the requirement of a component exceeds 50,000 pieces, the product design and development engineer should consider the possibility of manufacture from sheet metal by modifying the design suitably. For example, the outer races of the steering bearings of two-wheelers (Fig. A1)

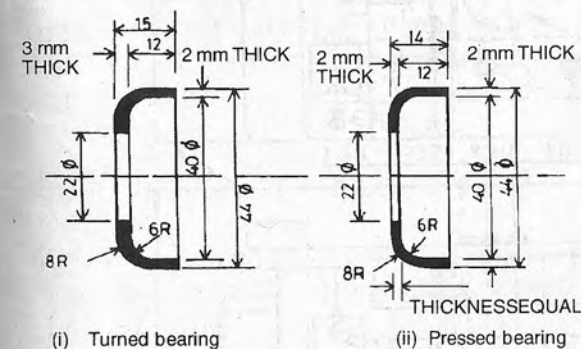


Fig. A1 Modification of turned part for manufacture from sheet metal

were turned from bar-stock for years till an imaginative development engineer changed the design to make the thickness of the rim equal to the thickness of the flange to facilitate manufacture from sheet metal. This reduced the material requirement and the manufacturing time to less than half and ensured interchangeability.

It is possible to control dimensions of pressed components within the eighth grade [IT8] without much difficulty. Even finer tolerances can be achieved through finishing processes such as sizing, burnishing, and ironing.

A1.00 PRESS TOOL DRAWING CONVENTIONS

Press tool drawings differ slightly from the conventional tool drawings. The plan in the press tool drawing shows plan of the die only and excludes

- STAMP
- (1) TONNAGE : 7 TONNES
 - (2) STROKE : 10 MIN
 - (3) SHUTHEIGHT : 130 mm
 - (4) STRIP SIZE : 36 mm × 1.6 mm

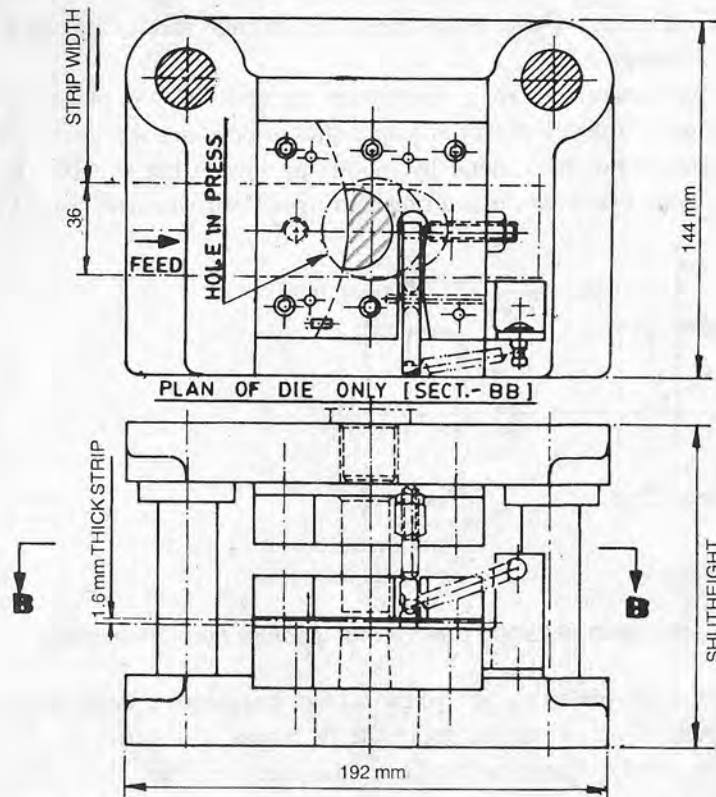
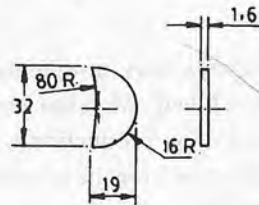


Fig. A2 Press tool drawing conventions

the punches and the top tool for clarity. The plan view should also show the strip in chain-dotted lines and specify the width and thickness of the strip to be used and the direction of strip feed. It is also necessary to draw the fall through hole in table/bolster in chain-dotted line in the die plan. The overall dimensions and tool shut height should be stated to facilitate checking the suitability of tool for use on various presses. The tool drawing also states the tonnage (force) and the minimum stroke required for the operation.

The component description and drawing number as well as the tool drawing number should be stamped on the tool for easy identification and reference.

It is convenient to draw the workpiece with relevant dimensions before and after the operation in the right hand corner of the assembly drawing. This facilitates easy comprehension as well as quick checking of the tool drawing.

Press tool drawings should be checked and cross-checked thoroughly since cutting punches and dies used for metals are made from costly tool steels and are hardened to RC 58–62 hardness. The machining after hardening is generally limited to finishing, as it is rather difficult to machine a punch or die which is as hard as a high speed cutting tool. Of course it is possible to cut hardened steel by Electrical Discharge Machining (E.D.M.) but the process is very slow and rather costly.

The precision press tools used for manufacture of electrical laminations and stampings often cost more than the presses on which they are used. A designer can not afford to leave a single error in the drawings of such tools. For an error in a press tool can prove very costly in terms of money as well as time.

A2.00 DESIGN OF PRESS TOOLS

Design of any press tool involves the following steps:

- (a) Determination of force (press tonnage) required for the operation
- (b) Selection of press for requisite force, workpiece size and shape
- (c) Determination of shut height of the tool
- (d) Computing die thickness, and margins (minimum cross-section)
- (e) Drawing strip layouts and comparing material utilization
- (f) Design of locating elements
- (g) Selection of hardware
- (h) Drawing die plan and selection of pillar die set
- (i) Deciding punch length and mounting

- (j) Finding centre of pressure and checking scrap disposal
- (k) Drawing details

✓(a) **Determination of Force** This chapter deals with determination of shearing force only. Methods for determining forces for bending, forming and drawing (cupping) operations are explained in the following chapters.

Press tools shear off the required workpieces from the parent strip/sheet. The work material yields and bends before cracking at punch and die edges (Fig. A3). The cracks originating at the edges meet to shear

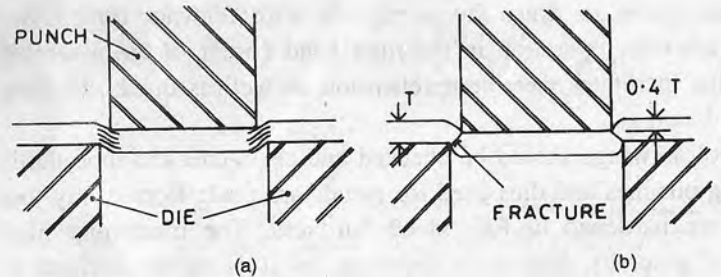


Fig. A3 Shearing action in press tools

the piece from the parent material (Fig. A3). This severance takes place when the punch has penetrated about 40% of the worksheet thickness. Further motion of the punch only pushes the fractured piece through the die. The edges of the severed piece are confined within punch and die dimensions. The punched out piece generally appears as shown in Fig. A4.

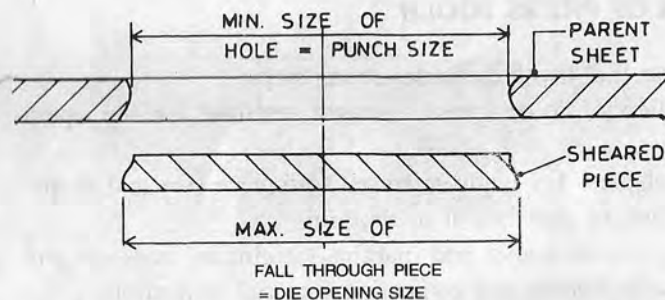


Fig. A4 Edges of sheared piece and parent sheet

Forces Disposition

The forces developed in the shearing operation can be represented by a triangle as depicted in Fig. A5. The vertical shearing force is represented by V while the horizontal lateral force is designated H . The resultant force is represented by R .

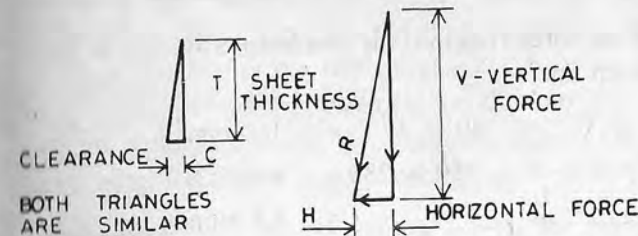


Fig. A5 Forces in shearing

Vertical Force

The value of the vertical component V depends upon the shear strength of the material to be cut and the area to be sheared. Shear area is the product of the length of the cut and the sheet thickness.

Shear Cut Area, $S = \text{Cut Length } [C] \times \text{Sheet Thickness } [T]$

$$S = C \times T \quad [\text{Eqn A1}]$$

$$V = S \times f_s \quad [\text{Eqn A2}]$$

where

V = Vertical shearing force N

f_s = Shear strength of material cut (N/mm^2)

Table A1 states the shear and other strengths of the materials commonly used in sheet metal work.

Table A1 Maximum Strengths of Materials (in N/mm^2)

For materials workhardened in rolling. For 1/2 hard, 1/4 hard, dead soft (refer section M 01.10 in Appendix).

Material	Ultimate Strength		Yield Strength
	Tensile f_t (N/mm^2)	Shear f_s (N/mm^2)	f_y (N/mm^2)
Structural steel	620	400	300
IS C35, C40, St-50, St 58			
Electrical stamping steel	800	530	350
Aluminium IS 19000, 19500	520	280	400

(Contd)

Brass hard, rolled (60% Cu, 40% Zn)	580	310	420
Copper rolled	450	230	260
Magnesium	290	160	220
Nickel	850	400	610
Silicon bronze	980	480	480

- **Example A1** Find the force required for shearing a 40 mm wide $\times$ 4 mm thick Aluminium flat.

$$\begin{aligned} \text{Solution } S &= C \times T = 40 \times 4 = 160 \text{ mm}^2 \\ V &= S \times f_s = 160 \times 280 = 44800 \text{ N} \\ &= 4.5 \text{ tonnes} \end{aligned}$$

- **Example A2** Find the force required to shear a 35 dia hole in a 3 mm thick M.S. sheet.

$$\begin{aligned} \text{Solution } C &= \pi d = \pi \times 35 = 109.96 \\ S &= C \times T \\ &= 109.96 \times 3 \\ &= 329.87 \text{ mm}^2 \\ V &= S \times f_s = 329.87 \times 400 \\ &= 131948 \text{ N} \\ &= 13.5 \text{ tonnes} \end{aligned}$$

Horizontal Force

The value of the horizontal or lateral force H depends upon the die clearance: *the gap between the punch and die cutting edges*. The die clearance depends upon the work material and ranges from two to ten per cent of worksheet thickness.

Let us draw a triangle with workpiece thickness as vertical side, clearance as a horizontal, and the third as a diagonal (Fig. A5). This triangle is similar to the triangle representing the vertical and horizontal forces in shearing. Consequently [the horizontal force can be stated in terms of vertical force percentage. This percentage is the same as the die clearance percentage *per side*.]

- Example A3** Find horizontal force developed while shearing a section with 14.5194 tonnes vertical force and die clearance : (a) 2% (b) 5%

$$\begin{aligned} \text{Solution } (a) \text{ Vertical force} &= V = 145194 \text{ N} \\ H &= 0.02 \times 145194 = 2903.9 \\ (b) H &= 0.05 V = 0.05 \times 145194 = 7259.7 \text{ N} \end{aligned}$$

Thus excessive clearance increases the horizontal force component in shearing operation. It also increases tensile burr on the blank.

Die Clearance

The intentional gap between the punch and die cutting edges, *die clearance*, depends upon the physical properties of the material to be sheared. It is only logical that the ductile materials should have lesser die clearance. Otherwise the soft metal will be drawn into the gap. On the other hand, the harder materials need more die clearance for good shearing action. Excessive die clearance causes more burr on the sheared component. Reduction in die clearance reduces the burr, but hastens the

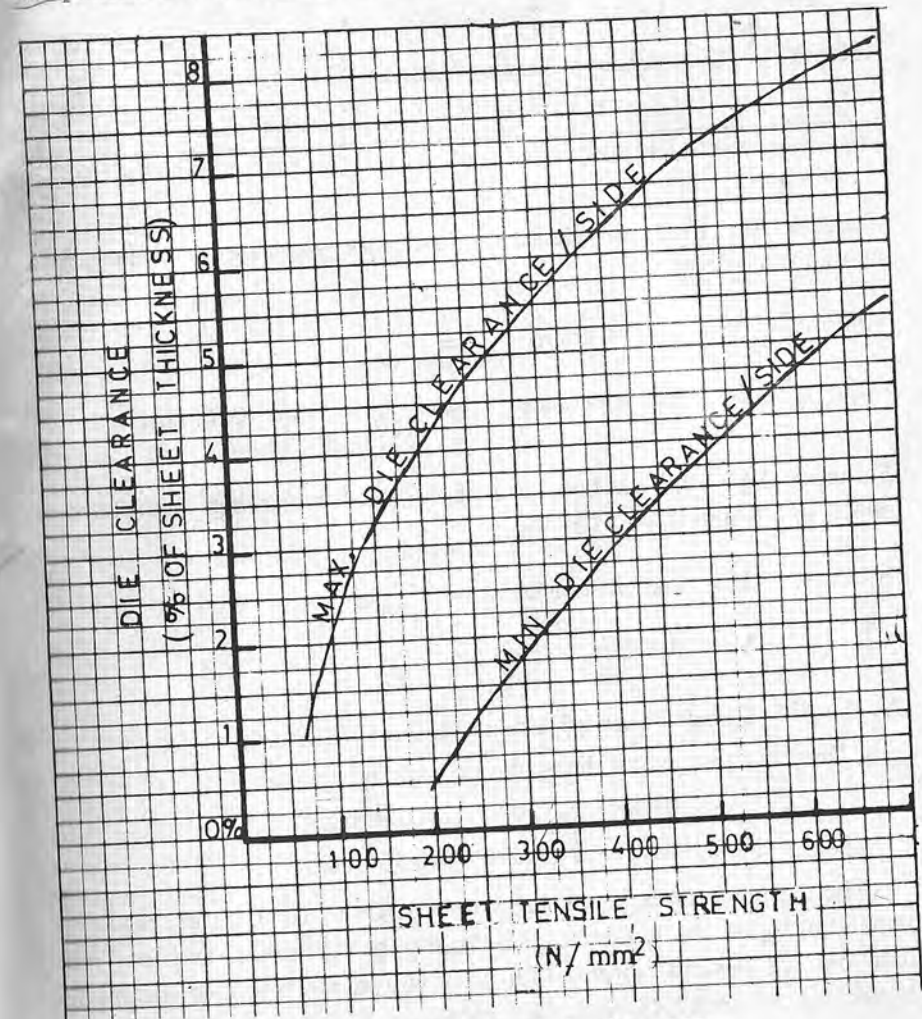


Fig. A6a Workpiece tensile strength and die clearance

blunting of the cutting edges of dies and punches. This results in frequent resharpener of press tools and, decreases the tool life and the number of components the tool can produce. Generally, a press tool produces thousands of components per shift. It is uneconomical and impracticable to deburr the millions of components usually produced in mass production runs. So many industries sacrifice tool life to reduce the inconvenient burr on the sheared components.

Table A2 states the range of die clearances for various materials used in press work. Note that the die clearances are specified in percentage of sheet thickness. The clearances are *per side*. For a closed cutting profile there would be die clearance between the die and the punch all around the profile. Fig. A6a shows the relationship between workpiece strength and die clearance graphically.

Table A2 Die Clearance for Various Materials

Material	M.S.	Aluminium	Brass
Clearance % of sheet thickness	2.5 – 5%	1.5 – 3%	1.5 – 3%

Example A4 Find die clearance range for shearing a 2 mm thick aluminium sheet.

$$\begin{aligned}\text{Solution} \quad \text{Min. die clearance} &= \frac{1.5}{100} \times 2 = 0.03 \text{ mm} \\ \text{Max. die clearance} &= \frac{3}{100} \times 2 = 0.06 \text{ mm}\end{aligned}$$

Example A5 Find the bore size of the die for piercing 10.0 diameter punch in 1.6 mm thick M.S. sheet.

$$\begin{aligned}\text{Solution} \quad \text{Min. die clearance/side} &= \frac{2.5}{100} \times 1.6 = 0.04 \\ \text{Max. die clearance/side} &= \frac{5}{100} \times 1.6 = 0.08\end{aligned}$$

As the die clearance runs all around the piercing punch,

$$\begin{aligned}\text{Die bore} &= \text{punch dia} + 2 (\text{die clearances/side}) \\ &= 10.00 + 2 \times 0.04 = 10.08 \text{ min.} \\ \text{to} &= 10.00 + 2 \times 0.08 = 10.16 \text{ max.}\end{aligned}$$

The die bore can be anywhere within 10.08 to 10.16 range. However depending upon the policy formed from past experience, and tool runs and tool life desired, various industries aim at the lower or the higher limits, i.e. minimum or maximum clearance. Many industries manufac-

turing press tools in hundreds aim at the minimum die clearances stated in Table A2.

The piercing tools used in structural work, on the other hand, aim at maximum die clearance as this increases the range of sheet thickness which can be pierced. There will, of course, be more burr for thinner sheets. But burr can be removed manually, quantities are not very high in structural work. The burr can often be neglected as it rarely affects functional aspects in structural work.

Example A6 Find die bore size for punching 16 ϕ hole in mild steel sheets ranging from 1.5 to 3 mm in thickness.

Solution For maximum thickness 3 mm

$$\begin{aligned}\text{Min. die clearance} &= 3 \times 0.025 = 0.06 \\ \text{Die bore} &= 16 + 2 \times 0.06 = 16.12 \phi \\ \text{For min thickness 1.5 mm max die clearance} &= 1.5 \times 0.05 = 0.075 \\ \text{Die bore} &= 16 + 2 \times 0.075 = 16.15 \phi\end{aligned}$$

It would be preferable to have bigger size 16.15 ϕ die for structural work.

Work Tolerance and Die Clearance

It is not possible to get tolerances closer than die clearance on work. As a result, sometimes it is necessary to have an additional finishing operation such as shaving for high precision work.

Example A7 What will be the punch and die sizes for punching a 25 ϕ H7 hole in 2.5 mm, thick aluminium sheet.

Solution For 25 ϕ H7 the limiting sizes are 25.021/25.000.

If we keep die of 25.021 ϕ and punch 25.00 ϕ

$$\begin{aligned}\text{Die clearance} &= \frac{0.021}{2} \times \frac{1}{2.5} \times 100 \\ &= 0.42\%\end{aligned}$$

Since this is less than the recommended minimum 1.5% per side for aluminium it would be necessary to first pierce a hole of 24 ϕ and shave it to 25 ϕ H7 in finishing.

Example A8 Find the process tolerance for blanking 40.0 ϕ piece from 2.00 mm thick M.S. Sheet.

Solution Taking min. die clearance of 2% per side

$$\text{Die clearance} = 2 \times \frac{2}{100} = 0.04/\text{side}$$

$$\text{Clearance of diameter} = 0.04 \times 2 = 0.08$$

$$\therefore \text{Process tolerance} = 0.08$$

The die can be made of 40.00 ϕ bore and the punch can be reduced by 0.08 to 39.92 ϕ . This would produce blanks to $\phi 40 - 0.08$ tolerance consistently.

Die Clearance and Tool Life

Increase in die clearance increases tool life. Doubling clearance from 2.5–5 % (for mild steel worksheet) doubles the tool life. So when the requirements of blanks is not very high, it is convenient to keep die clearance more and remove the excessive tensile burr on the blanks manually. Figure A6b shows the relationship between die clearance and tool life graphically. It can be noted that increase in die clearance does not enhance tool life as much for stainless steel workpiece as for carbon steel workpiece.

(b) Selection of Press The press should be capable of delivering about 33% more force than required. The cutting edges of dies and punches

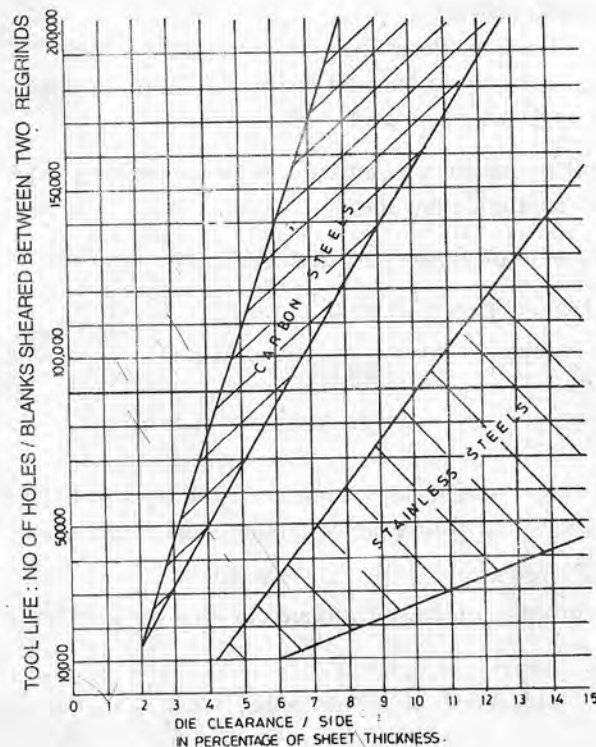


Fig. A6b Die clearance and tool life

get blunt due to usage which increases the vertical force considerably. The press tool size, too, should suit the press. After selecting one of the available presses with suitable tonnage, the following specifications of the selected press should be perused for tool suitability.

Table Length and depth (transverse width) of press table should be more than width and length of tool to ensure proper resting of the tool on the table. [Fig. A7a] Overhanging parts of tools bigger than press table should be supported adequately with screw jacks or brackets screwed to press table sides.

Clear hole in the table should be bigger than the scrap/blank which must fall through the table hole. When a bolster is used, the hole in the bolster must be bigger than the fall through scrap/blank.

Shank hole Tool shank should be running fit in the shank hole. The length of the shank should be 1 to 2 mm less than the shank hole depth to ensure full contact of the ram face with the top bolster of the tool. The shank clamping screw should be almost at the centre of the tapered part of the shank. (Fig. N8).

Shank positions the press tool on the table in such a way that the fall through scrap/blank can have clear passage through the bolster and table holes.

Throat The maximum distance from the shank centre to the rear end of the tool must be less than the throat of the press. Otherwise it will not be possible to assemble tool shank in the shank hole in the press. Generally the throat is half the table depth. [Fig. A7a]

Opening at back In inclinable presses blanks/scrap bigger than table hole size can be disposed off through the opening in the rear frame of the press. The press is usually inclined to a 30° descent towards the rear to effect gravitational slide down of the blank/scrap through the opening in rear frame. Naturally the blanks should be smaller than the opening at the back.

Stroke Fixed stroke as well as adjustable stroke presses are used widely. The stroke of the press should be long enough to accomplish the work executed on the press. (Bending tools require longer press strokes than cutting tools while deep drawing calls for longest strokes.) The clearance required for loading and unloading workpieces must be taken into account while determining the minimum stroke necessary for the operation. [Fig. A7b]

(c) Tool Shut Height It is the height of the press tool in the closed condition, at the end of the downstroke position.

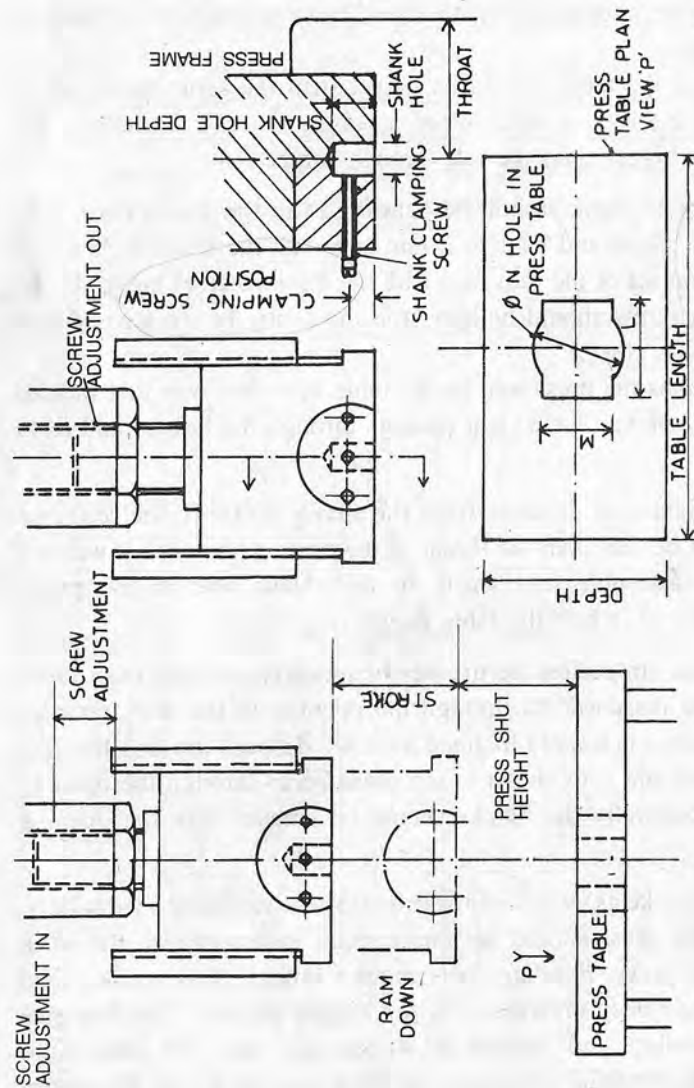


Fig. A7a Press dimensions required for press tool design

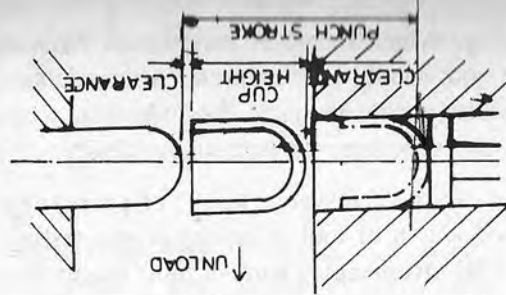


Fig. A7b Stroke required for operation

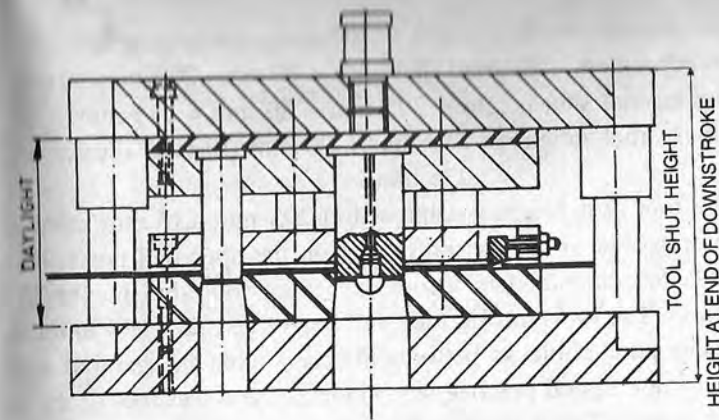


Fig. A7c Tool shut height

Press shut height Press rams are provided with a screw for height adjustment (Fig. A7a). Press shut height is measured when the adjusting screw is inserted fully up into the pitman (connecting rod) of the press. Thus press shut height is the distance between the table and the ram face in ram down, screw adjustment up position. In case of adjustable stroke presses the maximum stroke available should be considered while computing the press shut height.

Tool shut height should be kept 5–10 mm less than the press shut height to provide a little height adjustment during press setting.

When the cutting edges of punches and dies become blunt due to repeated use, the cutting faces are ground on a surface grinder to resharpen the cutting edges. This reduces the height/length of die/punch, and results in a decrease in the tool shut height. The screw adjustment of the press ram can be used to bring the ram down as the press tool wears and shut height decreases.

Sometimes the tool shut height is kept much lesser than the press shut height to effect material economy. Under such circumstances the screw adjustment for the ram should be availed fully to reduce the tool shut height. At the same time it is necessary to allow for reduction in the tool shut height due to regrinds. It is customary to keep 10–20 mm of screw adjustment for this purpose.

Example A9 Find optimum tool shut height for a press with the following specifications:

Press Specifications

- | | |
|--------------------|----------|
| (1) Shut Height | = 305 mm |
| (2) Ram Adjustment | = 80 mm |
| (3) Stroke | = 70 mm |

Solution Maximum tool shut height = $305 \text{ mm} - 10 \text{ (adj)} = 295 \text{ mm}$
 Screw adjustment – Re grind allowance = $80 \text{ mm} - 20 \text{ mm} = 60 \text{ mm}$
 Minimum tool shut height = $295 \text{ mm} - 80 \text{ mm} = 215 \text{ mm}$
 Optimum tool height = $215 \text{ mm} + 20 \text{ mm (regrind allowance)}$
 $= 235 \text{ mm}$

Unless the tool shut height is kept within 295 mm–215 mm range it would not be possible to use the press tool on the specified press. It is just impossible to accommodate a tool exceeding tool shut height 305 mm on the press. The tools having tool shut height less than 215 mm can be used by using parallel blocks between the press table and the tool base (Fig. A7d). It is not a good practice as it subjects the lower tool or die to high bending stress. The deflection of lower tool should be checked before using the parallel blocks.

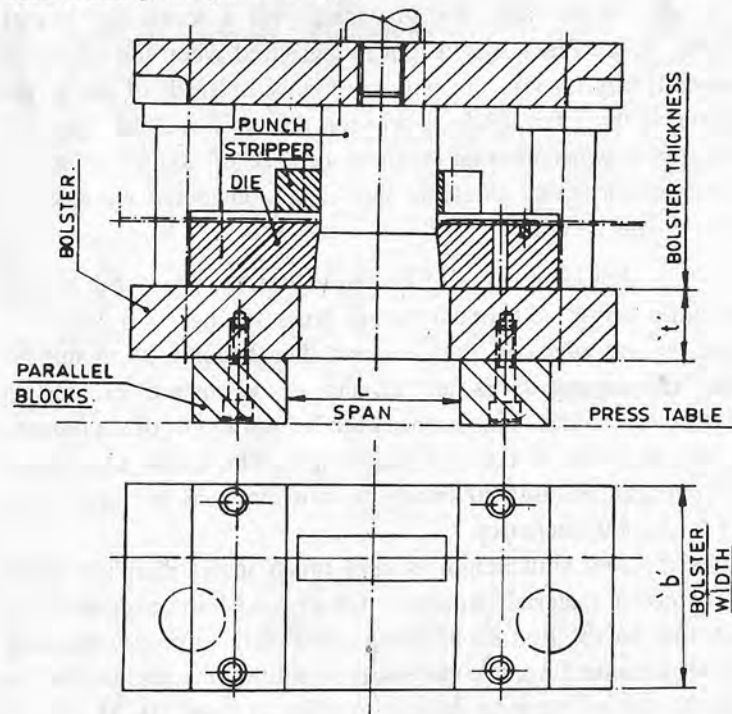


Fig. A7d Use of parallel blocks to increase shut height

The deflection of the die bottom bolster (die shoe) should be contained to 0.025 mm by controlling the span between the parallel blocks, or by increasing the bottom bolster thickness in the lower tool.

The lower tool can be considered a simply supported beam with a uniformly distributed load. The deflection can be found from the following formula:

$$\text{Max. Deflection} = d = \frac{5WL^3}{384EI}$$

where W = Load on the bolster (N)

L = Span between parallel blocks (mm)

E = Modulus of elasticity

$= 2.080 \times 10^5 \text{ N/mm}^2$ for steel bolsters

$= 1.000 \times 10^5 \text{ N/mm}^2$ for cast iron bolsters

I = Moment of inertia of bolster (mm^4)

$$= \frac{bt^3}{12}$$

b = Transverse width of bolster (mm)

t = Thickness of bolster (mm)

Example A10 Find maximum permissible span between parallel blocks to be fitted to a die bottom bolster having width (b) 112 mm and thickness (t) 50 mm and subjected to blanking force (W) 20 tonnes if the bolster is made of (i) cast iron and (ii) mild steel.

Solution $I = \frac{bt^3}{12} = \frac{112 \times 50^3}{12} = 1166666.7 \text{ mm}^4$

$d = 0.025 \text{ mm}, W = 200000 \text{ N}$

$L = \sqrt{\frac{d \times 384 \times EI}{5W}}$

(i) For C.I. $E = 1.000 \times 10^5$

$L = \sqrt[3]{\frac{0.025 \times 384 \times 1.000 \times 10^5 \times 1166666.7}{5 \times 200000}}$
 $= 105 \text{ mm}$

(ii) For M.S. $E = 2.08 \times 10^5$

$L = \sqrt[3]{\frac{0.025 \times 384 \times 2.08 \times 10^5 \times 1166666.7}{5 \times 200000}}$
 $= 132 \text{ mm}$

If the blank length is more than the calculated span, it is necessary to increase the die bolster thickness to provide suitable span for easy fall of blank.

Example A11 Calculate the thickness of a mild steel die bottom bolster for a press tool subjected to 20 tonnes load if the distance between the parallel blocks is 200 mm and the deflection must be contained within 0.02 mm. Width of bolster = 112 mm

Solution $W = 20 \times 9806.6 \text{ N}; L = 200 \text{ mm}$

$$d = 0.02 \text{ mm}; E = 2.08 \times 10^5 \text{ N/mm}^2$$

$$I = \frac{bt^3}{12} = \frac{112 t^3}{12} = 9.333 t^3$$

$$d = \frac{5}{384} \frac{WL^3}{EI}$$

$$\therefore I = \frac{5}{384} \frac{WL^3}{E \times d} = 9.333 t^3$$

$$\therefore t = \sqrt[3]{\frac{5 \times 196133 \times 200^3}{384 \times 2.08 \times 10^5 \times 0.02 \times 9.333}}$$

$$\therefore t = \sqrt[3]{\frac{8 \times 10^{11}}{1.46 \times 10^6}} = 81.6 \text{ mm}$$

The span between the parallel blocks should be controlled by screwing the parallel blocks to the bottom bolster to prevent tampering with the span.

(d) **Computing Die Thickness and Margins** Circular dies used for shearing round holes/blanks are subjected to bending stress. The tensile stress depends upon the vertical force, inside and outside diameters and the thickness of the die. Hardened shearing dies can be safely stressed upto 160 N/mm^2 .

$$\text{Circular die height} = T_c = \sqrt{\frac{1.5V}{f_t} \left[1 - \frac{D}{3d} \right]}$$

where

V = Vertical shearing force [Newtons (N)]

f_t = Permissible tensile stress (N/mm^2)

= 160 N/mm^2 for hardened die

d = Inside ϕ of die (mm)

D = Outside ϕ of die (mm)

= $2d$ preferably

Note: $(D - d)$ should not be less than 6 mm.

Height T_c should be increased by 3 mm for resharping.

Example A12 Find the die height for piercing a $\phi 20$ hole in 2 mm thick steel sheet having 350 N/mm^2 shear strength.

Solution

$$\begin{aligned} V &= \pi d \times f_s \\ &= \pi \times 20 \times 2 \times 350 \\ &= 43982.3 \text{ N} \end{aligned}$$

Now

$$d = 20 \text{ mm}$$

Taking

$$D = 2d$$

$$D = 2 \times 20 = 40 \text{ mm}$$

$$= \sqrt{\frac{1.5V}{f_t} \left(1 - \frac{D}{3d} \right)}$$

$$= \sqrt{\frac{1.5 \times 43982.3}{160} \left(1 - \frac{40}{3 \times 20} \right)}$$

$$T_c = 11.66 \text{ mm} = 12 \text{ mm}$$

3 mm resharping allowance must be added to the computed value.

$$\text{Die thickness} = 12 \text{ mm} + 3 \text{ mm} = 15 \text{ mm}$$

Minimum section of die should be checked for shear strength.

Die shear area

$$= (D - d) (T_c)$$

$$= (40 - 20) (12) \text{ mm}^2$$

$$= 240 \text{ mm}^2$$

$$\text{Shear stress on die} = \frac{43982.3}{240} = 183 \text{ N/mm}^2 = \frac{F}{A} < 240$$

Although higher than the tensile design stress, the shear stress is within the acceptable limit of 240 N/mm^2 .

Rectangular dies are more convenient for rectangular piercing/blanking. Thickness of rectangular die can be found from the following formula:

$$T_r = \frac{3V}{f_t} \left[\frac{\frac{(B)^2}{(A)}}{1 + \left(\frac{B}{A} \right)^2} \right]$$

where

T_r = Thickness of rectangular die (mm)

V = Vertical force (N)

f_t = Permissible tensile stress (N/mm^2)

$$= 160 \text{ N/mm}^2$$

B = Width of slot/blank (mm)

A = Length of slot/blank (mm)

Example A13 Find thickness of die for piercing 20×40 slot in an aluminium blank having 3 mm thickness. ($f_s = 250 \text{ N/mm}^2$)

Solution

$$V = 2 [20 + 40] \times 3 \times 250$$

$$= 90000 \text{ N}$$

$$f_t = 160 \text{ N/mm}^2; B = 20 \text{ mm}; A = 40 \text{ mm}$$

$$\therefore Tr = \frac{3V}{f_t} \left[\frac{\left(\frac{B}{A}\right)^2}{1 + \left(\frac{B}{A}\right)^2} \right]$$

$$= \frac{3 \times 90000}{160} \left[\frac{\left(\frac{20}{40}\right)^2}{1 + \left(\frac{20}{40}\right)^2} \right]$$

$$= 18.4 = 18 \text{ mm}$$

$$\therefore \text{Die thickness} = 18 \text{ mm} + 3 \text{ mm} = 21 \text{ mm}$$

Margin usually ranges from one to two times the die thickness. Taking the maximum value,

$$M = 2 Tr$$

$$= 2 \times 18 \text{ mm} = 36 \text{ mm}$$

Let us check the shear stress on the die.

$$\text{Die shear area} = 2 MT_r$$

$$= (2 \times 36 \times 18) \text{ mm}^2$$

$$= 1296 \text{ mm}^2$$

$$\text{Shear stress} = f_s = \frac{90000}{1296 \text{ mm}^2}$$

$$= 69.4 \text{ N/mm}^2$$

As an exercise let us calculate the margin for shear stress 120 N/mm^2 .

$$2 MT \times f_s = 90000 \text{ N}$$

$$M = \frac{90000}{2 \times 18 \times 120 \text{ N/mm}} = 20.8 \text{ mm}$$

$$= 21 \text{ mm}$$

Thus the margin can be safely be 20% more than the die thickness.

Margin is the solid cross-section around the die cutting edge. (The fixing screws and dowels should be placed outside the margin to prevent weakening of the die.) In other words there should not be any hole in a 21 mm wide band around $20 \text{ mm} \times 40 \text{ mm}$ die opening: in a $62 \text{ mm} \times 82 \text{ mm}$ rectangle around the slot. [Fig. A7f]

(e) Drawing Strip Layout and Computing Material Utilization The first stage in press work entails shearing out flat workpieces (blanks) from a sheet metal strip. Correct positioning of blanks on strip can reduce material wastage considerably. So designers draw at least three different types of strip layouts and compute material utilization to compare their merits.

(Refer Section. B4.00 'Blanking Tools' for further details)

(f) Design of Location Elements This depends upon the annual requirement, the type of tool and workpiece shape. Chapter 'H' describes various types of press tool elements: stops, pilots and strippers, etc. Press Tools described in Chapters 'B' to 'G' illustrate the applications of the elements and the criteria for selection.

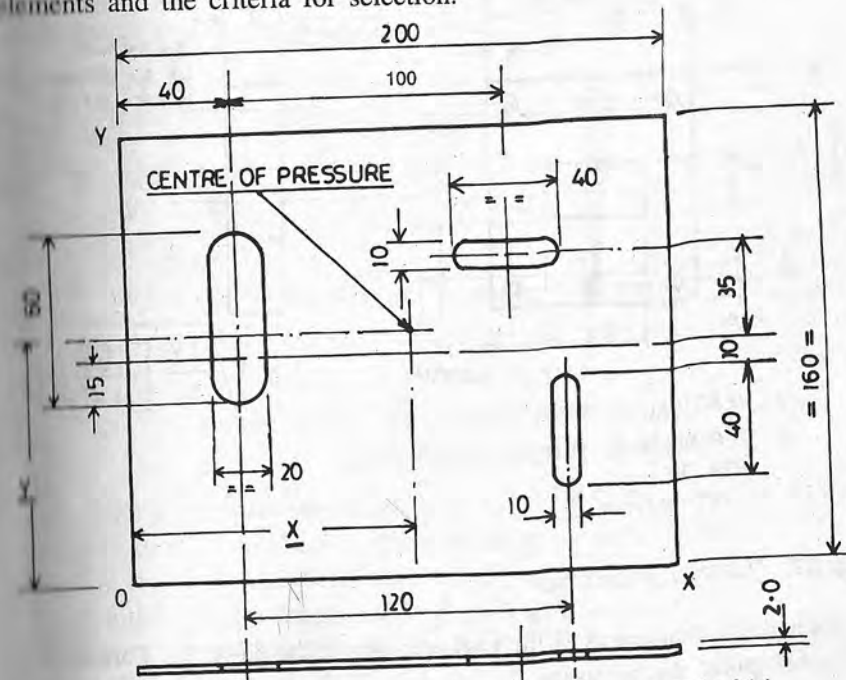


Fig. A7e Finding centre of pressure: workpiece for example A14

(g) **Selection of Hardware** The screws securing punch/punch plate and die to die set bolsters should be able to withstand the stripping load. (Refer Section B1.20 for details). As the stripping force is about one-tenth the vertical shearing force V the securing screws should be able to withstand 10% of the vertical force safely. Heat treated socket head cap (Allen) screws can withstand double the load permissible for commercial hexagonal head bolts and nuts. The dowels should withstand shear stress due to the horizontal force H dependent on die clearance. Example B1 in section B1.24 illustrates the procedure for computing sizes and number of screws and dowels. By this method, piercing tool in example A13 can be secured by four M8 screws. If screws are placed on parallel lines on both sides of slot.

Minimum centre distance = $62 + 8 = 70$ between screws [Fig. A7f].

(h) **Drawing Die Plan and Selection of Pillar Die Set** The screws and dowels are positioned beyond the die margin and are well clear of the strip feed passage. They are provided with a margin equal to the screw/dowel diameter from the outer periphery. Minimum die size can be found from die and screw margins and screw positions. In example A13 the die width would be 86 [Fig. A7f]. The tool area of die set should be about 5 mm more in width and length to permit slight shift of die for

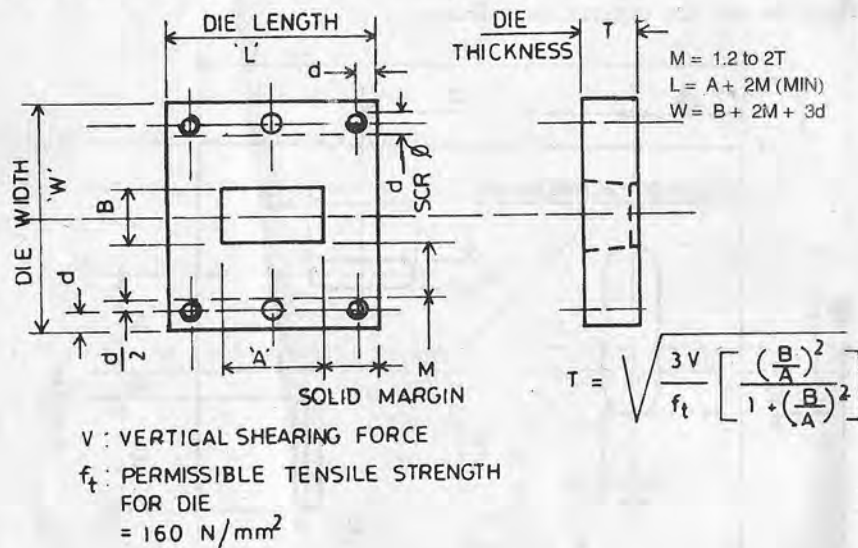


Fig. A7f Design of die block

alignment. In example A13 the tool area would be 87×91 . Para B1.11 describes pillar die set usage.

(i) **Deciding Punch Length and Mounting** The Punch length depends upon the shut height of the press tool and thickness of die set bolsters, die, and back plate.

Punch length = Shut height - Die Thickness - Sum of die set bolster thickness - Back plate thickness (When used) + 3

Punch mounting depends upon the interface area between the punch and die set top bolster/back plate. When pressure exerted by the punch on the bolster is less than 80 N/mm^2 no back plate is necessary. Large punches subjected to deflection less than 0.025 mm during cutting can be directly screwed to top bolster of die set. Piercing punches as well as small blanking punches are usually housed in a punch plate. Punches subjected to bending (due to cutting on one side only) are usually anchored in die set bolsters.

(ii) **Finding Centre of Pressure and Checking Scrap Disposal** For even wear of press ram guides, the location shank (refer para B1.12 for function) centre line should coincide with the shearing force V . When only one shape is being sheared, the force V acts at the centroid of the area of the shape. So the shank should be placed at the centroid.

However, when more than one punches are used it is necessary to find out the position of the resultant force. The shank position should coincide with the resultant force position. This position is called **Centre of Pressure**. It can be found by taking moments about two square edges of the die.

Example A14 Find the centre of pressure for the piercing die shown in Fig. A7c, if the blank thickness is 1 mm and $f_s = 400 \text{ N/mm}^2$.

Solution Shearing force for a $60 \text{ mm} \times 20 \text{ mm}$ wide slot = V_1

$$V_1 = 400 [\pi \times 20 + 2(60 - 20)] = 57132.7 \text{ N}$$

$$V_2 = \text{Shearing force for a } 10 \text{ mm} \times 40 \text{ mm slot} \\ = 400 [\pi \times 10 + 2(40 - 10)] = 36577.4 \text{ N}$$

$$\text{Resultant Force} = V_1 + 2 V_2 = 57132.7 + 2 \times 36566.4 = 130265.5 \text{ N}$$

Taking moments about left hand edge OY

$$\text{Moment} = 57132.7 \times 40 + 36566.4 \times 140 + 36566.4 \times 160 = 13255228 \text{ N}$$

Equating this to the moment of resultant V around OY

$$130265.5 \times X = 13255228 \\ X = 101.75 \text{ mm}$$

Similarly, taking moments about die edge OX

$$130265.5 \times Y = 57132.7 \times 95 + 36566.4 \times 50 + 36566.4 \times 115$$

$$\therefore Y = 87.98 \approx 88 \text{ mm}$$

The centre of pressure is situated at 101.75 mm from left hand edge OY and 88 mm from edge OX. The shank should be placed, theoretically, at the centre of pressure.

However, the shank position should be checked for disposal of sheared pieces falling through the hole in press bolster/press table. This can be done by drawing the hole in the press bolster with the shank at the centre of pressure. If the sheared pieces do not fall within the press bolster hole, the shank position can be shifted marginally to bring the fall through blank/scrap within the press bolster hole area even at risk of uneven wear of ram guides.

If shifting the shank is not possible as in long progressive tools a special bolster can be provided for disposal of the sheared pieces (refer section B6.12 and Fig. B42). Blanking tools for workpieces bigger than fall through hole in press bolsters are designed as inverted tools with ejection through knockout. (Refer Section B4.50 and Fig. B24(b)).

- (k) **Drawing Details** Hardened parts such as punches, dies, and locators should be examined for vulnerability during heat treatment.

Sheet metal press tools can be broadly classified as follows:

(1) Cutting Tools:

- (a) Shearing tools
- (b) Cropping tools
- (c) Piercing tools
- (d) Blanking tools
- (e) Trimming tools
- (f) Compound tools
- (g) Progressive tools

(2) Bending Tools:

- (a) V and L bending tools
- (b) Channel bending tools
- (c) Tube bending tools
- (d) Curling tools
- (e) Multi-action bending tools

(3) Forming Tools:

- (a) Flanging tools
- (b) Beading tools

(4) Drawing Tools:

- (a) Single-action drawing tools

(5) Miscellaneous Tools:

- (b) Multi-action drawing tools
- (c) Ironing tools
- (a) Bulging tools
- (b) Reducing tools
- (c) Embossing and Coining tools
- (d) Cold working tools
- (e) Extrusion tools
- (f) Shaving and Sizing tools

sizing punch - round edge.

Cutting Tools

This section describes various types of cutting tools.

B1.00 SHEARING TOOLS

Shearing tools cut an *open contour* while blanking implies *closed contour* cutting (Fig. B1). Standard shearing machines are convenient for cutting big sheets into strips and other configurations with straight line periphery.

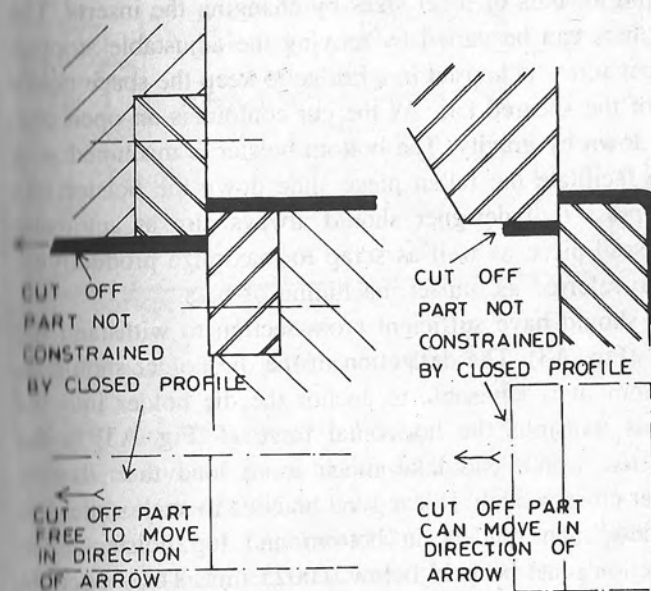


Fig. B1a Open contour cutting in shearing

It is however more economical to use a smaller capacity press with a suitable press tool for smaller work pieces. Flats, bars, and strips can be

cut to length on simple shearing tools. These can be provided with adjustable stoppers to vary the lengths of the workpieces.

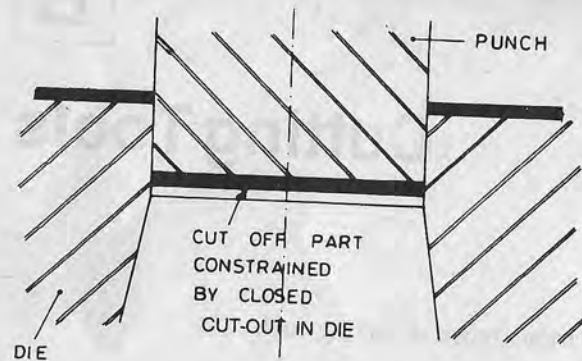


Fig. B1b Closed contour cutting

B1.10 Shearing Tool for Bar [Fig. B2]

Insert type construction saves costly die steel, simplifies replacements and facilitates cutting of bars of other sizes by changing the inserts. The lengths of the cut bars can be varied by moving the adjustable stopper. Note that the stopper screw is housed in a bridge to keep the space below clear for passage of the sheared bar. As the cut contour is an open one, the cut piece falls down by gravity. The bottom bolster is machined with an inclined slot to facilitate the fallen piece slide down the bolster into the receptacle. A press tool designer should always aim at automatic disposal of the pressed piece as well as scrap to maximize productivity. Bar shearing is also referred as impact machining of bars.

The die holder should have sufficient cross-section to withstand the horizontal force H (Fig. A3). The deflection of the die holder should be limited to 0.0025 mm. It is advisable to anchor the die holder into the bottom bolster. This transmits the horizontal force H (Fig. A3) to the sturdy bottom bolster, which can take much more load than dowels having much smaller cross-section. It is a good practice to anchor dies/die holders and punches/punch holders in bottom and top bolsters. The punch holder deflection must be held below 0.0025 mm. The Appendix at the end of this book gives the formulae for computation of thickness of die holders, punch holders/punches, and heels. All these elements should be treated as cantilevers subjected to bending moments resulting from the cutting action.

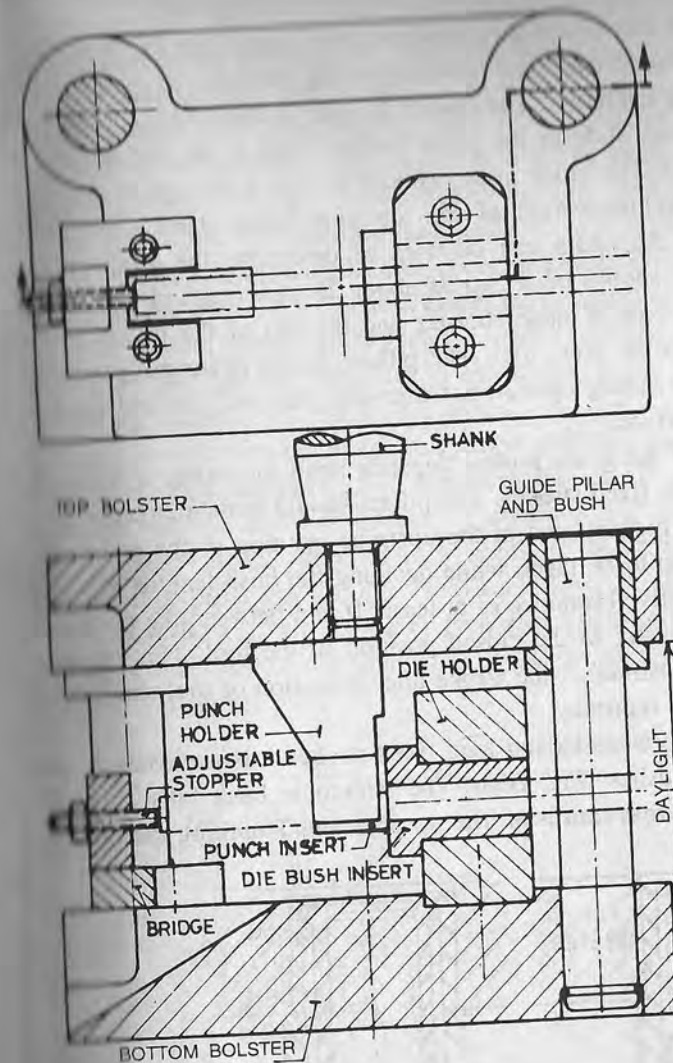


Fig. B2 Shearing tool for round bars

B1.11 Pillar Die Sets

In olden days the press tools relied on accuracy of press ram stroke for maintaining the alignment between punch and die. The skill of the tool setter or lack of it could affect centrality of the punch with the die. Eccentricity between these two elements leads to uneven die clearance around the cut periphery, causing uneven burrs around the periphery of the component. The rams of old worn out presses can take different paths with each stroke. The ram might wander beyond the die clearance and hit, chip, and damage a costly die.

To overcome this eventuality, modern press tools align the punch and die accurately once for all, and provide guiding elements to maintain the alignment during operation. The bottom bolster is fitted with at least two guide pillars which slide in the guide bushes fixed in the top bolster as shown in Fig. B2. The guide pillars should be strong enough to keep the deflection due to the weight of the top tool below 0.0025 mm. The formulae in the Appendix can be used to determine the guide pillars diameters. There should be a gap of about 20 mm (regrind allowance) between the top face of upper bolster and the top of the pillars in the closed position of the press tool. The pillars should never project above the upper bolster during operation. Otherwise they will hit and damage the press ram surface.

The length of the guide bushes depends upon the stroke to be used. Some presses have fixed strokes. The pillars should remain engaged with the bushes at the highest, end of the upstroke position of the press ram. Another precaution to be taken while deciding the bush lengths is to see that there is a positive clearance of at least 20 mm between the bush face and the bottom bolster in the closed position of the tool. This prevents the bushes from obstructing the stroke after reduction of tool shut height due to sharpening regrinds.

In the case of presses having long fixed strokes it is necessary to use telescopic guide bushes (Fig. B3a). The telescopic bush falls down by gravity when the press ram is in the up position. Touching the bottom

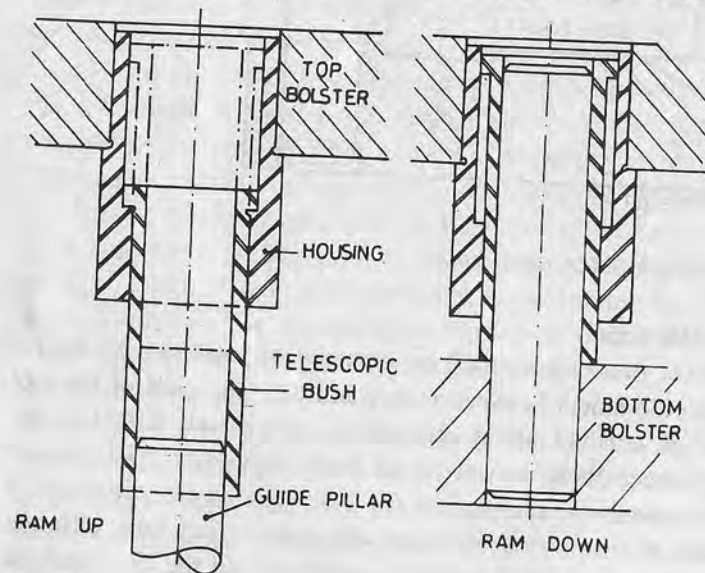


Fig. B3a Telescopic bush

bolster during the downstroke, the telescopic bush slides up into the housing fixed in the upper bolster.

The bottom bolster is generally kept thicker than the top bolster. For the press tables generally have a big hole at the centre for disposal of workpiece/scrap. The hole causes higher bending stresses in the bottom bolster which calls for stronger cross-section.

The top bolster rests against the press ram surface having small holes for a location shank. As the hole in the ram is smaller than the hole in the table the top bolster is subjected to lesser bending stress and is less thick than the bottom bolster. The Appendix gives the formulae for calculating thickness of the bolster plates.

It is convenient to buy readily available pillar die sets and mount die, punch and other elements on a precision die set. Figs L4a and 4b in Standards Section state dimension of standard rear pillar die sets; the most popular model, due to easy accessibility from three sides. A diagonal type pillar die set (Fig. N5a) acts like a simply supported beam and deflects lesser than cantilever type rear pillar sets. For very heavy work it is necessary to use four pillar sets (Fig. N6) which deflects even less than a diagonal pillar set.

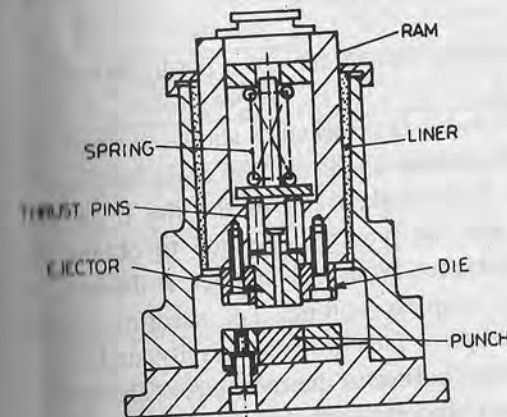


Fig. B3b Old subpress type die set

Pillar die sets used for high speed production such as lamination notching are provided with linear ball bearing type guide bushes (Fig. M5) to minimize wear under heavy usage. Fig. B3b shows an olden subpress used in watch industry for precision alignment of top and bottom tools.

B1.12 Location Shank

The top bolster has got a threaded hole for the location of the shank. The shank aligns the threaded hole in the top bolster with the press ram centre.

The shank is also used to clamp the top bolster to the ram face. The press ram is provided with a horizontal bolt for clamping the shank. It is a good practice to make the shank tapered in the holding part. The downward taper on the shank pushes the press tool top bolster up towards the ram surface as the clamping bolt is screwed in. When the top bolster touches the ram the clamping bolt can not go further, and can be tightened to clamp the shank. Thus the taper on the shank ensures that ram face transmits the press force V directly to the top bolster of the tool.

If there is a clearance between the top bolster and the press ram the vertical force V will be transmitted through the shank. This is undesirable. For shank has got much less cross-section than the press ram or top bolster of the tool. Moreover the shank will transmit the force to the threaded hole in the top bolster. The threads might get damaged. For shank threads are designed to withstand the stripping load (see Blanking Tools) which rarely exceeds 10% of the cutting force V . The Appendix gives tables as well as formulae for calculating the strength of threaded parts. The shank is placed preferably at the centre of pressure as described earlier in this chapter.

B1.20 Scrapless Shearing Tool for Fork

Fig. B4 shows a shearing tool which cuts the ends of a flat to forked and tongued shapes.

When a new flat is taken, its end is first forked as shown in stage I of the strip layout drawn in Fig. B4. Material indicated by cross hatching is an unavoidable scrap. In stage II the forked end of the flat is pushed forward to touch the stopper; and the press is operated to obtain the forked profile shown in the strip layout. Note that in stage II the strip is separated along the profile in scrapless cutting, i.e. shearing. After separation in stage II the separated piece falls down by gravity, and slides down the inclined slot in the bottom bolster to the receptacle. The bridge type stopper provides a clear space under the stopper for passage of the separated piece.

The die is anchored in the bottom bolster. Die must be provided with dowels to prevent movement during operation. The die is fitted with two strip guides. These locate the flat to be cut. The strip guides are radiused at the entry point. The overhung portion of strip guides is screwed with a support for the strip. The guides are topped with stripper.

B1.21 Stripping [Fig. B7]

The work material bends slightly before shearing. After shearing a blank, the bent portion in the strip cut-out as well as the blank external

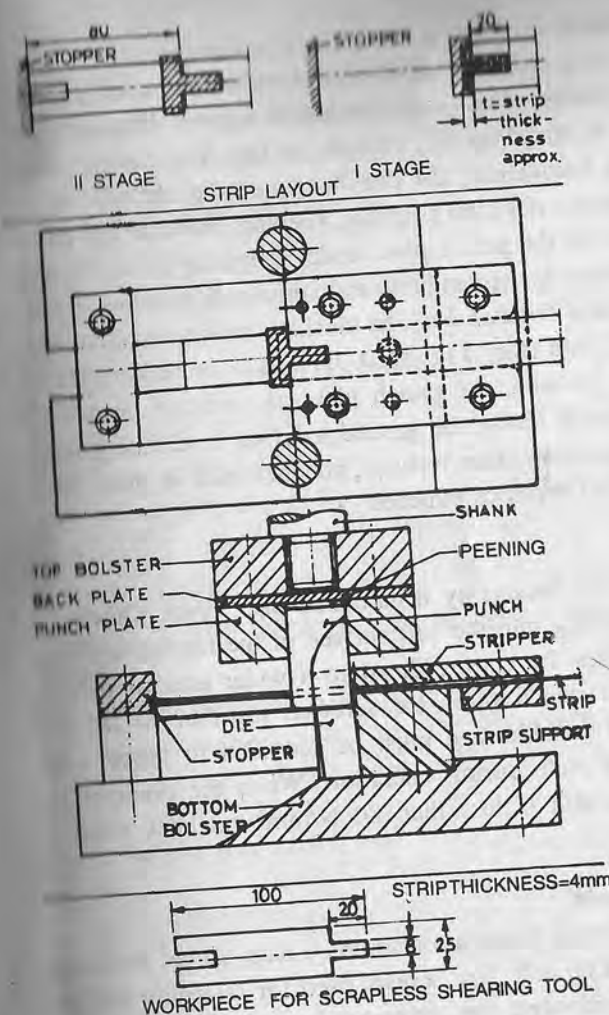


Fig. B4 Scrapless shearing tool

periphery tends to spring back to its original position. This causes the punch to get jammed in the cut-out pierced in the strip. Even the cut-off portion tends to get jammed in the die. The cut-off work material in the die is pushed down by the following blanks and ultimately reaches the angular clearance in the die (angle $1\frac{1}{2}^\circ$ in Fig. B5) to fall through the press table cut-out.

The strip jammed on the punch tends to rise with it during return upstroke. The strip is removed off the punch by stripper fitted above guides in Fig. B4. All press tools used for shearing closed contours must be provided with strippers for extracting the punch from the parent work material. The following pages and chapter H describe other types of strippers and their applications.

B1.22 Peening Punch

The punch is fitted in a close fit mild steel plate called punch plate or punch holder. The punch plate supports punch against bending. The punch slot has got 1–4 mm deep 45° chamfer at top. The cutting punch is also chamfered by hammering the punch against the chamfer in the punch plate. This process is called peening. Peening prevents the punch from being pulled out of the punch plate under stripping force. Peening is particularly convenient for rectangular and contoured punches. Round punches can be provided with an easy to machine collar and a suitable counterbore in punch plate (Ref. Figs B10, B11, B12 in Section B3.00: Piercing tools). After peening, the punch plate as well the peened (or collared) end of the punch should be ground level on a surface grinder. The following pages describe other types of punches used in press tools. Chapter (H) describes all types of punches.

B1.23 Back Plate

The punch plate must be backed by a hardened back plate. Otherwise the hardened punch will dig into the soft surface of the top bolster. The back plate also distributes the cutting thrust to a wider area of the top bolster. (Back plate and punch plate are screwed together to the top bolster. Two dowels of suitable size must be provided to prevent the movement of the punch plate during operation.) When the pressure on the mounting face of punch is less than 80 N/mm² no back plate is necessary.

B1.24 Screw and Dowels

Most of the elements of Press Tools are assembled with socket head cap screws (Allen screw) and dowels. The screws used for fastening the die and punch plate must withstand the stripping force generated during operation. The stripping force can be assumed to be 10% of the vertical shearing force. (The design stress for socket head cap screws (SHCS.) ranges from 80–120 N/mm².) The root diameter of the screw is considered under direct tensile stress resulting from the stripping load. (Section M20.01 states safe loads for screws.)

(Dowels are subjected to shear stress due to horizontal force resulting from die clearance. Dowels are rarely stressed beyond 50–80 N/mm².)

Example B1 A press tool is subjected to 40 tonnes vertical force and has got 5% die clearance per side. Find the number and size of the screws and dowels necessary if the stripping load is 10% of the vertical force.

Solution Stripping load = $0.10 \times 40 \times 9807$
= 39228 N

Root area for metric screws can be found from the following formula [Eqn B1]

$$A = 0.7854 (D - 1.227P)^2$$

For M 12 × 1.75 Screw

$$A = 0.7854 (12 - 1.227 \times 1.75)^2$$
$$= 76.24 \text{ mm}^2$$

Load capacity at 80 N/mm²

$$L = 76.24 \times 80 = 6100 \text{ N}$$

We can use six screws of M 12 size.

Alternatively for M 16 × 2 Screw

$$A = 0.7854 (16 - 1.227 \times 2)^2$$
$$= 144.12 \text{ mm}^2$$

Load capacity at 80 N/mm²

$$L = 144.12 \times 80$$

$$= 11530 \text{ N/screw}$$

Four screws of M 16 size can be used to take 45720 N load at 80 N/mm².

$$\text{Vertical Force} = V = 39228$$

$$\text{Horizontal Force} = \text{Die Clearance} \times V$$

$$\text{Horizontal Force} = 0.05 \times 392280$$
$$= 19614 \text{ N}$$

If two dowels are used

$$\text{Load/Dowel} = \frac{19614}{2} = 9807 \text{ N}$$

$$\text{Area} = \frac{9807}{50} = 196.1 \text{ mm}^2$$

$$\text{Dowel } \phi = \sqrt{\frac{196.1}{0.7854}} = 15.8$$

Two 16 φ Dowels can be used.

If dowel size becomes too big more number of smaller dowels having same total sectional area can be used.

For example if 12 φ dowels are to be used

$$\text{Area per dowel} = \frac{0.7854 \times 12^2}{12}$$
$$= 113.1 \text{ mm}^2$$

No of dowels at 50 N/mm² stress

$$= \frac{19614}{50 \times 113.1} = 3.47 \approx 4$$

As area of dowel varies according to square of dowel ϕ it is better to use two big dowels instead of a number of smaller dowels.

The tool is provided with guide pillars and bushes for alignment of the punch and the die.

This tool uses a 25 mm wide $\times$ 4 mm thick flat as a raw material. The width 25 mm remains unchanged during the operation. The product designer must consider the possibility of modifying the component dimensions marginally to facilitate use of a standard flat as a raw material.

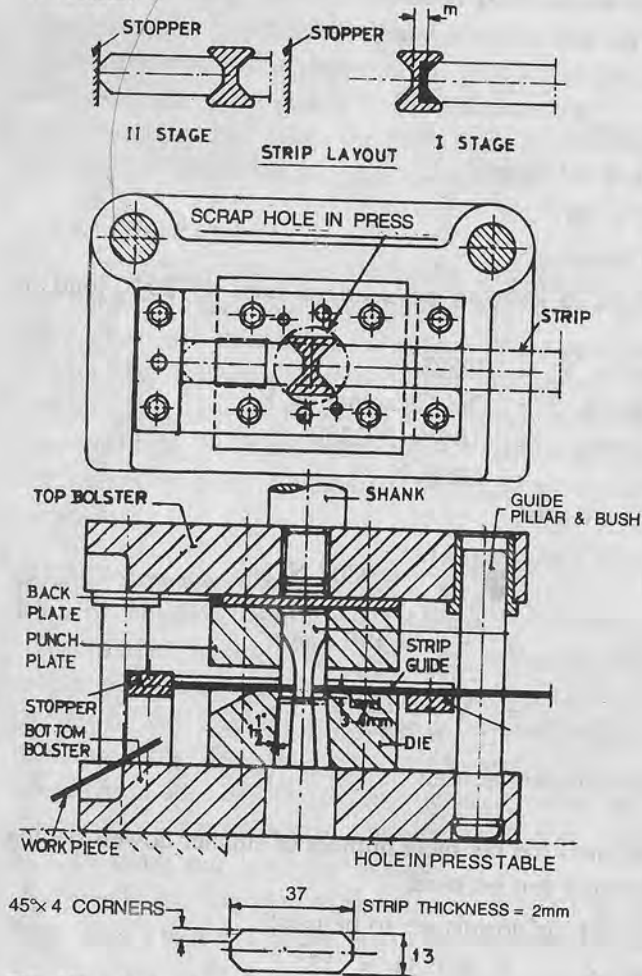


Fig. B5 Cropping tool for flats

B2.00 CROPPING TOOLS

Fig. B5 shows a Cropping Tool for cutting and chamfering flats to obtain the piece depicted in the lower part. The end of the flat length is first cut

off as shown in stage I of the strip layout. For stage II, the cut end is fed ahead to touch the bridge type stopper. The cropping punch chamfers the tail end of the first piece, and the front of the remaining flat, simultaneously cutting off the first finished piece from the parent flat. The die is provided with a 30° slope. The cropped piece slides down the incline into the receptacle.

The chamfered end of the remaining flat is fed ahead to touch the stopper to obtain the following piece in the next stroke of the press. The cycle is repeated till the flat length is exhausted.

The die is fitted with strip guides for locating the flat. The entry points of the guides must be radiused (or chamfered). The punch is peened in the punch plate, and topped by a hardened back plate. The punch plate and die are screwed to top and bottom bolsters and secured by dowels. Two guide pillars and bushes maintain the alignment between the punch and the die.

B2.01 Margins for Strips

The hatched part in, stage II of strip layout goes waste with every piece produced. (The margin m between two pieces should not be less than the thickness of the flat sheet being cut. Nor should m exceed twice the thicknesses of the material to be cut. Table in Fig. B18 states suitable margins for various thicknesses and flat/strip widths.)

As the punch is not likely to get jammed in the workpiece no stripper is necessary. The finished piece is free to fall under gravity, but the scrap between two pieces cannot fall by itself. As the cut contour is a closed one, the scrap gets jammed tightly in the die. To simplify the disposal of the scrap in the die the die cut-out is provided with a taper of about $1\frac{10}{2}$ on the lower side. About 3–4 mm parallel land is left at the die top for resharpener. The taper in the die facilitates free fall of the scrap under gravity after the cut piece is pushed below the parallel land.

The parallel land allows grinding of the die surface for resharpener without increasing the die clearance. The die life is directly proportional to the land length. Nonetheless excessive land subjects the die to excessive load. The cut pieces get jammed in the parallel land. Each jammed piece requires a push of about 10% of the cutting force V for downward movement. Excessive land results into more number of jammed pieces in the die. (Fig. B6). The punch must push all the jammed pieces in the die downwards with every stroke. Five jammed pieces in the die increase the force on the die and punch to one and a half times. The bottom bolster must be provided with a hole for passage of scrap which falls through the hole in the press table to the receptacle below. The hole

in the bottom bolster is generally shaped like scrap, but it is bigger than the scrap to allow free fall under gravity.

The scrap/piece falling through the die must fall through the hole in the press table. Otherwise the press tool might get damaged. For if the scrap does not fall through the hole in the press bed it will get accumulated on the press table, bottom bolster and the die cut-out. Soon the accumulated stack will rise in height, obstruct the punch stroke, and the die will burst. Even the punch might get damaged. Hence the designer

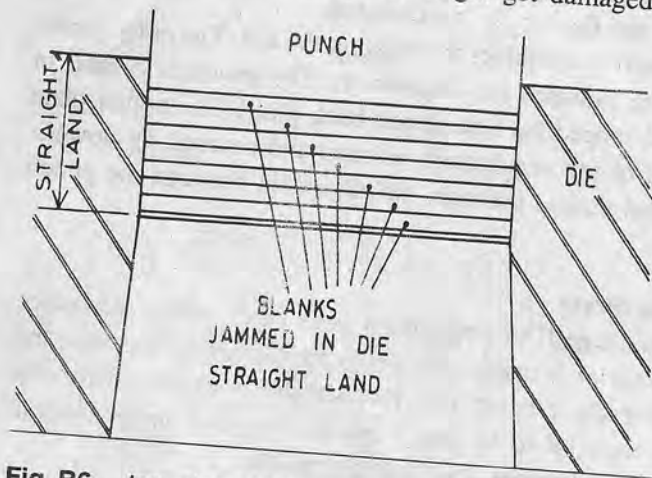


Fig. B5 Jamming of blanks in die due to excessive land

must ensure positive disposal of the scrap/piece falling through the die cut-out.

This can be done by drawing the hole in the press table in red chain-dotted line on the die plan as shown in Fig. B5.

B2.02 Shank Position and Scrap Disposal

Scrap disposal is an important criterion for deciding the position of the shank in the top bolster. As the shank hole centre line coincides with the table hole centre line, it is convenient to place the shank at the centre of the scrap periphery in single punch tools such as shown in Fig. B5.

(There should be a uniform die clearance between 0.05 to 0.1 mm (2.5 to 5% T) between the die and the punch all around the cut contour.) For closed contour cutting tools lay more stress on dies and punches than the open contour shearing tools. (Die clearance reduces stresses on dies and punches.) The open contour shearing tools can theoretically operate with zero die clearance although in practice (at least 0.01 mm gap is necessary for a suitable slide fit between the die and the punch.) The closed contour tools function well with adequate die clearance between the die and the punch.

B3.00 PIERCING (PUNCHING) TOOLS

Piercing involves making closed profile holes in the sheet metal. The part sheared off from sheet goes scrap whereas the part in which the hole is made is the workpiece to be used. It is important to note this for distinguishing piercing operation from blanking (Refer Section B 4.0).

Generally the hole pierced in the workpiece is used to house some male part such as shafts or fasteners. Consequently the minimum size of the hole should be big enough to permit passage of the mating male part.

B3.01 Die Clearance

Refer Fig. A4. The hole pierced in the sheet is a tapered one, with minimum opening equal to punch size near the top. The maximum size of the hole at the bottom depends upon the die opening which depends upon die clearance. As the minimum size is important in piercing (punching), the punch is made equal to the hole size shown on component drawing. The die clearance is provided on the die cut-out which is naturally bigger than the size stated on the workpiece drawing. (For example for piercing a 22 ϕ hole in 2 mm M.S. sheet,

$$\begin{aligned} \text{Punch diameter} &= 22.0 \\ \text{Die clearance/side at 2.5\% of sheet thickness} &= 2.0 \times 0.025 = 0.05/\text{side} \\ \text{Die bore} &= 22 + 2 \times 0.05 \\ &= 22.10 \phi \end{aligned}$$

B3.02 Control of Pierced Hole Size

Piercing punch bends the workpiece sheet slightly before piercing. The spring back of the bent portion jams the punch into the workpiece sheet, and the hole contracts after removal of the punch. The spring back depends upon the hole size as well as the worksheet thickness. Table B1 states the approximate shrinkage of the holes for various sheet thicknesses and hole sizes. (The piercing punch for precision holes should be made slightly (0.15) oversize than the shrinkage stated in Table B1.) A specimen workpiece sheet is pierced with the oversize punch. The punch is removed and the shrunk hole size is measured. The punch is then ground suitably in light of the measured contraction to obtain the desired hole size.

Table B1 Shrinkage of Pierced Holes

Sr. No.	Sheet Thickness	Shrinkage Hole Size (mm)		
		Up to 75	76 – 200	200 – 600
1.	0.64	0.076	0.127	0.203
2.	0.76	0.076	0.152	0.254
3.	1.52	0.102	0.203	0.305
4.	2.13	0.127	0.229	0.356
5.	3.17	0.152	0.254	0.406
6.	4.75	0.254	0.406	0.635
7.	6.35	0.381	0.508	0.889

B3.03 Strippers for Piercing Tools



Fig. B7 Stripping jammed sheet from punch

Fig. B8 shows a piercing tool with a fixed stripper. All piercing tools must be provided with strippers for removal of the pierced sheet from the punch. The stripper can also be used to support and guide slender piercing punches during operation. The slots in the stripper are made slide fit with the corresponding punches. A close-fitting stripper supports piercing punches against bending during piercing.

It is convenient to use cheap urethane stripper bushes for simple single punch tools for round holes in structural work. Urethane bush is tight on punch and no fastening is necessary. The outside diameter of the urethane bush should be two to three times the counter bore diameter on which the bush holds. The portion guiding the cutting diameter of punch should be one-third to the one-tenth pierced hole size for good stripping.

Fig. B9b shows a urethane bush stripper with (desired proportions).

B3.04 Strip Guides [Fig. B8]

The guides fitted on the die also locate the workpiece longitudinally. Guide thickness should be 1.5–2 mm more than the sheet thickness to be punched to facilitate easy loading/unloading of the workpiece. The guides should be provided with a radius/chamfer at the entry point. The stopper at the rear provides cross location for the workpiece. The stripper, guides, and die are screwed to the bottom bolster and provided

with two dowels to prevent movement during operation and handling. Each guide as well as the rear stopper must be provided with minimum two dowels each for the same reason.

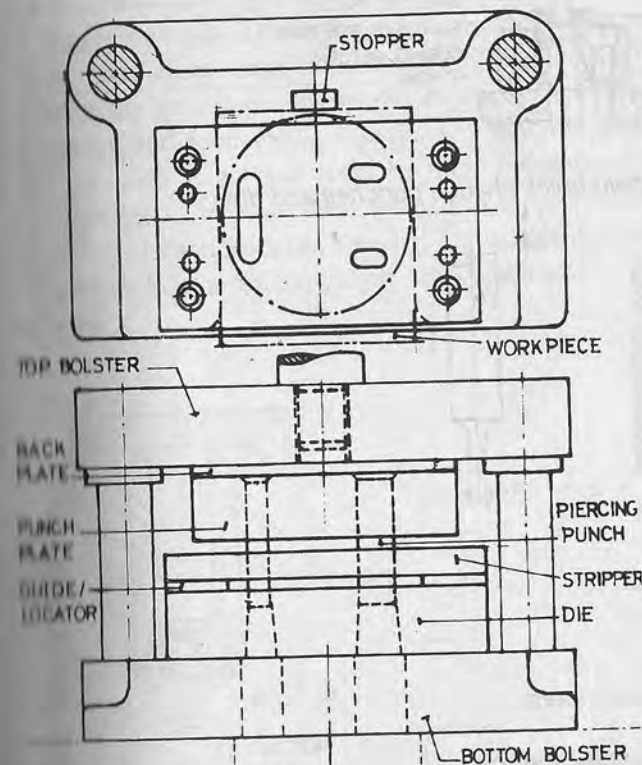


Fig. B8 Piercing tool with fixed stripper

B3.05 Punch Assembly *fixing methods.*

As shown in Fig. B8 smaller, non-cylindrical punches are usually fitted in the punch plate and peened at the top. Piercing tools usually have a hardened back plate above the punch plate to prevent punches digging into unhardened top bolster. The back plate and punch plate are screwed and dowelled to the top bolster.

Round holes are used so frequently in press work that it is possible to buy ready commercial punches and die bushes of various sizes in the market. Even quick change variety (Fig. B9a) is available. Figure M3 in the appendix shows standard types and sizes of cylindrical piercing punches.

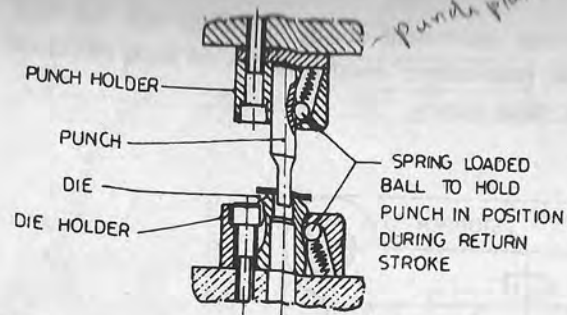


Fig. B9a Spring held quick change punches and dies

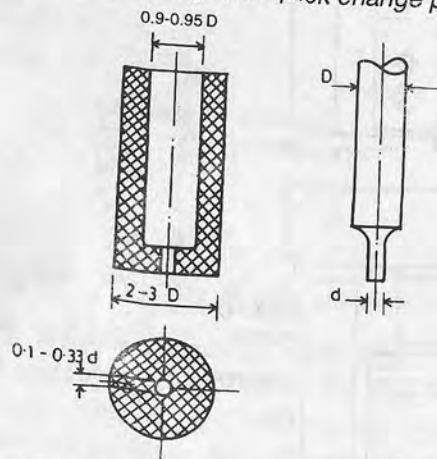


Fig. B9b Urethane strippers

B3.06 Piercing Punch Designs

As piercing punches are hardened to 58-62 RC, their shapes should be suitable for heat treatment, i.e. quenching. In round punches the length should not exceed eight times the diameter. When the situation calls for a long slender punch it is better to design a long housing and a small punch (Fig. B10). A separate thrust pin can be provided to transmit the cutting force from the punch to the back plate.

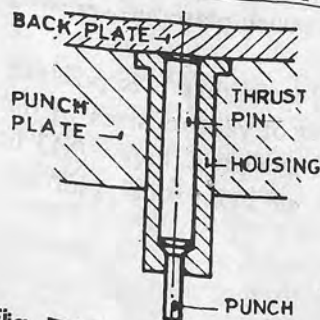


Fig. B10 Housing slender punches

B3.07 Quick Change Punches

Piercing punches should be at least equal to the sheet thickness in diameter (or minimum cross-section) for satisfactory operation. Nevertheless, it is often necessary to pierce holes smaller than sheet thickness in mass production. Inevitably, the smaller punches break sooner than the bigger punches. Under such circumstances it is necessary to use a design facilitating quick replacement of the broken punch. Fig. B11 shows a design developed by the author, which has been found very convenient and economical. The flanged punch is located in the housing by a precision spigot and fixed by three countersunk head screws. The punch flange is also provided with three tapped holes for extraction of the broken punch from the housing. The advantages of this design is that you can replace a broken punch without removing the press tool from the press.

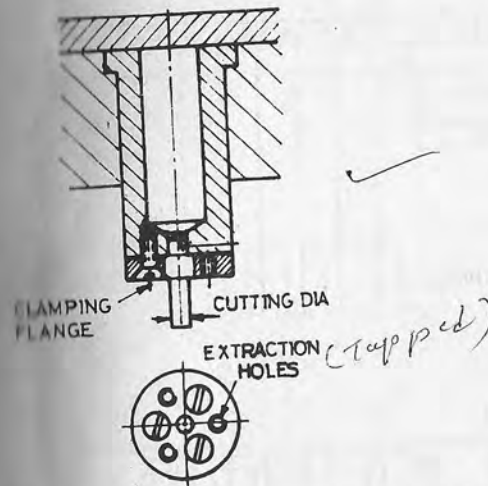


Fig. B11 Quick change slender punch

B3.08 Stepped Punches

Sometimes it is cheaper to make a stepped punch instead of using a separate housing (Fig. B12a). The two diameters should be joined with a liberal radius to effect gradual change of cross-section. If there is a large difference in the cutting and the location diameter it is convenient to provide a hole in the big location diameter in such a way that the wall thickness is approximately equal to the cutting diameter. This facilitates an even rate of cooling and good heat treatment. The stripper can be counterbored to accommodate the radius and bigger location diameter of stepped punch (Fig. B12a). Alternatively, it can be provided with a

separate thinner guide which can be screwed to the stripper from below (Fig. B12b). There must always be some guide for the smaller cutting diameter. This prevents upward flanging of the pierced hole during extraction of the punch. Even non-circular punches are provided with a circular location diameter and flats on retaining collar for angular location (Fig. B12c). Punch plate top is milled with slots push fit with the punches. The slots position the punches and prevent rotation. Fig. B12d shows a tool with a gang of rectangular stepped punches retained by the collars at top and clamped by a screw in the location slot of the punch plate.

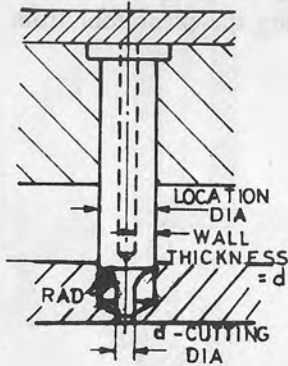


Fig. B12 (a) Stepped slender punch

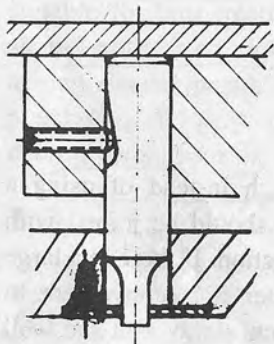


Fig. B12b Quick change stepped punch

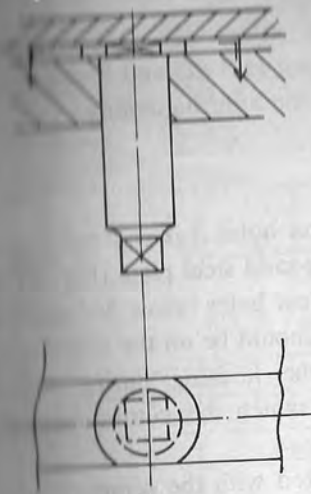


Fig. B12c Prevention of rotation of punches

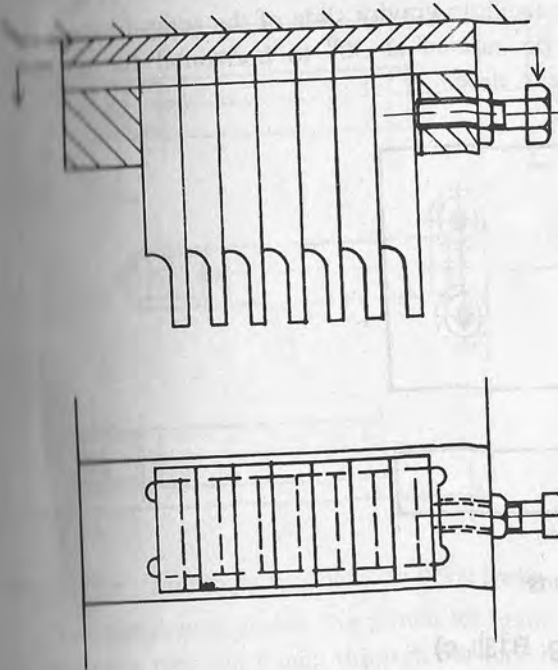


Fig. B12d Mounting gang of rectangular punches

B3.09 Heat Treatment of Punches

No cross-section of punch should be less than 3 mm in thickness. It is the minimum thickness necessary for crackfree heat-treatment. In case smaller cross-section punches are required these are machined oversize to bigger sections which can withstand heat-treatment. The oversize

punches can be ground to required size after heat-treatment. For example, a round 1.5 dia punch will be turned to 3 dia and heat-treated. It would be ground from 3 dia to finish 1.5 dia after hardening.)

B3.10 Die Bush Inserts

For a big workpiece with a few small diameter holes it is convenient and economical to use die bush inserts in a larger mild steel plate (Fig. B37). The bushes are provided with 1 mm bigger clear holes below 3–5 straight land for fall of scrap. The collar of the bush should be on the lower side. This prevents the bush coming out of the housing during punch withdrawal, and increases the area through which the cutting force is transmitted to the bottom bolster.

The spacing of the holes should be checked with the scrap disposal cut-out in the press table. In case some of the pierced holes fall outside the press table cut-out it is necessary to use a special bolster (Fig. B37) with inclined slots which facilitate gravity slide of the scrap to the press table. The slots should be inclined at 30° to horizontal for an easy gravitational slide down the slope.

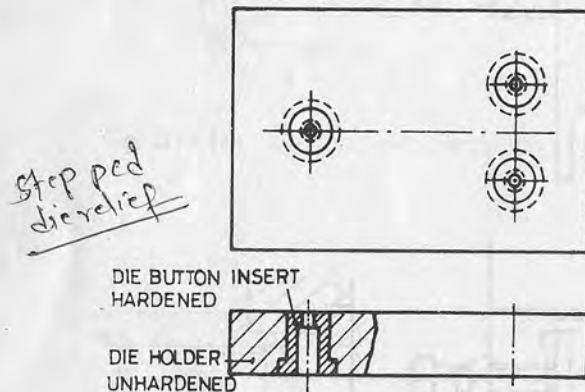


Fig. B13a Die button inserts

B3.20 Unit Tooling (Fig. B13b, c)

A logical development of the pillar die set—the unit tooling system—comprises of punch, die with built-in alignment, punch guiding and stripping arrangement. Built in form of a sturdy 'C' with a large throat, unit tooling is an integral single punch tool with a minipress only without a power drive. Unit tooling set is mounted on a press bed and the press ram is used only as a source of energy.

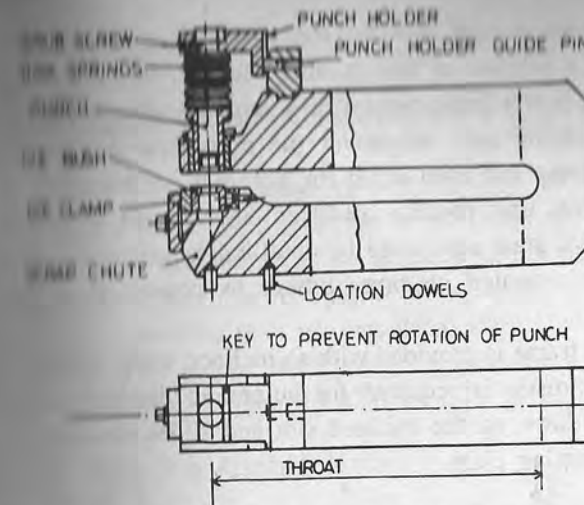


Fig. B13b Unit tools mounted on press

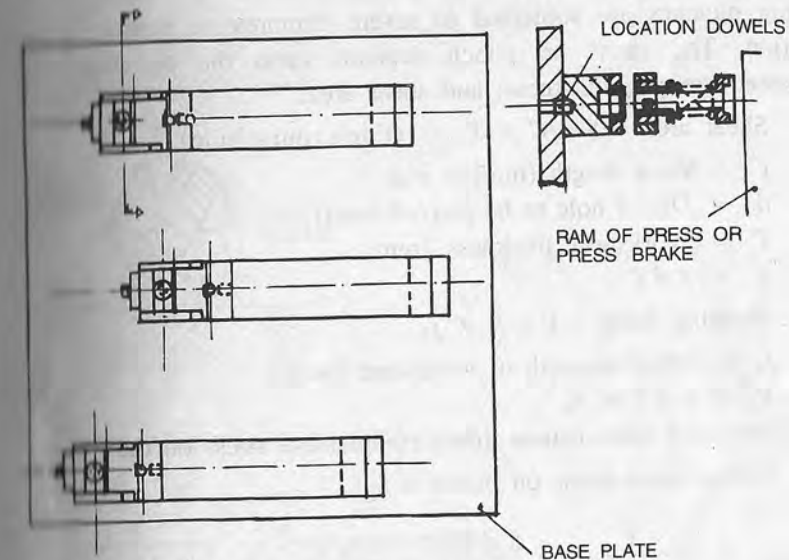


Fig. B13c Unit tools mounted on press brake

The press ram pushes the punch top against the stripping disc spring to push the piercing punch through the worksheet. As the ram withdraws in upstroke, the stripping spring raises the punch, extracting it from the jammed worksheet. The stripping spring holds the piercing punch in up position even after the ram ceases contact with the punch top. Unit tooling can also be used to pierce square or rectangular slots. The punch collar is provided with a flat which prevents rotation of the punch and wrong assembly. The die too, is provided with a flat for correct assembly.

The height of all die tops as well as punch tops are at same level for one make and model. So a number of unit tooling sets can be mounted in desired positions on a power press bolster or a separate plate to quickly build a multi-hole piercing tool. Moreover the individual sets can be dismantled from the press and used again for different combinations. In addition to saving time, unit tooling reduces investment in tooling considerably, which is a great advantage in small batch production. Unit tooling sets are often mounted on press brakes to convert them into gang-piercing presses.

As unit tooling 'C' frame is provided with an inclined scrap slot below die bush, no special bolster is required for automatic disposal of the scrap. The scrap falls down on the inclined slot and slides down to the press table or the mounting plate.

B3.30 Minimum Size of Hole Possible

Piercing punches are subjected to severe compressive stresses during operation. The stress on punch depends upon the piercing force: worksheet strength, thickness, and shear area.

$$\text{Shear area} = S = C \times T \quad (\text{For a round hole})$$

$$C = \text{Shear length (mm)} = \pi d$$

$$d = \text{Dia of hole to be pierced (mm)}$$

$$T = \text{Worksheet thickness (mm)}$$

$$\therefore S = \pi d T$$

$$\text{Shearing force} = V = S \times f_s$$

$$f_s = \text{Shear strength of worksheet (N/mm}^2\text{)}$$

$$\therefore V = \pi d T \times f_s$$

The shearing force causes direct compressive stress on the punch.

$$\text{Compressive stress on punch} = f_c$$

$$f_c = \frac{V}{\text{Punch area}} = \frac{\pi d T f_s}{\pi d^2 / 4} = \frac{4 T f_s}{d}$$

$$\therefore d = 4 \frac{f_s}{f_c} \cdot T \quad \text{[Eqn B2]}$$

Although there is an immense increase in the strength of tool steel due to hardening (above 1730 N/mm² at RC 50), the piercing punches are rarely stressed beyond 800 N/mm². Referring the Table B1, for structural steel $f_s = 400 \text{ N/mm}^2$

$$\therefore d_{\min} = \frac{4 \times 400}{800} = 2 T$$

$$\text{For aluminium, } d_{\min} = \frac{4 \times 280}{800} T = 1.4 T$$

$$\text{For electrical stampings, } d_{\min} = \frac{46 \times 550}{800} T = 2.65 T$$

As the punch material is not stressed to ultimate compressive strength, the punch will not break immediately if smaller size of hole is pierced. However there will be a heavy stress on the punch. This will cause early failure due to fatigue. Nonetheless, it is often necessary to punch holes smaller than recommended size. Under such circumstances the punches should be made easily replaceable by adopting one of the designs described in para B3.07 (Figs B11, B12).

B3.40 Piercing Angular Holes

Angular holes can be pierced by holding the workpiece at an angle (Fig. B14a).

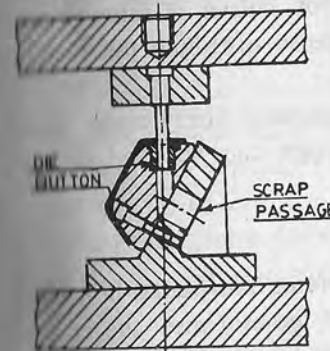


Fig. B14a Holding cup at an angle cup

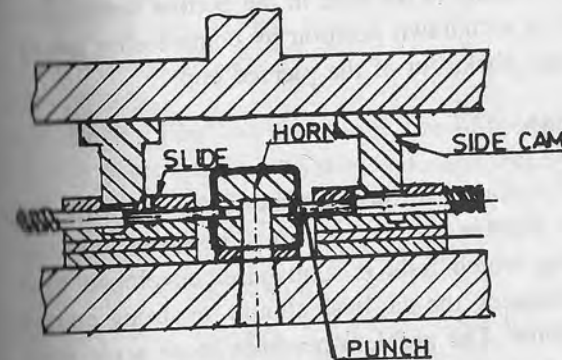


Fig. B14b Gang piercing tool for angular holes

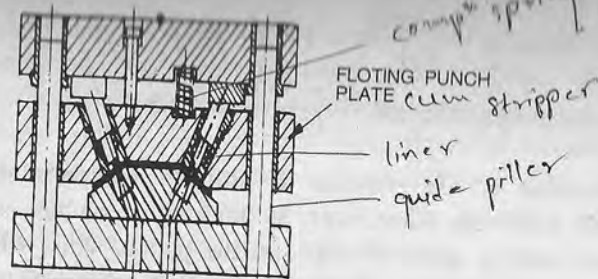


Fig. B14c Cam operated piercing tool

B3.41 Gang Piercing Tool for Angular Holes

If there are a number of angular holes it is convenient to use a punch holder-cum-stripper which slides up and down on guide pillars (Fig. B14c). The punches are housed in angular holes with a hardened liner to minimize wear. The punches are held in withdrawn position by compression springs which also strip the punches out of the workpiece. The punch tops are ground horizontal and the top bolster is screwed with hardened back plate pads at punch interface to distribute the piercing thrust over a wider area.

The spring loaded stripper holds the workpiece firmly under spring force before piercing commences. This design can be used for any number of holes, even at different angles.

B3.42 Cam Operated Piercing Tool

Fig. B14b shows a cam operated tool for piercing four radial holes in a cup. The angular cams screwed to the top of the tool meet the angular faces of the non-piercing ends of the punches housed in the blocks on the bottom tool. The central locator for the cup is fitted with hardened die bushes in line with the piercing punches. The locator is provided with a counterbore for passage of scrap to the hole in the bottom bolster. The piercing punches are held in withdrawn position by compression springs which also strip the punches back, out of the pierced cup.

B3.50 Piercing of Tubes

Piercing of tubes is a tricky affair. For the tube should be supported by a die within the tube bore. Further, special care must be taken to ensure automatic disposal of scrap which falls in a mandrel enveloped by a closed tube. The mandrel housing the die bush should be strong enough to withstand the piercing force. The problem becomes more acute when the mandrel must be left open, unsupported, at operator end for loading and unloading the tubular workpieces.

B3.51 Maximum Size of Hole which can be Pierced in a Tube

The mandrel which serves as a die must be smaller than the minimum size of tube bore to permit loading and unloading of the tube on the mandrel. If the die hole is made integral with the mandrel the approximate cross-sectional area of mandrel after making die hole can be found as follows.

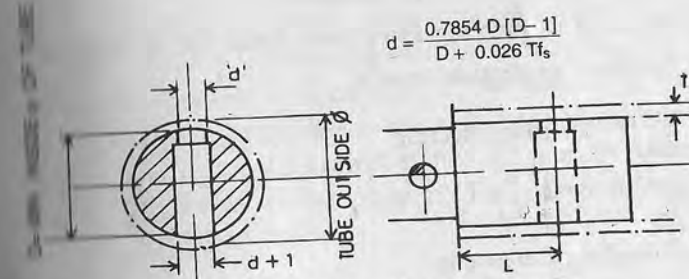


Fig. B15a Maximum size of pierced hole in a tube

Shear area of mandrel = A

$$A = 0.7854 D^2 - D(d + 1) \text{ (approx)}$$

[Eqn B3]

This area is subjected to shear as well as bending stress. Design stress of 160 N/mm^2 in tension or compression gives long die life. Take shear strength as 75% of tensile strength, i.e. 120 N/mm^2 . For piercing a mild steel tube having shear strength $[f_s] = 400 \text{ N/mm}^2$

$$A \times f_s = 120 (0.7854 D^2 - D[d + 1])$$

= Piercing force

$$= \pi d T f_s$$

where T and f_s are thickness and shear strength of tube material respectively. Solving the above equation,

$$d = \frac{0.7854 D (D - 1)}{D + 0.026 T f_s}$$

[Eqn B4]

Example B2 Find the maximum size of the hole which can be pierced in a 19ϕ bore pipe with 28ϕ outside and shear strength is 260 N/mm^2 .

$$\text{solution } D = 19; T = \frac{28 - 19}{2} = 4.5$$

$$f_s = 260 \text{ N/mm}^2$$

$$\begin{aligned} d &= \frac{0.7854 \times 19 (19 - 1)}{19 + 0.026 \times 4.5 \times 260} \\ &= \frac{268.6}{49.42} = 5.43 \text{ mm} \end{aligned}$$

B3.52 Bending Stress and Deflection

As die-mandrel is usually fixed at the rear end, and kept free at front for loading/unloading of the tube, the mandrel acts like a cantilever with a concentrated load at the piercing point. The bending stress and deflection of the mandrel can be found from the following equations.

$$\text{Bending Stress} = \frac{VL}{Z} = f_b \quad [\text{Eqn B5}]$$

V = Vertical piercing force (N/mm^2)

L = Distance of piercing force from fixed end of mandrel (mm)

Z = Modulus of section (mm^3)

$$= \frac{\pi}{32} D^3 \text{ for round section}$$

$$\text{Deflection} = \delta = \frac{VL^3}{3EI} \quad [\text{Eqn B6}]$$

E = Modulus of elasticity

$$= 2.08 \times 10^5 \text{ N/mm}^2 \text{ for steels}$$

I = Moment of inertia (mm^4)

$$= \frac{\pi D^4}{64} \text{ for round section}$$

Bending stress f_b should not be allowed to exceed 400 N/mm^2 for hardened mandrel-cum-die. If the mandrel is fitted with a die insert, the bending stress of the mandrel should not exceed 160 N/mm^2 . When a die insert is used, shear stress area A of mandrel will also be lesser due to the wall thickness of die bush.

Example B3 Find bending stress and deflection of a solid mandrel-cum-die while piercing a 6ϕ hole at 12 mm from one end of a $19 \phi \times 28 \phi$ pipe with ultimate strength 480 N/mm^2 .

Solution Pipe $\phi = D = 19$

$$I = \frac{\pi}{64} \times 19^4 = 6397.12 \text{ mm}^4$$

$$Z = \frac{\pi}{32} \times 19^3 = 673.38 \text{ mm}^3$$

$$f_t = 480 \text{ N/mm}^2; f_{st} = 0.75 f_t$$

$$f_{st} = 48 \times 0.75 = 320 \text{ N/mm}^2$$

$$\therefore V = \pi d T f_{st} = \pi \times 6 \times \frac{28 - 19}{2} \times 320 = 27143.4 \text{ N}$$

$$\text{Bending Stress} = f_b = \frac{VL}{Z}$$

$$L = 12$$

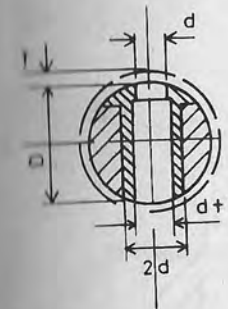
$$f_b = \frac{27143 \times 12}{673.38}$$

$$= 403.1 \text{ N/mm}^2$$

$$\text{Deflection} = \delta = \frac{VL^3}{3EI} = \frac{27143.4 \times 12^3}{3 \times 2.08 \times 10^5 \times 6397.12}$$

$$= 0.0117 \text{ mm}$$

Example B4 Find maximum size of hole which can be pierced in 51ϕ tube $\times 62 \phi$ outside a tube with ultimate tensile strength 520 N/mm^2 if the locating mandrel is fitted with a die bush insert having outside diameter twice the inside diameter. Also find the maximum distance of the pierced hole from the nearest end of the tube for maximum bending stress of 200 N/mm^2 in the mandrel. The shear stress in the mandrel should not exceed 150 N/mm^2 .



$$d = \frac{0.7854 f_{sm} D^2}{\pi T f_{st} + 2 f_{sm} D}$$

f_{st} = PERMISSIBLE SHEAR STRESS FOR MANDREL Kgf/mm^2

f_{sm} = SHEAR STRENGTH OF Kgf/mm^2

Fig. B15b Mandrel with die insert

Solution Refer Fig. B15b — When a die bush is fitted
Mandrel shear area $= A = 0.7854 D^2 - 2dD$

Shear strength of tube = 0.75 tensile strength

$$f_{st} = 0.75 \times 520 = 390 \text{ N/mm}^2$$

$$V = \pi d T f_{st}$$

$$\text{Permissible shearing force on mandrel} = f_{sm} (0.7854 D^2 - 2dD)$$

$$= \pi d T f_{st}$$

Solving the equation

$$d = \frac{0.7854 f_{sm} D^2}{\pi T f_{st} + 2 f_{sm} D} \quad [\text{Eq B7}]$$

d = Maximum size of hole which can be pierced in tube (mm)

f_{sm} = Permissible shear stress in mandrel (N/mm^2)

f_t = Ultimate shear strength of tube (N/mm^2)

$= 0.75$ ultimate tensile strength

D = Minimum tube bore (mm)

T = Tube thickness (mm)

∴ For Example B4

$$d = \frac{0.7854 \times 150 \times 51^2}{\pi \times 5.5 \times 390 + 2 \times 150 \times 51}$$

$$= 13.4 \text{ mm}$$

f_{bm} = Permissible bending stress in mandrel

$$= 200 \text{ N/mm}^2$$

For 51 ϕ round section

$$Z = \frac{\pi}{32} \times 51^3 = 13022.98 \text{ mm}^3$$

$$I = \frac{\pi}{64} \times 51^4 = 332086.02 \text{ mm}^4$$

From [Eqn B5]

$$f_b = \frac{VL}{Z} = \frac{\pi d T f_{st} \times L}{Z}$$

$$\therefore f_b = \frac{\pi \times 13.40 \times 5.5 \times 390 \times L}{13022.98}$$

$$= 6.93L$$

$$= 200 \text{ N [given]}$$

$$\therefore L = \frac{200}{6.93} = 28.8 \text{ maximum}$$

Had the mandrel been made of solid die steel with integral die the maximum permissible bending stress of hardened mandrel could have been as high as 400 N/mm² and the distance L would have been 57.6, i.e., double the value calculated above.

Deflection can be found from [Eqn. B6]

$$\delta = \frac{VL^3}{3EI} = \frac{(\pi \times 13.4 \times 5.5 \times 390) 57.8^3}{3 \times 2.08 \times 10^5 \times 332086.02}$$

$$= 0.084 \text{ mm}$$

Thus the choice of material for mandrel depends upon the distance of the hole from the nearest end of the pipe. If the centre distance is less than 28.8, a medium carbon steel (C40, C60) mandrel hardened 45 RC 45 can be used with a die bush insert hardened to RC 58–62.

B1.53 Supporting Die Mandrel at Both Ends

Provision of an auxiliary support at the free end of the mandrel converts it to a simply supported beam. This reduces the bending stress on the mandrel to one-fourth (25%) of the stress on the overhanging and unsupported mandrel. The deflection for simply supported beam is even lesser, one-sixteenth (6.25%), of the deflection for an unsupported cantilever. For a simply supported beam with pierced hole at centre (Fig. B16a).

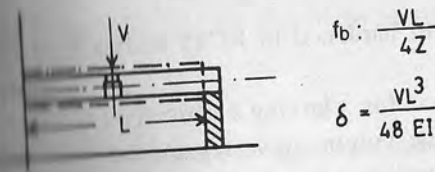


Fig. B16a Piercing tube with mandrel supported at both ends

$$f_b = \frac{VL}{4Z} \quad [\text{Eqn B8}]$$

$$\delta = \frac{VL^3}{48EI} \quad [\text{Eqn B9}]$$

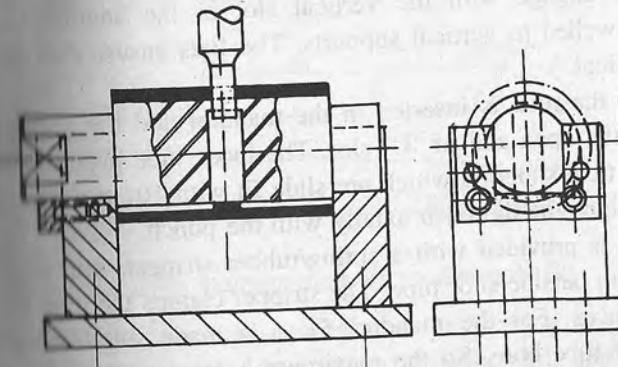


Fig. B16b Piercing tool for tube

Example B5 Find bending stress and deflection of a 51 ϕ mandrel used for piercing a 12 ϕ hole mid-length in a 51 $\phi \times 62 \phi \times 101 \phi$ long tube with 300 N/mm² shear strength if the distance between the mandrel supports is 101 mm.

$$\tau = 2.08 \times 10^5 \text{ N/mm}^2$$

Solution Piercing force = V

$$V = \pi d T f_s = \pi \times 12 \times 5.5 \times 300 = 62200 \text{ N}$$

$$L = 101$$

$$Z = \frac{\pi}{32} \times 51^3 = 13023 \text{ mm}^3$$

$$I = \frac{\pi}{64} \times D^4 = 332086 \text{ mm}^4$$

$$f_b = \frac{VL}{4Z} = \frac{62200 \times 101}{4 \times 13023} = 120 \text{ N/mm}^2$$

$$\delta = \frac{VL^3}{48EI} = \frac{62200 \times 101^3}{48 \times 2.08 \times 10^5 \times 332086} = 0.019 \text{ mm}$$

A medium carbon steel mandrel hardened to RC45 with a hard die steel insert can be used.

Fig. B16b shows the press tool for piercing a central 12 ϕ hole in 51 $\phi \times 62 \phi \times 101$ long tube. The bottom tool is provided with two vertical supports 101 mm apart. The supports are provided with 'U' slots open at top for loading and unloading the die mandrel. The mandrel has got a 51 $\phi \times 101$ long male cylinder at the centre of the tube. The ends are turned down to 40 ϕ and are precision slide fit (H7/f6) with the 'U' slots in the vertical supports mounted on bottom bolster.

The mandrel is provided with two flats on the extended length of supporting 40 mm diameter. The flats are parallel with the axis of the die bush. The flats engage with the vertical slot in the angular locator screwed and dowelled to vertical supports. The flats ensure that the die bush axis is vertical.

In operation the tube is inserted in the mandrel and the mandrel is loaded through the open end of 'U' slot. The loose tube positions itself between two vertical supports which are slide fit with 101 mm length of mandrel. This aligns the die bush axially with the punch.

The top tool is provided with a spring/rubber stripper with a radius equal to maximum outside ϕ of pipe. The stripper clamps the pipe before piercing commences. For the mandrel 51 ϕ is made suitable for the minimum size of tube bore. So the maximum bore size of commercial tube would be loose on the mandrel. Hence the loose tube must be held firmly by stripper to prevent its movement during piercing. If a die insert bush is used it should also be ground cylindrical, flush with mandrel after assembly.

For resharpener, the die bush is raised by a shim under collar and ground to 0.02–0.05 mm more radius than the radius of mandrel, so that the die bush projects 0.025–0.050 mm above the mandrel cylinder after resharpener. The punch face can be kept flat to facilitate resharpener on a surface grinder.

The tool uses pillar die set for alignment between top and bottom tools.

B164 Gang Piercing Tubes

If the hole to be pierced is offset, or more than one holes are to be pierced, it is convenient to use a mandrel pivoted at the end farther from operator. (Fig. B17a). The pivoted mandrel can be swung upwards for loading and unloading the tubular workpiece. The free end of the mandrel rests in a 'U' slot during piercing. The pivot pin should be strong enough to withstand the shear load due to piercing force. The pivoted end of the mandrel is ground with flats which are close fit in the mating tool. Even the 'U' slot should be running precision fit with the mandrel.

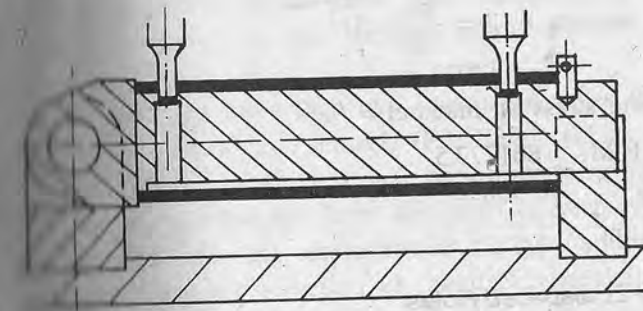


Fig. B17(a) Pivoted mandrel

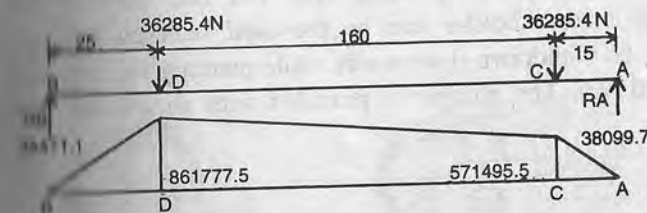


Fig. B17b Bending moment diagram for Example B6

The resultant bending moment due to piercing forces for different holes must be calculated to find the maximum bending stress and deflection.

Example B6 Find the maximum bending stress resulting from piercing two Nos of 6 ϕ holes in 51 $\phi \times 62 \phi \times 200$ long tube if one hole is situated at 15 mm from one end and the other hole is at 25 mm from the other end. The shear strength of the steel tube is 350 N/mm². $\mu = 2.1 \times 10^5$ N/mm². The 51 ϕ die mandrel is supported at both ends.

Solution Refer Fig. B17b

$$\begin{aligned} \text{Piercing force} &= \pi d T f_{st} = \pi \times 6 \times 5.5 \times 350 \\ &= 36285.4 \text{ N} \end{aligned}$$

Reactions at both supports A and B (Fig. B17b) must be calculated by finding out bending moments.

Taking moments about A

$$R_B \times 200 = 15 \times 36285.4 + (200 - 25) 36285.4$$

$$\therefore R_B = 34471.1 \text{ N}$$

$$R_A = 2 \times 36285.4 - 34471.1 = 38099.7 \text{ N}$$

$$\begin{aligned} \text{B.M. at C} &= 38099.7 \times 15 \\ &= 571495.5 \text{ N/mm} \end{aligned}$$

$$\begin{aligned} \text{B.M. at D} &= 34471.1 \times 25 \\ &= 861777.5 \text{ N/mm} \end{aligned}$$

Fig. B17b shows the bending moment diagram.

$$\begin{aligned} \text{Modulus of section} &= Z = \frac{\pi}{32} \times 51^3 \\ &= 13023 \text{ mm}^3 \end{aligned}$$

Maximum bending stress on mandrel = f_b

$$\begin{aligned} \therefore f_b &= \frac{\text{Max. B.M.}}{Z} = \frac{861777.5}{13023} \\ &= 66 \text{ N/mm}^2 \end{aligned}$$

B3.55 Indexing for Equispaced Holes

Equispaced holes can be pierced by providing workpiece (tube) indexing arrangement on a single punch piercing tool. For two diametrically opposite holes the bottom bolster can be provided with an indexing plunger which can be withdrawn downwards while piercing the first hole in the tube (Fig. B17c). The plunger is provided with an arrestor with

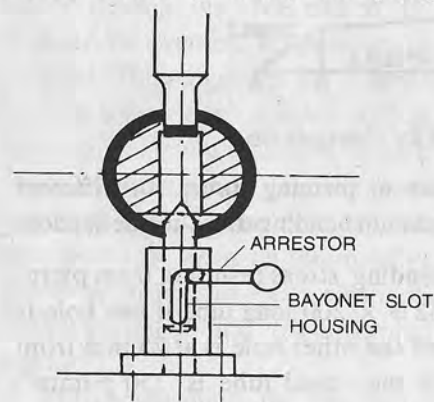


Fig. B17c Piercing diametrically opposite holes

handle. The arrestor is guided in a bayonet slot in the housing. When withdrawn, the indexing plunger arrestor is held in the axial portion of the bayonet slot. After moving the indexing plunger upwards, the plunger is turned towards the right by the arrestor handle to bring the arrestor

in line with the circumferential portion of the slot. The plunger moves upwards to engage with the hole pierced earlier in the tube. So after piercing the first hole, the tube is rotated on mandrel to bring the pierced hole in line with the indexing plunger on the bottom bolster to pierce the second hole.

The indexing plunger is provided with 'V' shape with 90° – 120° included angle at top for gravitational slide down of the scrap. For the scrap cut-out piece of pierced hole falls on the indexing plunger which plunges well within the mandrel to engage fully with the pierced hole in the tube. At the same time that indexing plunger should not engage so long that the piercing punch will hit it during the ram downstroke.

For piercing more than two equispaced holes the indexing plunger should be positioned suitably (Fig. B17d) taking care that no part of the indexing arrangement will be hit by any part of the top tool during the downstroke. It is advisable to keep all parts of indexing mechanism below the centre line of the die mandrel. Furthermore, the piercing plane cross-section of mandrel is weakened by the hole for the indexing plunger, so the strength of the mandrel at the weakest section should be checked carefully for the maximum shear stress.

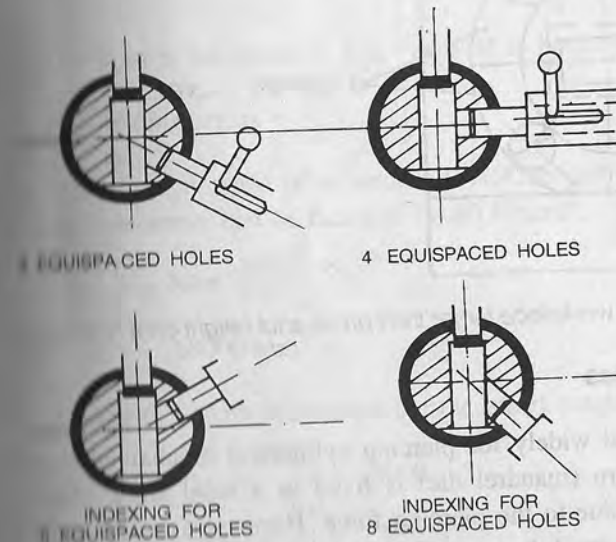


Fig. B17d Piercing equispaced holes by indexing

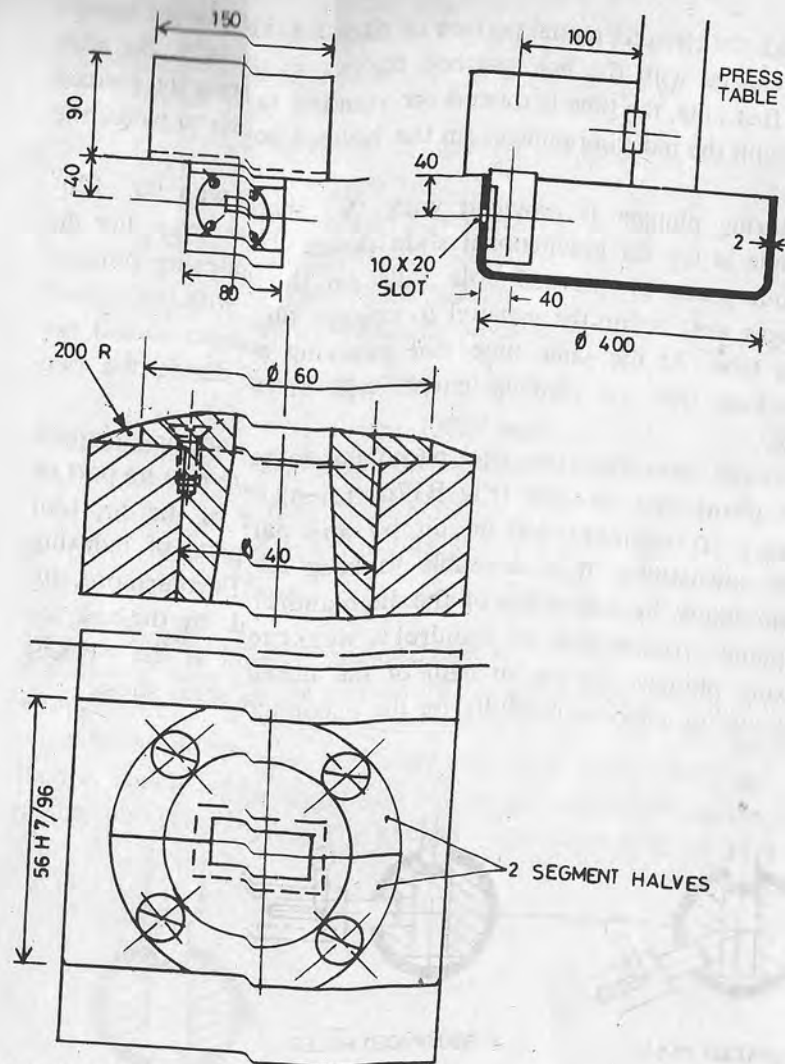


Fig. B17e Piercing workpiece larger than press shut height on a horned die.

B3.60 Horned Dies

Horned dies are used widely for piercing cylindrical or channel-shaped workpieces. The Horn (mandrel die) is fixed in a solid angle plate to minimize deflection due to the piercing force. Horn type design enables piercing workpieces much bigger than the shut height of the press. (Fig. B17e). The horn protrudes beyond the table edge to provide space for a large workpiece. As both the piercing punch as well as the die mandrel overhang beyond the table and ram faces, both bolsters should be sturdy with deflections limited to 0.0025 mm.

The die-insert comprises of two cylindrical halves with 'U' slots. The collar of the insert is provided with flats which engage with the location slot in the mandrel to prevent wrong assembly and rotation during operation. The flange is also provided with holes for fixing screws. The size and number of screws depends upon the force required for stripping the punch out of the pierced cup.

Example B7 Design insert for piercing a 20 mm × 10 mm rectangular slot in 2 mm thick M.S. cup shown in Fig. B17e. The shear strength of cup is 300 N/mm².

$$\begin{aligned} \text{Solution } V &= [20 + 10] \times 2 \times 2 \times 300 = 36000 \text{ N} \\ \text{Stripping force} &= 36000 \times 0.1 \\ &= 3600 \text{ N} \end{aligned}$$

The die bush outside dia should be twice the maximum slot length, i.e. $20 \times 2 = 40$ dia.

Die collar is subjected to shear due to piercing force.

Shear area of collar = $\pi \times 40 \times \text{Thickness}$

Taking permissible shear stress of insert collar 80 N/mm²

$$40 \pi \times \text{Thickness} \times 80 = 36000$$

$$\begin{aligned} \text{Collar thickness} &= \frac{36000}{3200\pi} = 3.58 \\ &\approx 4 \end{aligned}$$

The horn is subjected to shear as well as bending stress.

$$\text{Bending stress} = \frac{VL}{Z}$$

If the horn is made of unhardened medium carbon steel (C40/50) the permissible stress can be taken to be 80 N/mm².

$$\begin{aligned} \frac{VL}{Z} &= 80 = \frac{36000 \times 40}{Z} \\ Z &= 18000 \text{ mm}^3 \end{aligned}$$

Taking the width of horn double the insert outside ϕ , i.e. $40 \times 2 = 80$

$$Z = \frac{bd^2}{6} = \frac{80d^2}{6} = 18000$$

$$d = 36.74 \approx 40$$

The collar is provided with flats to prevent rotation of inserts as well as wrong assembly. The horn is provided with 56 mm wide location slot. Check shear stress on the horn.

$$f_s = \frac{36000}{40(80 - 40)} = 22.5 \text{ N/mm}^2$$

Check deflection of horn

$$I = \frac{bd^3}{12} = \frac{80 \times 40^3}{12} = 426666.1 \text{ mm}^4$$

$$\text{Deflection} = \frac{VL^3}{3EI}$$

$$= \frac{36000 \times 40^3}{3 \times 2.08 \times 10^5 \times 426666.1}$$

$$= 0.0086 \text{ mm}$$

The plate horn is anchored in an angle plate. The angle plate deflection should also be contained. Taking the width of angle plate as 150 mm, i.e. 70 mm more than horn.

$$I = \frac{bd^3}{12} = \frac{150d^3}{12}$$

$$Z = \frac{bd^2}{6} = \frac{150d^2}{6}$$

The bending moment due to piercing force on horn is equal to B.M. on angle plate. If the centre of the horn is at 100 mm height from bottom bolster

$$F \times 100 = 36000 \times 40$$

$$\therefore F = 14400 \text{ N}$$

$$L = 100$$

$$\therefore \text{Angle deflection} = \frac{14400 \times 100^3}{3 \times 2.1 \times 10^5 \times I} = 0.0025$$

$$\therefore I = 9142857.1$$

$$= \frac{150d^3}{12}$$

$$\therefore d = 90.09 \approx 90 \text{ mm}$$

$$\text{Bending Stress} = \frac{FL}{Z} = \frac{14400 \times 100}{\frac{150 \times 90^2}{6}} = 7.1 \text{ N/mm}^2$$

B4.00 BLANKING TOOLS

Blanking Tools are similar to piercing tools. However the workpiece, called blank, falls through the cut-outs in die, bottom bolster, and press table leaving the remainder scrap above the die. Thus in blanking the

piece falling through the die is the required blank, whereas in piercing the piece falling through the die is scrap.

B4.01 Die Clearance

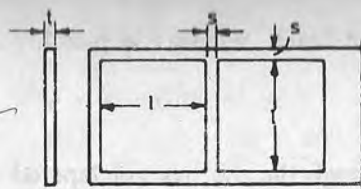
Refer Fig. A4. The male piece falling through the die has got tapered edges with minimum size equal to the punch size at top and maximum size equal to the die cut-out at the lower end. Often a male blank is assembled in a confined opening which determines the overall dimensions of the piece. As such, the maximum dimensions of the blank should not exceed the sizes stated on the component drawing. So in blanking, the die cut-out is made equal to the dimensions stated on the component drawing and the die clearance is provided on the punch by making punch size lesser than the requisite workpiece dimensions. (For example if we want to blank off a 22 mm dia piece from a 2 mm thick M.S. sheet

Die bore	= 22.00 mm
Die clearance at 2.5% of sheet	= 2.0×0.025
	= 0.05/Side
Punch dia	= $22.00 - 2 \times 0.05$
	= 21.9 ϕ)

Referring the example in the previous section (B3.0) it can be observed that for piercing a 22 ϕ hole, the die is 22.10 bore and the punch diameter is 22.00 mm as the die clearance is provided on the die.

B4.02 Strip Margins

Blanks are generally sheared off from strips of suitable size. The strip size depends upon the size and thickness of the blank. There should be a margin of at least 1.5 mm between two blanks and the edges of the strip and the blank (Fig. B18). For thicker sheets the margin can be made equal to sheet thickness. For wider strips and bigger blanks wider margins are necessary. Fig. B18 gives the margins found satisfactory in practice. The margins should be sufficient to provide suitable bridges for handling the blanked out scrap strip. On the other hand excessive margins cause needless waste of material. As blanks are usually produced in thousands, even a single millimetre extra margin leads to a waste of 1 metre long strip for every thousand blanks. Additional blanks can be produced by reducing this waste by providing optimum margins.

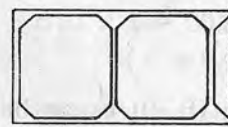


SHEET THICKNESS 't'							
t	0.3	0.5	0.8	1.0	1.5	2	3
20	1.5	1.5	1.5	1.5	1.5	2	3
60	1.5	1.7	1.7	2.0	2.0	2.0	3.0
125	2.0	2.2	2.2	2.5	2.5	2.8	3.0
200	2.2	2.2	2.5	2.5	2.8	2.8	3.0
300	2.5	2.5	2.8	2.8	3.0	3.0	3.2

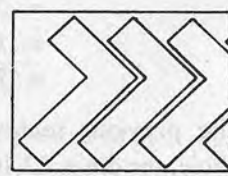
Fig. B18 Margins and bridges for blanking strips

B4.03 Strip Layout

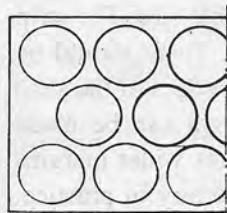
Material economy is of paramount importance in press work. Blanking being the first operation, raw material economy can be effected by using



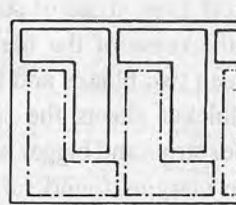
UTILIZATION = 80.3%
(a)



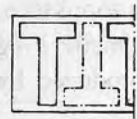
UTILIZATION = 68.2%
(b)



UTILIZATION = 56.4%
(c)



UTILIZATION = 69.4%
(d)



UTILIZATION = 40.1%



UTILIZATION = 68.2%
(e)



UTILIZATION = 38.9%

Fig. B19 Strip layouts

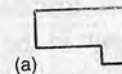
the most economical strip layout which can give the highest material utilization. Experienced press tool designers generally draw at least three strip layouts and compute and compare their material utilizations before commencing the design of the blanking tool.

Fig. B19 shows some commonly used strip layouts for various shapes of blanks. Rectangular blanks are normally blanked in a straight layout (Fig. B19a). Whereas L-shaped blanks can be produced economically on an angular layout (Fig. B19b). Small circular blanks are usually arranged in staggered rows, the number of the rows depending upon the blank size and the press capacity. Blanks shaped like letters T, U, and W can be produced economically by inverted layout (Fig B.19e). In inverted type of layout, two blanks can be sheared simultaneously or the strip can be turned upside down and fed again in a single blanking die. Material utilization for various layouts, can be computed from the following formula

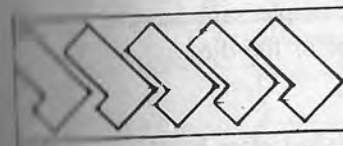
$$\text{Material utilization} = \frac{\text{Area of blanks from strip}}{\text{Area of the strip before blanking}}$$

$$= \frac{\text{Weight of blanks/strip}}{\text{Weight of strip before blanking}}$$

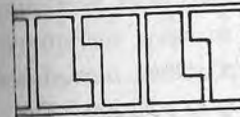
Fig. B20b, c, d show three layouts for the component shown in Fig. B20a and states the material utilizations for the layouts. When blanks are sheared from a strip slit from a flat sheet, the length may not be an integer multiple



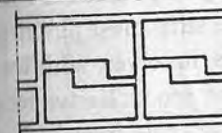
(a)



UTILIZATION = 50.8%
(b)



UTILIZATION = 61.9%
(c)



UTILIZATION = 62.2%
(d)

Fig. B20 Strip layout and material utilization

of the blanking pitch. This leads to end waste due to half/partial cuts at the tail end of the strip. This end wastage must be taken into account while computing material utilization. If a big roll of coiled strip is used the material

utilization can be calculated by dividing the area of 100 blanks with the area of the material required for producing those blanks.

B4.10 Control of Pitch by Stops

(After shearing off a blank, the strip is moved longitudinally towards the right to position it for shearing the next blank. The distance moved, called pitch, depends upon the shape and the size of the blank, the type of layout, and the margins provided. Pitch is controlled precisely by providing various types of stops in blanking tools.

B4.11 Simple Forward Stop

Fig. B21a shows a blanking tool with a simple forward stop. The strip end is held against the curved left hand end of the stop and the first blank is sheared. Then the strip is lifted to clear the height of the stop, and moved towards the right. It is lowered to insert the stop in the cut-out left by the previous blank, and moved again towards right till the left end of the opening in the strip touches the curved stopper face. The next blank can now be sheared with certainty that there will be adequate margin between the two following blanks. The cycle can be repeated to shear the following blanks till the entire strip length is consumed.

The gap between the stripper and the die should exceed the sum of stopper height and strip thickness by at least 1 mm to facilitate lifting the strip to clear the stop height. Note that the location hole for the stopper has been placed far from the cut-out in the die to avoid weakening of the die near the cutting edge. There should be ample safe margin without any weakening holes around the cutting edge of the die.

B4.12 Backward Stop [Fig. B21b]

When a backward stop is used the strip is lifted after blanking, moved ahead in the direction of feed, and lowered to insert the stopper in the opening, left by the previous blank. The strip is then moved backwards to touch the front end of the opening to the stop to position it for blanking the next piece. Thus after feeding forward the strip must again be moved backwards to touch the backward stop. This involves additional backward motion which takes time and reduces the productivity. Nonetheless backward stoppers are used extensively in small scale industries for small batch production due to their simplicity and cheapness.

B4.13 Inclined Pin Stops

The lifting of the strip can be eased by providing a slope on the top of the backward stop as shown in Fig. B21b. The operation can be speeded

up further by placing a spring-loaded back stop in the stripper. This design eliminates lifting of the strip altogether as the stop face is provided with a slope. The light spring holds the stopper down in contact with the die. The forward movement of the strip pushes the pin upwards against the spring and the strip can be slid below the stopper. Crossing the opening in the strip by the spring. The strip is then moved backwards to touch the front end of the cut-out to the stop. As this end of the stop is not inclined, the stop will not move upwards even if the strip is pulled backwards by excessive force.

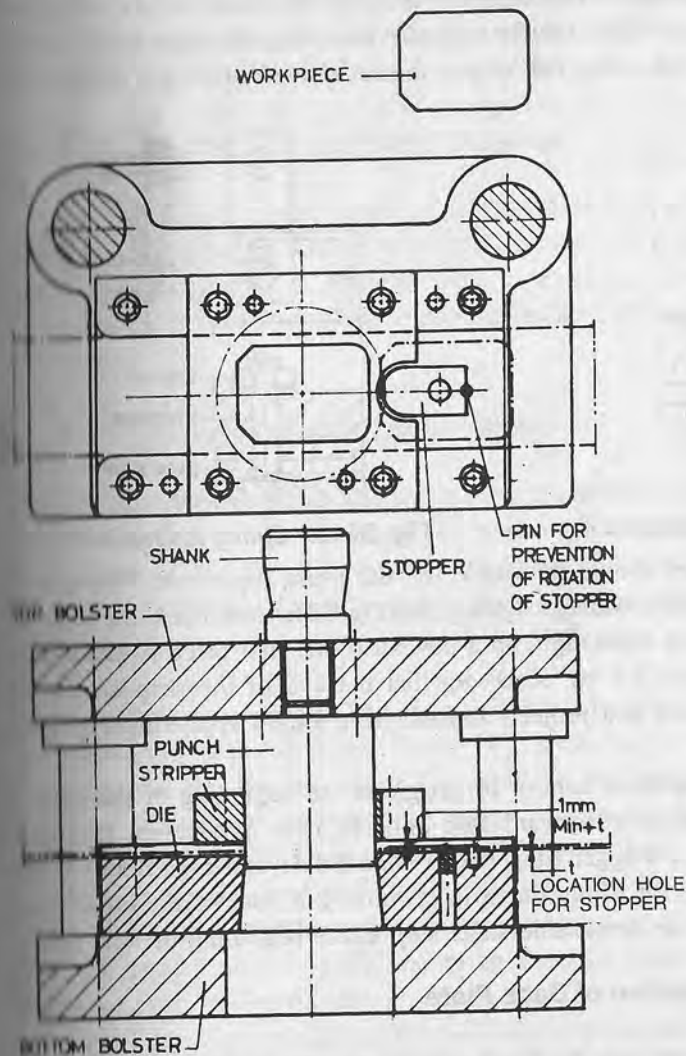


Fig. B21a Blanking tool with simple forward stop

There is another design which uses a compression spring instead of a flat spring. The spring keeps the pivoted stop pressed against the die surface. The inclined face of the stop acts as a cam, and the stop swivels anticlockwise to provide passage for the strip feed when the strip is pulled toward right. The stop drops automatically, under spring force, into the cut-out left by the previous blank. When the strip is pulled back towards left the non-inclined face of the stop touches the die and stops the strip from moving backwards.

In another stop which uses a compression spring, the stop pivots around a pin assembled in the die. The compression spring is housed in the bottom bolster. The inclined face of the stop allows strip feed passage towards right, but the opposite face stops the strip from moving backwards by arresting the strip in the cut-out left by the previous blank.

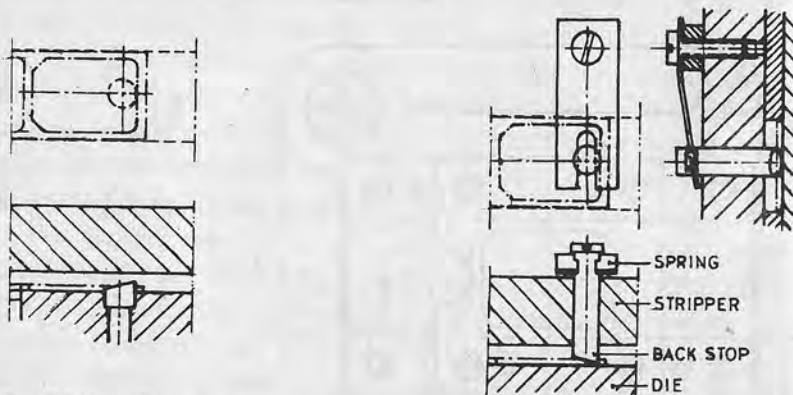


Fig. B21b Back stop

Fig. B21c Spring loaded back stop

The stopper should be visible to the press operator. This can be accomplished by providing a sighting slot (Fig. B21a) or a hole in the stripper.

Commencing blanking with a new strip, the first piece is blanked by sighting location, i.e. by observing that the end of the strip covers the entire die cut-out and projects beyond by a length approximately equal to the margin.

For more accurate control of margin at the beginning of the strip, it is necessary to use a forward stop only. In mass production it is convenient to use a Trigger Stop (Refer Para B4.41 and Fig. B22a) which eliminates need for lifting the strip or moving it backwards. Progressive Tools (B6.00) use retractable stage stop at the beginning of new strip.

B4.20 Elimination of Back Plate

Blanking punches can be fitted directly to the top bolster if there is sufficient contact area between the punch and the bolster to transmit the

cutting force. The pressure on the contact area should not exceed 80 N/mm². For example for piercing a 100 mm square hole in 1.5 mm thick sheet

$$\text{Cutting force, } V = (100 \times 4 \times 1.5) \times 400 = 240000 \text{ N}$$

$$\text{Area of blanking punch} = 100 \times 100 = 10000 \text{ mm}^2$$

$$\text{Pressure} = \frac{240000}{10000} = 24 \text{ N/mm}^2$$

Since the stress is below 80 N/mm² the punch can be directly fitted to top bolster without an intermediate back plate. Blanking punches for cutting M.S. sheets less than 3 mm thickness generally do not require back plates.

B4.30 Shank Position and Blank Disposal

In single blanking tools the shank is usually placed at the geometrical centre of the punch to minimize eccentric loading. The hole in the press table should be drawn in the die plan to ensure positive automatic disposal of the blank and adequate resting of the bottom bolster on the press table.

B4.40 Segmental Die with Trigger Stop

Fig. B22 shows a blanking tool for rapid mass production of the component illustrated in the drawing. The segmental design simplifies the manufacture of the die. The left hand segment 'L' can be turned and ground to 80.00 mm radius. The die-maker has only to file a fall through $1\frac{1}{2}^\circ$ relief angle on the cutting part of the 80.00 mm radius. The non-cutting part of 80.00 mm radius should be left parallel to bear with the mating radius on segment R. This segment too can be bored for 16.00 mm and 80.00 mm radii on lathe. Even $1\frac{1}{2}^\circ$ relief taper for 16.00 mm radius can be finished on lathe. This reduces the manufacturing time considerably. Imagine the time a die-maker will take to make the closed precision cut-out by drilling and filling a one piece die.

The two segments of the die are aligned by a key. The segments should be clamped together with a mating pressure on 80.00 mm radius. This can be accomplished by anchoring the two segments in a light interference fit (H7/m6) slot in the bottom bolster, entailing careful grinding. The manufacture can be simplified by making the anchoring slot in bottom bolster bigger and providing a cheap key packing (Fig.

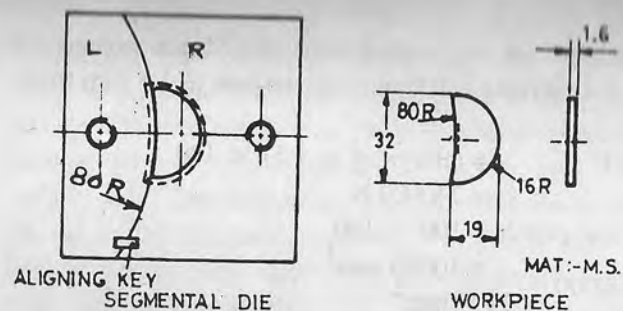


Fig. B22a Blanking tool with segmental die trigger stop

B23a). The key can be ground separately to suit the width of the assembled segments, and replaced cheaply if ground undersize by error. Segmental dies needing removal from bottom bolster for resharpening grind are provided with angular clamps for quick assembly of the die segments (Fig. B23b). This arrangement is used widely in notching tools for electrical laminations and stampings (Fig. B60a), for notching tools wear out rapidly and require frequent replacements. Only hardened die segments (inserts) and punches need to be replaced. Bolsters and other

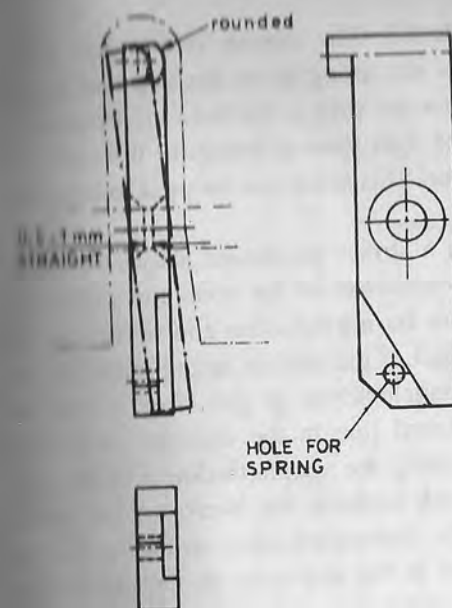


Fig. B22b Enlarged view of trigger stop

elements last much longer. Fig. B23b shows die segments for a rectangular slot.

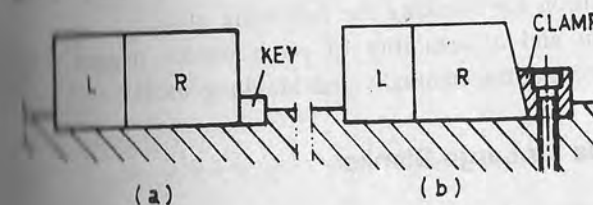


Fig. B23 Segments mounting arrangements

B4.41 Trigger Stop

The trigger stop (Fig. B22a) eliminates the need to lift the strip or move it forward and backward for feeding. Moreover the stop is fitted in the stripper without weakening the die with stop location holes. Trigger stop is housed in a slot 2–3 mm wider than the thickness of the stop. The stop oscillates around the pivot pin fitted in the stripper. The pivot hole in the trigger stop should be at least 1 mm bigger than the diameter of the pivot pin. Furthermore the pivot hole is chamfered from both the ends to leave only 0.5–1 mm straight land at the centre. The chamfer and clearance allow the trigger stop to tilt (out of square) towards left as shown by chain-dotted line in the enlarged view [Fig. B22b]. The slot in the stripper is tapered beyond (below in enlarged drawing) the pivot pin to facilitate

the tilting of the stopper towards left. The stopper is attached with a tension spring. The angular pull of the spring keeps the stop end pressed downwards and towards left. When the strip is fed forward from left to right the stopper moves against the light tension spring till it touches the adjusting screw fitted in the stripper. This screw can be used to adjust the margin between two blanks.

The top tool is provided with a striker positioned above the spring end of the trigger stop. During downstroke of the press the striker hits the stopper. This pivots the stopper raising the other end well above the strip thickness level. The angular pull of the tension spring pulls the stop towards right. The stopper tilts anticlockwise in the clear slot in the stripper as shown by the chain-dotted line in the enlarged view (Fig. B22b). As a result the stop moves above the margin thickness in the strip. The stopper descends on the margin between the blanks as the striker rises during return upstroke, and the downward force on the spring end of stop is removed. The lower face of the stop rests on the margin and rubs the top face of the strip as it is fed forward. Crossing the margin the stop falls in the strip cut-out and touches the die. The angular pull of the spring keeps the stop tilted and pressed downwards on the die. During strip feeding, the left hand edge of the cut-out in strip pushes the stopper against the light tension spring till the stop touches the adjusting screw. The strip is now in position for blanking the following piece.

Automatic operation and adjustability of pitch render trigger stop indispensable in high production, manually fed blanking tools.

✓ B4.50 Inverted Tools for Large Blanks

(When blank is bigger than the fall-through hole in press table it is necessary to use Inverted Blanking Tool (Fig. B24a). The blanking punch is mounted on the bottom bolster whereas the die is fitted to the top bolster.) Punches with cross-section big enough to accommodate two big (or many small) dowels can be mounted on bolster without any need for anchoring (Fig. B24a). Even back plate is not necessary for blanking thin sheet of soft materials.

B4.51 Spring Strippers.

The spring stripper reciprocates vertically with every cutting stroke. The stripper is held up by compression springs and retained in position by stripper adjusting screws. The stripper level should be adjusted at least 0.5 mm above the punch for positive stripping. The height of guides should be slightly (0.1–0.5 mm) less than the strip thickness to be used,

that strip is held firmly sandwiched between stripper and die before cutting commences.

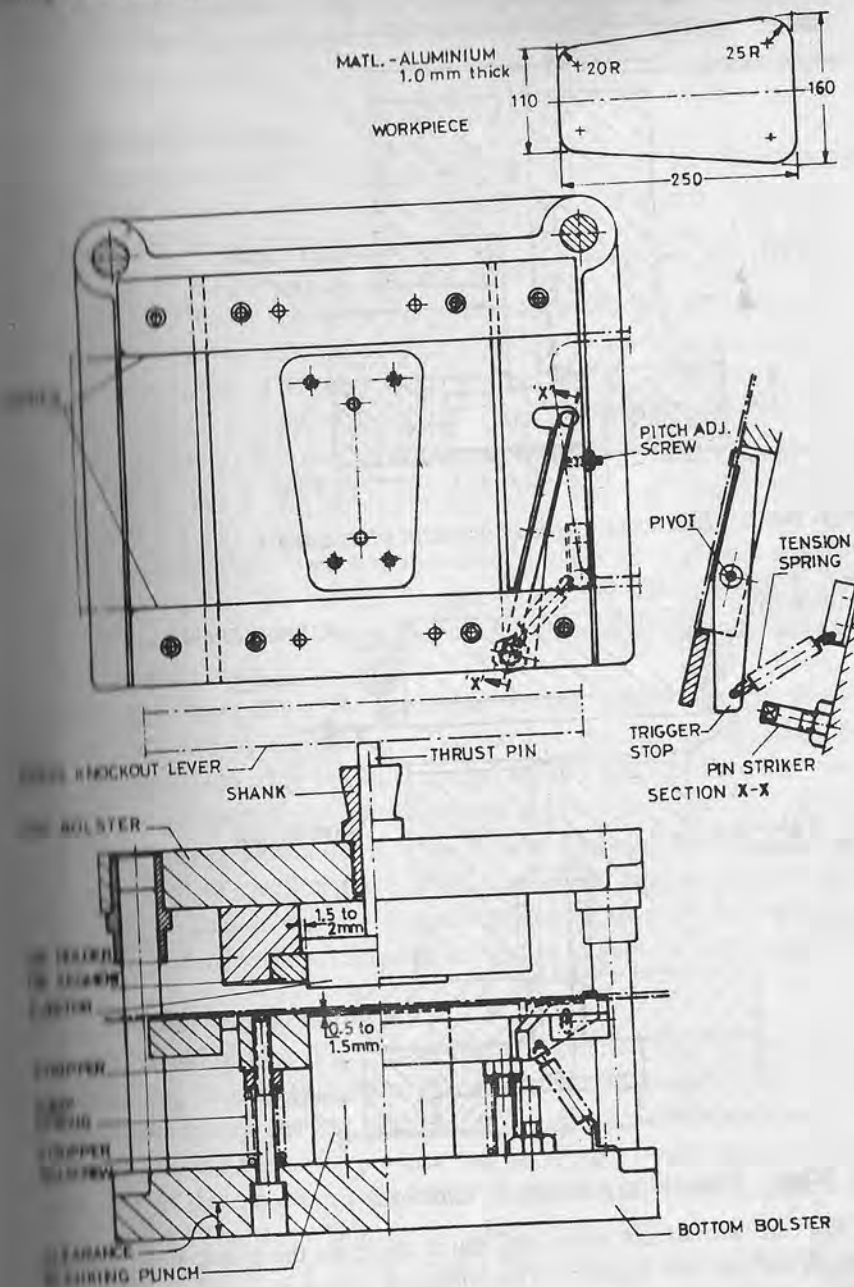


Fig. B24a Inverted blanking tool

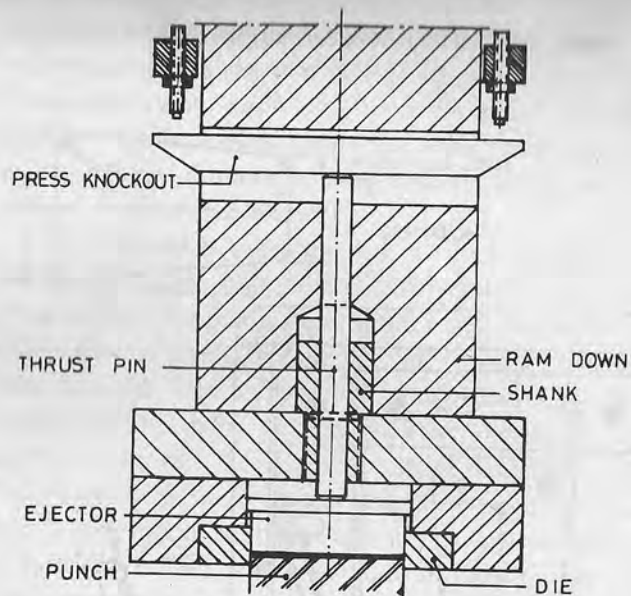


Fig. B24b Ejection by press knockout (ram down)

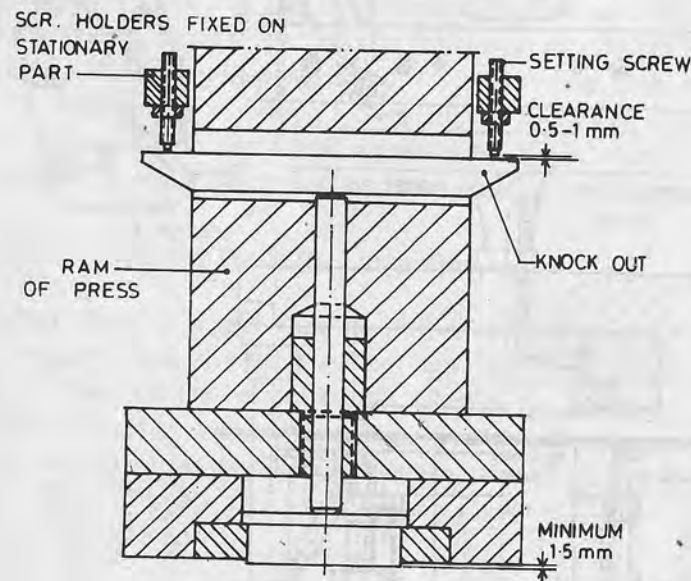


Fig. B24c Ram at top position for knockout

The die should not have any relief angle as the blank need not fall through the die for disposal. The cut blank enters the die cut-out and is sandwiched between the punch and the ejector which moves upwards. Simultaneously the blanked strip and the spring stripper are pushed downwards against compression springs by the die. The stripper adjust-

ing screws, too, move downwards with stripper. Naturally the head of the stripper adjusting screws should have sufficient clearance below to prevent the screw heads striking the press table. The stroke of the press should be adjusted carefully to prevent the stripper adjusting screws damaging the press table.

B4.02 Ejection Knockouts

Generally presses above 20 tonnes capacity are provided with knockout for ejection of components from the top tool. There is a hole above the blank hole. The ram is provided with a cross slot for the press knockout which is free to reciprocate in the slot. When the press ram is in up position (Fig. B24c) the ejector collar rests on the die and the thrust pin goes above the ejector which in turn supports the press knockout against the gravitational fall. The knockout setting screws should be about 1.5 mm clear of the top of the press knockout in this position. The ejector should protrude at least 1.5 mm below die face in ram up position. The collar of the ejector prevents the gravitational fall of the ejector out of the die.

During downstroke of the ram, the sheared blank and the punch push the ejector upwards. This pushes the thrust pin and knockout upwards in the ram slot [Fig. B24b]. The knockout setting screws are mounted on a fixed, stationary part of the press.

During return upstroke the stationary setting screws hit the press knockout and push it downwards. This pushes the thrust pin and the ejector downwards driving out the jammed blank from the die. After the jammed piece is ejected, the ejector, thrust pin and knockout fall down by gravity till the ejector collar touches the die. The ejector collar should not be subjected to ejection force which can be as high as 10% of the blanking force. That is the reason there should be at least 0.5 mm gap between the setting screws and press knockout in ram up position.

B4.03 Inverted Trigger Stop

The single blanking tool (Fig. B24a) uses an inverted strip layout [Ref. Para B4.03 and Fig. B19d]. The trigger stop pivots in a bracket mounted underneath the spring stripper. The slot in the bracket is wide enough to permit tilting of the trigger stop which has got a chamfered oversize pivot hole similar to the stopper in Fig. B22. However the striker is mounted on the bottom bolster. During a downstroke, the stopper moves downwards along with the spring stripper. The spring end of stopper hits the striker. This pivots the stop to lower the other end below the strip. Angular pull of the tension spring pulls the spring end of stop downwards right and the stop tilts towards left under the margin between

two blanks. As the ram withdraws, the tension spring raises the stop to touch the underneath of the margin with a light pressure. When the strip is fed forward the stop crosses the margin and rises to enter the strip cut-out under pull of the tension spring. Touching the left hand edge of strip cut-out, the stopper is pushed right against the tension spring till it touches the pitch adjusting screw. The tool is now ready for blanking the next piece.

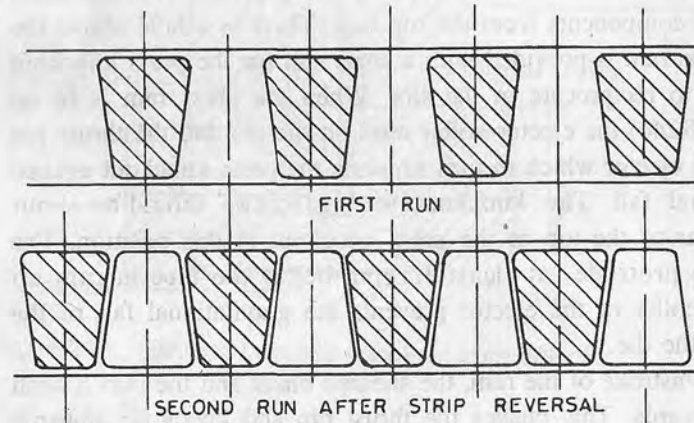


Fig. B25 Strip reversal for better material utilization

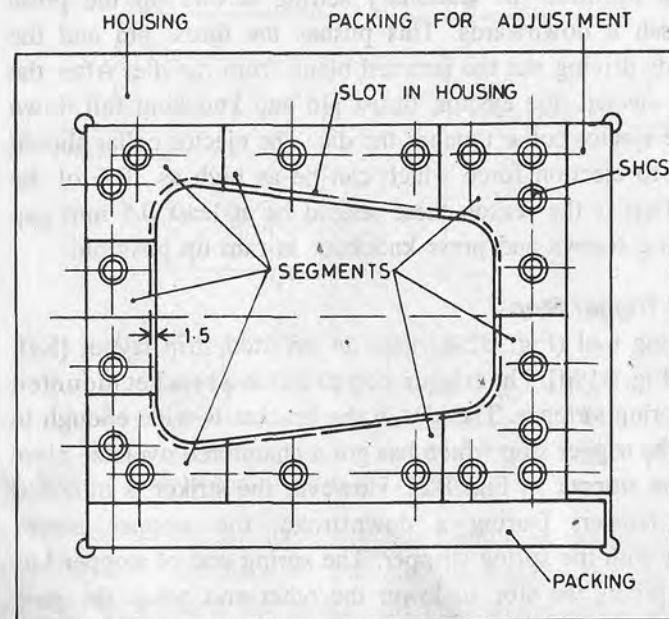


Fig. B26a Segmental die for Fig. B24 a

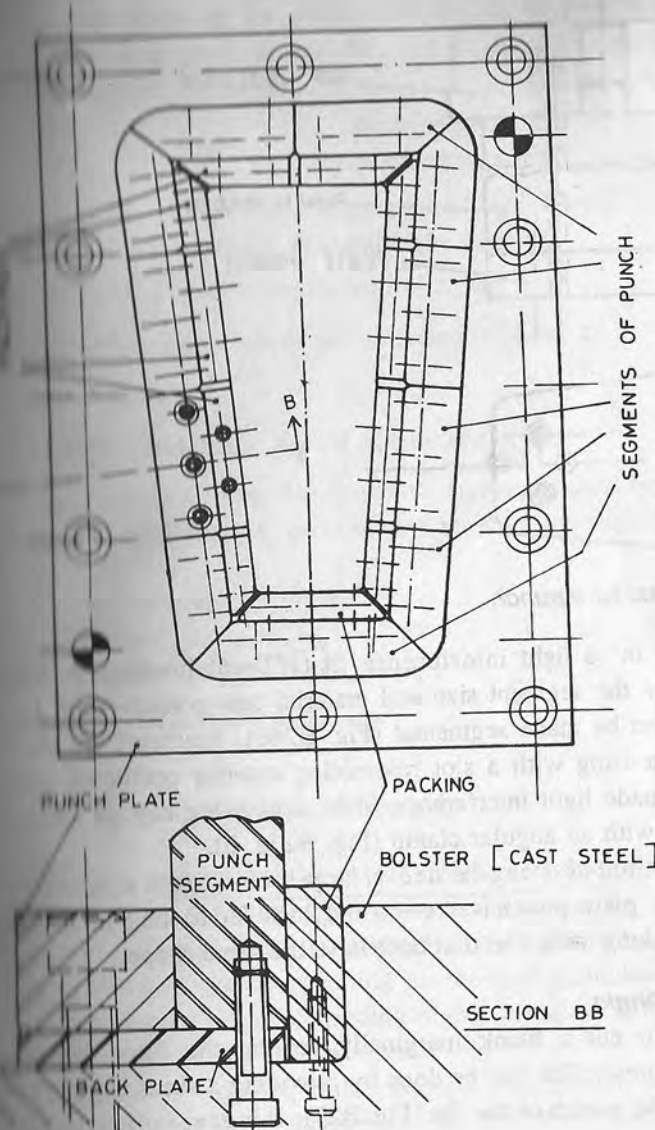
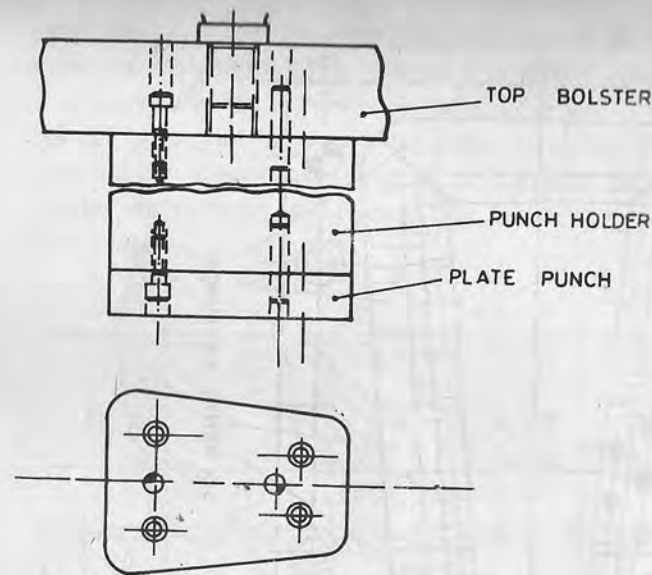


Fig. B26b Segmental punch

The first blank at the beginning of the strip can be cut by seeing by eye that the strip projects slightly beyond the blanking punch. After blanking the full length, the strip is reversed and fed again to cut the inverted blanks (Fig. B25).

84.84 Tool Steel Economy

Blanks for big blanks are generally segmented. This saves material, and simplifies manufacture and rectification (Fig. B26a). The segments are



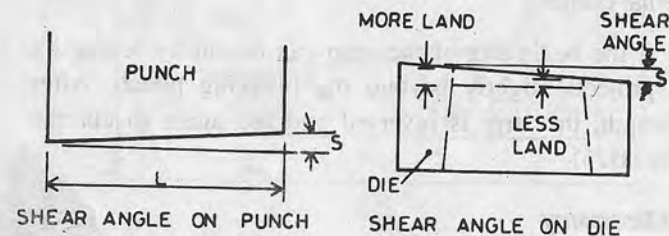
✓ Fig. B26c Plate type punch

screwed down in a light interference fit ($H7/m6$) housing. A sturdy housing reduces the segment size and material cost considerably. Large punches can also be made segmental (Fig. B26b). Segments are usually screwed in a housing with a slot resembling exterior profile of punch. Segments are made light interference fit in slots using key packings, or clamped down with an angular clamp (Fig. B23a, b).

Another method of saving die steel in large tools is to use a plate punch (Fig. B26c). The plate punch is screwed and dowelled to the punch holder and machined along with it so that both have the same shape.

✓ B4.55 Shear Angle

It is possible to cut a blank marginally beyond the force (tonnage) capacity of the press. This can be done by providing a shear angle on the cutting face of the punch or the die (Fig. B27). It is generally convenient



✓ Fig. B27 Shear angle on punch and die

to provide the angle on the punch. For the die land becomes uneven if the shear angle is given on the die. The shear angle can be calculated from the following equation

$$\cos (\text{shear angle}) S = \frac{\text{Press capacity (Tonnes)}}{\text{Reqd blanking force (Tonnes)}}$$

Shear angle spreads the cutting action over a longer part of stroke and the punch shears blank gradually like scissors.

$$\text{Additional stroke length reqd} = L \tan S$$

L = Length of the punch in the direction of shear angle

S = Shear angle

Generally the shear angle should not exceed 8° .

In gang piercing tools also, the press can be worked beyond its force capacity by keeping some punches longer than the remaining punches

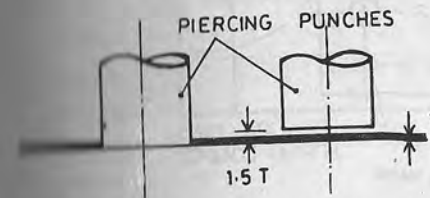


Fig. B28 Piercing beyond press capacity

by about one and a half times the workpiece thickness. The longer punches pierce the workpiece first (Fig. B28) before the shorter punches commence piercing. Thus the press frame is not subjected to heavy piercing force required for piercing all the holes simultaneously, and it can be used for a workpiece needing higher force capacity. This method can be used only on hydraulic presses.

Grinding shear angle as well as keeping punch lengths different entail more grinding time for resharpener. As such these methods should be used as a last resort only.

B6.00 COMPOUND AND COMBINATION TOOLS

Compound Tools combine two cutting operations in a single press tool. The blanking punch also serves as a piercing die. This ensures perfect relationship between the pierced hole and blank profile. Compound tools produce more flat blanks than ordinary blanking tools.

✓ B5.10 Compound Tool for Ring

Fig. B29 shows a compound tool for a big ring shaped like a washer. The blanking punch is anchored in the bottom bolster and fixed with socket

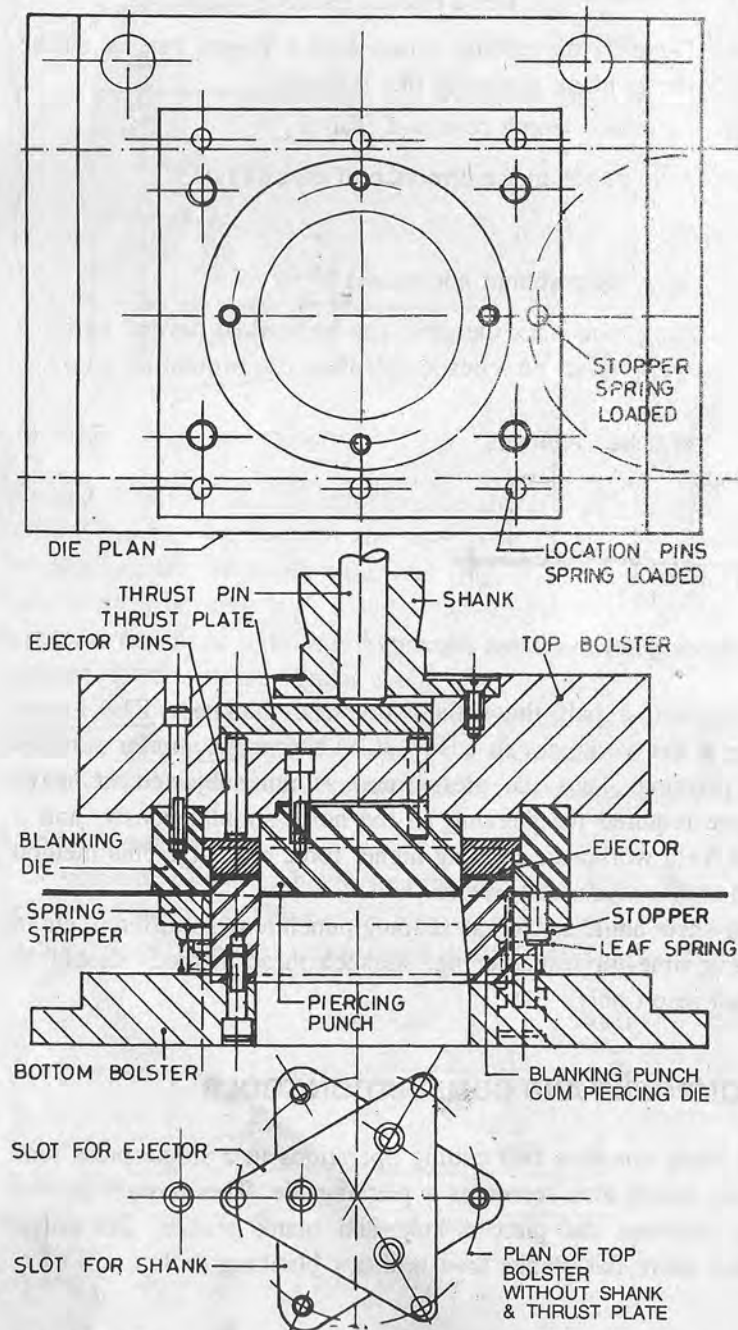


Fig. B29 Compound tool for ring

head screws. The blanking punch has got a central hole with a straight land and fall through relief angle. The hole serves as a die for the central piercing punch fitted to the top bolster. The bottom bolster also houses a spring stripper similar to one used in inverted blanking tools (Fig. B24a).

B5.11 Ejection of Blanks

The blanking die is fitted to the top bolster with screws and dowels. There is no fall through relief angle in the blanking die as the blank does not fall through the die. The ring like blank moves up between the blanking die bore and the piercing punch as shown in the elevation of Fig. B29. The blank is ejected from the blanking die by an ejector similar to the one used in inverted blanking tools. However, as the blank is shaped like a ring it is necessary to use ejector pins and a thrust plate to transmit the press knock-out impact from the central thrust pin to the ejector.

During upstroke the press knockout hits the thrust pin downwards. This pushes the thrust plate, ejector pins and the ejector downwards to eject the blank from the top tool.

The unsupported central part of the top bolster above the piercing punch should be strong enough to withstand the bending load due to the piercing force.

The bending stress on the minimum section of top bolster should be below 60 N/mm^2 .

B5.12 Flanged Shank

The flanged shank is housed in a triangular step milled in the top of the upper bolster. The top face of the shank flange should be below the upper face of the top bolster so that the blanking force is transmitted

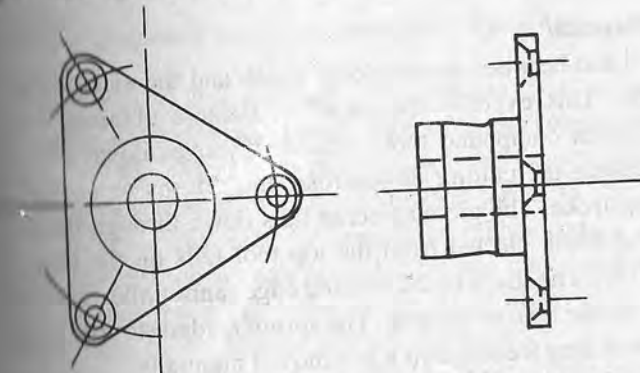


Fig. B30 Flanged shank for compound tool in Fig. 29

directly from the ram face to the top bolster. The triangular flange of the shank has got countersunk holes for the fixing screws (Fig. B30).

B5.13 Split Bolster

The deep counter-bore at top and the thick section required above the piercing punch increase the thickness of the top bolster considerably. The top bolster can be split into two plates if thick plates are not available.

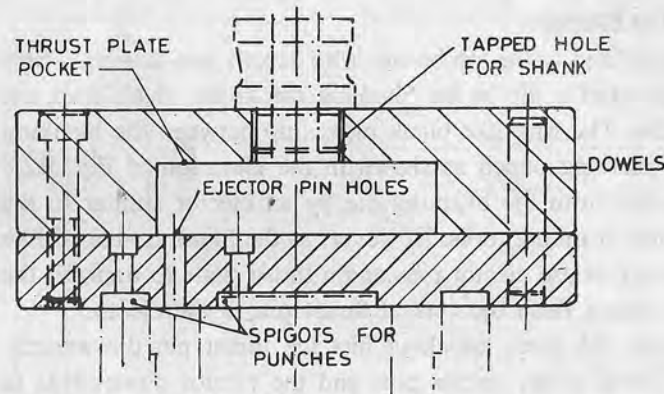


Fig. B31 Two piece bolster for compound tool

(Fig. B31). In this design a simple threaded shank can be used by increasing the combined thickness of two plates marginally. This increases the shut height of the tool.

B5.14 Spring Loaded Locator and Stopper Pins

Compound tools generally use spring loaded location pins for guiding the strip. The top blanking die pushes down the location pins against the flat single leaf springs during the cutting operation. Similar spring loaded pin is used as a stopper, as shown in sectional elevation [Fig. B29].

B5.15 Blank Disposal

The blank is held flat between the blanking punch and the ejector during the cutting stroke. This explains the excellent flatness obtained in the blanks produced from compound tools. The strip moves down with the spring stripper during the cutting downstroke and returns to normal up position during upstroke. The piercing scrap falls down through the press table hole. But the blank ejected from the top tool falls on the hole left in the strip (Fig. B32). The shape of the sheared edge cannot allow the blank to fall down through the hole in the strip. The spring-loaded stopper pushes the blank upwards during feeding and it is removed manually.

B5.16 Use of Air Jet for Blank Disposal

If compressed air is available the press can be fitted with an air nozzle. The nozzle can be directed to blow the blank ejected from the top tool

towards the rear of the press. The gap in the press rear frame can be fitted with a chute for gravitational slide of the blank into a receptacle. This method eliminates manual unloading of the blank, and speeds up production. The production can be speeded up further by using a trigger trap similar to Fig. B22.

B5.17 Built-in Precision

The concentricity of the bore with the outside diameter of the blank depends upon the concentricity of the piercing die and the blanking punch. As both of these are combined into a single unit, the concentricity of the blank can be built into the tool itself by making the piercing die and blanking punch outside diameter dead concentric.

B5.18 Compound Gang Blanking Tool

When the blank shape is small, and press tonnage required per blank is low a number of blanks can be accommodated in a single gang blanking tool to produce more than one blank/stroke of press.

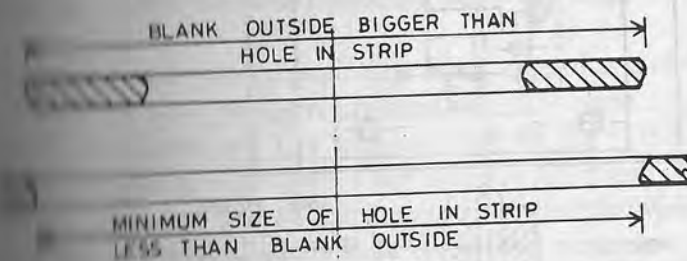


Fig. B32 Shapes of edges of blank and pierced hole in compound tools

The scrap falling through the bottom bolster falls through the hole in the die cushion adaptor plate, onto the conical plate fitted at top of the cushion. The scrap slides down the conical plate to the floor. The cushion provides the upward thrust to the bottom stripper eliminating any need for springs or rubber pads.

The die-cushion adaptor is guided by two pins fitted in bottom bolster to ensure that the scrap holes in the adaptor are aligned with the fall through holes in the bottom tool all the time.

It is necessary to use a thrust plate to transmit the knockout impact to the ejectors in the top tool. The thrust plate pushes down the thrust pins which in turn push down the annular ejector provided with a retaining pin at top to prevent gravitational fall. The ejectors should project about

1 mm below the piercing punch/blanking die face for positive ejection. Depending upon the ejection force required and the annular space available each ejector is provided with two to six thrust pins.

B5.20 Compound Tool for 'E' Lamination

Fig. B33a shows a compound tool for 'E' lamination. The lamination has got two pierced holes. The blanking punch mounted on the bottom

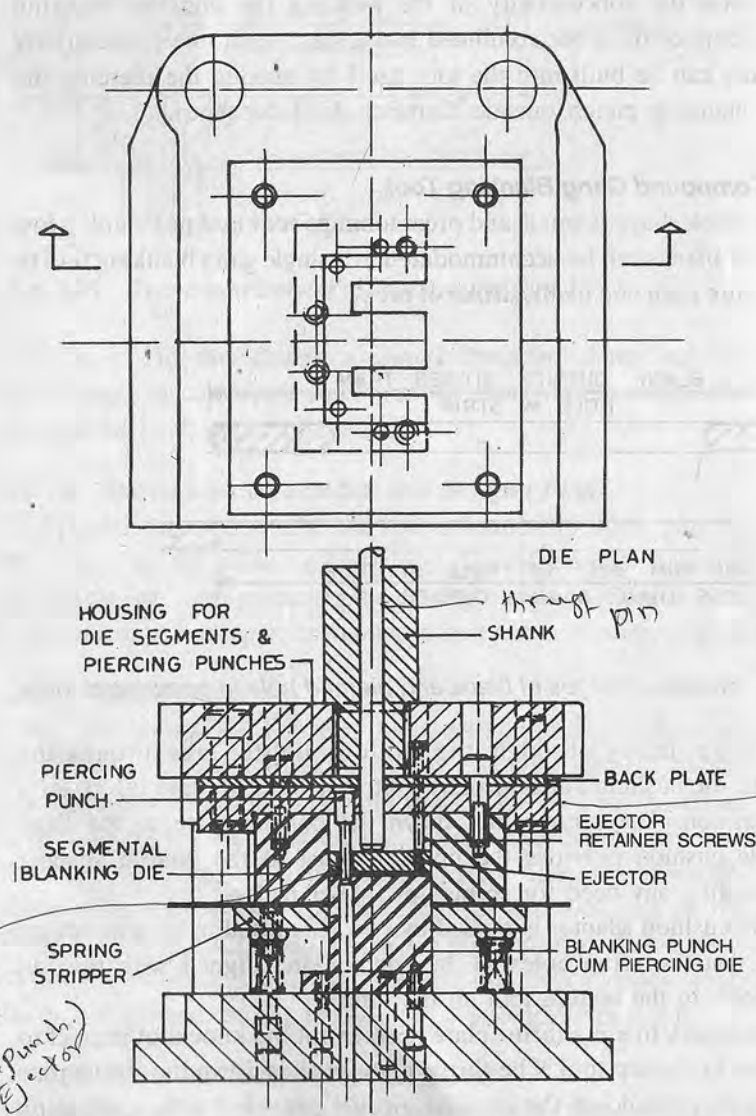


Fig. B33a Compound tool for 'E' lamination

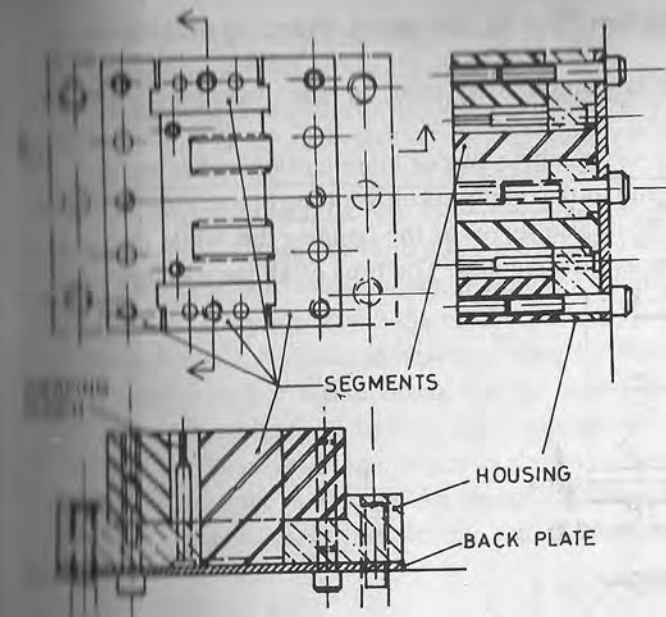


Fig. B33b Segmental die of compound tool in Fig. B33a

holder is provided with corresponding holes to serve as a die. For round holes of small sizes the die is provided with 0.5–1 mm bigger parallel sided holes instead of $1\frac{1}{2}^\circ$ angular relief for fall of the scrap. The blanking punch is provided with a big flange at the mounting end, and is fixed by screws and dowels. The ample contact area between the punch flange and the bottom bolster make back plate unnecessary. The segmental design of the die (Fig. B33b) simplifies the manufacture and replacement of die. The segments are anchored, screwed and dowelled in the die holder. The sub-assembly of die segments and die holder is fixed to the top bolster by strong screws and dowels. The ejector has been provided with three retainer screws instead of a collar which would require a weakening step in the segmental die. The stepped piercing punch, too, are fitted in the die holder. This calls for a back plate above the die holder. The ejector has been provided with bushes for guiding the smaller piercing punches. The collars of bushes should be flush with the ejector face to prevent denting of the blank. The shank has got a hole for the pin transmitting thrust from press knockout to the ejector. The clearances between the blank periphery and the pierced holes is built into the combined blanking punch and piercing die, and will not change as the blanking punch lasts.

B5.30 Combination Tool for Blanking, Piercing and Flanging

Fig. B34b shows a combination tool for the workpiece shown in Fig. B34a.

Combination tools combine two or more cutting and forming operations while compound tools compound only cutting operations. The blanking punch in Fig. B34b also serves as the flanging die, while the flanging punches also serve as piercing dies. The tops of all the ejectors must be

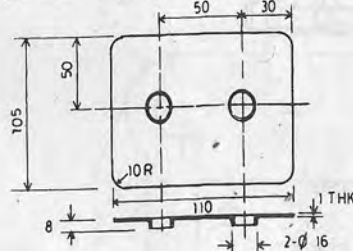


Fig. B34a Workpiece

ground level on assembly. The stripper in the bottom tool is actuated by die cushion. The piercing die top is shaped to serve as a punch.

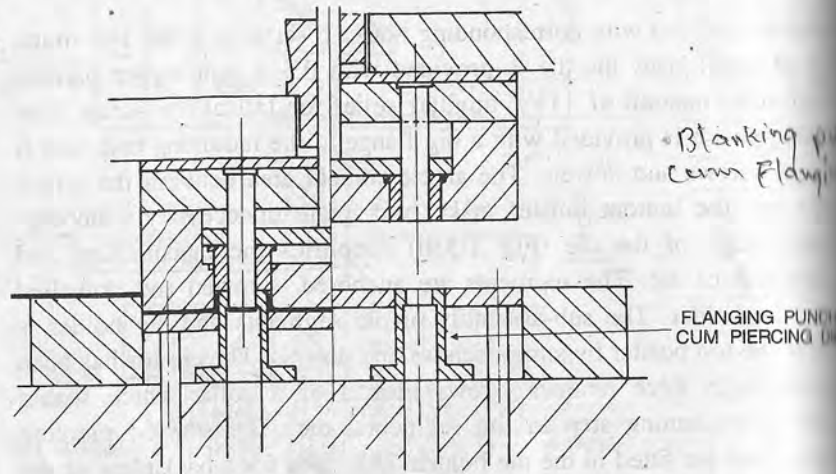


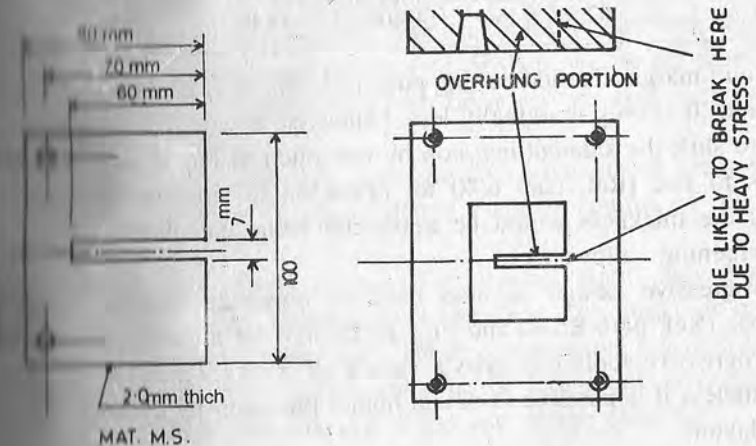
Fig. B34b Combination tool

B6.00 PROGRESSIVE TOOLS (FOLLOW ON TOOLS)

A progressive tool combines two or more tools into a single tool which produces one finished blank per stroke of the press. The operations are arranged in a succession to work strip progressively with each stroke. The number of stages depend upon the shape and size of the workpiece

depending upon the number of stages the tool is called 2-stage, 3-stage or multi stage progressive tool.

When a workpiece requires more than four press operations and the total requirement exceeds 500000, it is convenient and economical to use a progressive tool. Also, when the workpiece shape is such that a simple blanking tool would stress the vulnerable part of the die beyond its yield stress it is necessary to use a progressive tool to avoid a weak die or punch. For example, if we use a simple blanking tool for the workpiece shown in Fig. B35a the 7 mm wide $\times$ 60 mm long overhung portion of the die will be stressed heavily during blanking. It will bend the die and jam the tool or worse, break it at the right hand (fixed) end of the 60 mm $\times$ 60 mm section of the die. This problem can be overcome only by dividing the shearing in three stages as shown in the strip layout in Fig. B35a. One more stage is required for the side-cutting stop. The cantilever stress is eliminated completely. The thickness of die is calculated



Workpiece

Die for simple blanking tool

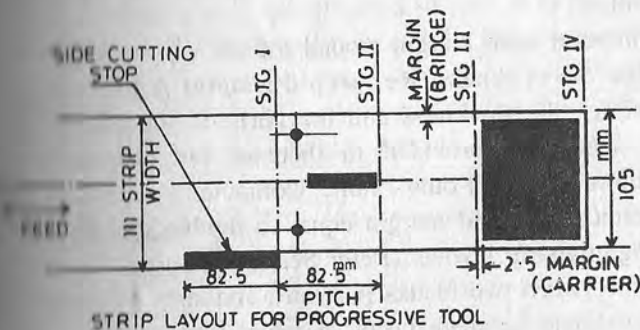


Fig. B35a Strip layout for progressive tool

for the punch with maximum perimeter, i.e. blanking in Fig. B35a. Solid margins for smaller die cut-outs are calculated after calculating shearing force for the individual operations and theoretical thickness. The theoretical die thickness for piercing ϕ 8 holes and $7 \text{ mm} \times 60 \text{ mm}$ slot would be lesser than the die thickness for the last blanking stage. The theoretical thickness is multiplied by 1.2 to find the die cut-out margins for these operations. Consequently margins for smaller die cut-outs will be lesser than for bigger cut-outs. For the strip layout in Fig. B35a the calculated thicknesses and margins for various cut-outs are as follows:

Sr. No.	Punch Size (mm)	Shearing Force V (Newtons)	Die Thickness (mm)	Die Margin	
				Reqd	Actual
1.	100×80	288000	57.38	68.86	85.0
2.	60×7	107200	14.50	17.40	33.8
3.	ϕ 8	20106	7.90	9.50	16.0
4.	82.5×6	141600	14.40	17.30	16.0

Solid margin for side-cutting punch (S. No. 4) is about 8% lesser than required. It is only marginally less. Otherwise it would have been necessary to shift the side-cutting stop by one pitch to left to increase No. of stages to five [Ref. para 6.40 for operation of side-cutting stop]. The actual die thickness would be maximum value calculated : $57.38 + 3$ (resharpening allowance).

Progressive design is also used to eliminate slender vulnerable punches (Ref. para B6.40 and Figs B42a, b, c for an example).

(Progressive tools can give accuracy of $\pm 0.15 \text{ mm}$ (IT 13 grade). Nonetheless it is possible to obtain higher precision by devising a proper strip layout.

✓ B6.01 Strip Layouts for Progressive Tools

The following guidelines can help in designing a good strip layout for progressive tools:

- The minimum solid margin around the die cut-out should be 1.2 times the die thickness (Ref. step d chapter A for methods for determining die thickness and margin). If necessary, an idle station should be provided to increase the distance between neighbouring die cut-outs. Some Computer Aided Die Design Programmes use solid margin equal to double the die thickness for designing strip layouts (Refer Section I).
- Margins between two blanks (Carrier), and strip edges and blank (Bridge) should be adequate (as per Fig. B18).

(c) Punches should be positioned in such a way that the press is loaded uniformly. The shank should be placed at the centre of pressure (Ref. step 'j' in chapter A).

(f) Punches disposition should ensure positive scrap/blank disposal. If the punches fall outside the fall through hole in press bolster/table a special bolster is necessary (Ref. Fig. B37).

(e) Features calling for positional tolerance between pierced hole is a single stage. If centre distance tolerance between pierced hole is less than ± 0.15 , the holes should be pierced in a single stage. For example the 8ϕ holes with ± 0.05 accuracy (Fig. B35a) on centre distance 80.0 should be pierced in a single stage to obtain the accuracy built in die itself. The distance 70 mm for the holes and length 60 mm for 7 mm wide slot will vary up to ± 0.15 due to segregation of piercing and blanking necessary in progressive design.

(f) Pilots must be provided for precise corrective positioning of strip before shearing takes place. The 8ϕ holes in the blank shown in Fig. B35a can be used for piloting. If there are no pilotable holes in workpiece, suitable holes can be added in scrap area of strip (Ref. Fig. B41a).

(g) The tonnage, table area, and ram face area of the press should be adequate for accommodation, and operation of the long progressive tool.

This section covers progressions of cutting operations only. Sophisticated progressive tools combine even bending, forming and drawing operations in a single tandem tool. These *combination progressive tools* are detailed in chapter 'H' after covering the individual processes such as bending, forming, and drawing in the intervening chapters.

B6.10 Two-Stage Progressive Tool

Fig B35b shows a two-stage progressive tool with the strip layout. The strip is pierced with the central hole and the key-way in the first stage. It is necessary to provide a first stage stopper for piercing the central hole for a new strip. The first stage stopper is held in a withdrawn position by a spring so that it will not obstruct the path of the strip during subsequent feeding. Care should be taken that the stopper will not protrude in the path of cutting punches. This can be accomplished by making a slot on one side of the stage stopper. A retainer pin engaging in the slot limits the forward as well as the backward travel of the stage stop. When commencing production with a new strip the first stage stop is pressed

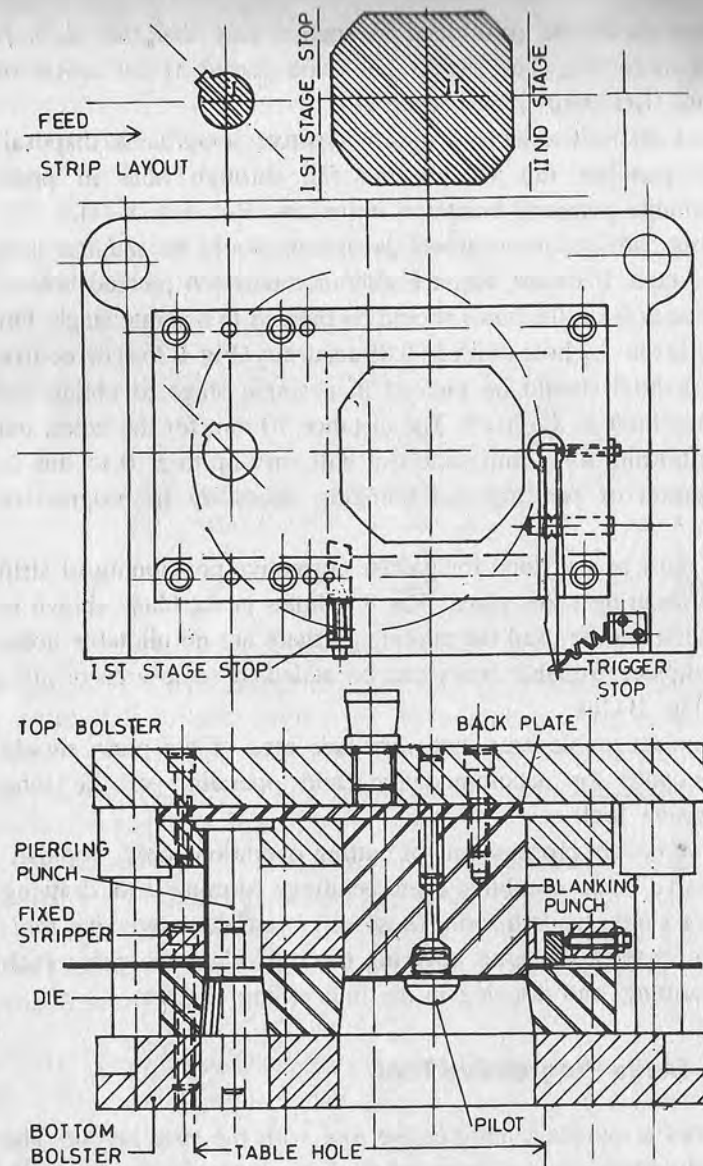
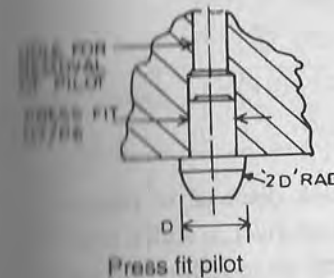


Fig. B35b Two-stage progressive tool

forward by the right hand, and strip end is pressed against the stop to ready it for the first stage piercing. After piercing, the first stage stop is released to clear the path for feeding, and the strip is moved towards right till its end touches the trigger stop used for the 2nd stage blanking.

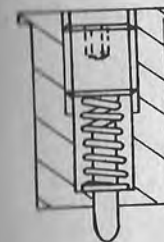
B6.11 Pilots *to Thumbs Stop*

The blanking punch is fitted with a pilot for accurate centralization of the pierced hole with the blanking punch. The pilot has been provided with a liberal radius or a chamfer at the entry point. This lead on the pilot moves the strip to correct the feeding (pitch) errors. Fig. B35c shows

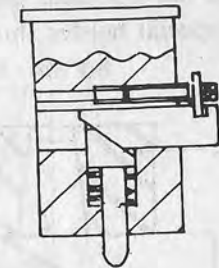


Press fit pilot

Press fit pilot for small holes



Spring loaded pilot



Height adjustment

Fig. B35c Pilot types

some other types of pilot designs. Pilots can be spring loaded with a grub screw for adjusting the spring compression. Pilot position can be made adjustable in height by machining an inclined face at top of the pilot and providing a wedge and adjusting screw in the housing (punch).

Generally the trigger stop of a blanking tool with a pilot is adjusted in such a way that the strip is fed about 0.1 mm more than the pitch. This allows space for the strip to slide backwards towards left as the pilot centralizes the pierced hole with the blanking punch. After piercing a hole in the first stage, the strip is moved towards right to halt against the trigger stop. The tool is now ready for blanking the following pieces. Each subsequent stroke produces a finished blank till the remaining strip length is consumed.

B66 Press Tools: Design and Construction

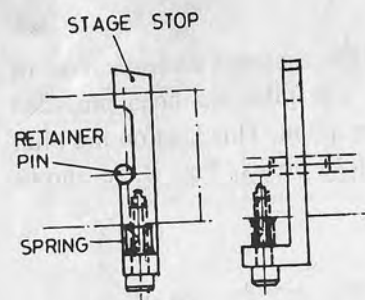


Fig. B36 Retention of stage stop (thumb stop)

B6.12 Scrap Disposal

One must be very careful about the scrap/blank disposal in progressive tools. For in multistage tools the scrap is spread over a wider area. The shank must be placed in such a way that all the scrap falling through the die has got clear passage through the press table. If that is not possible a special bolster should be provided to facilitate the scrap slide down an

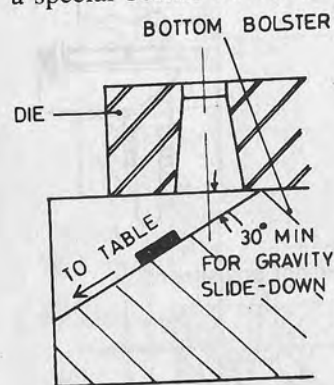


Fig. B37 Disposal of scrap beyond fall through hole in press

inclined slot in the bolster (Fig. B37) to the press table from where it can be removed manually periodically.

B6.20 Four-Stage Tool for Washers

Fig. B38 shows a four-stage progressive tool for gang blanking three washers per stroke. The strip layout beside the component drawing shows the disposition of punches on the tool. It should be noted that the punches are spaced widely to provide healthy margin around the cutting holes in the die. This is accomplished by leaving an idle (non-cutting) stage between the staggered piercing and blanking stages. Thus after

piercing the three 11 dia holes, the next stage is left idle. The last stage blanks three finished washers.

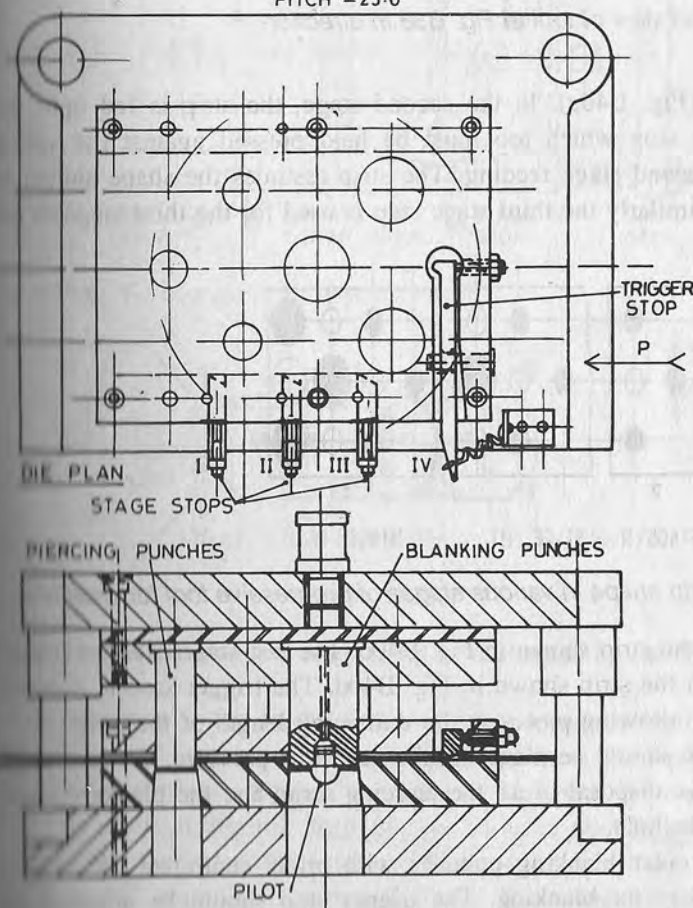
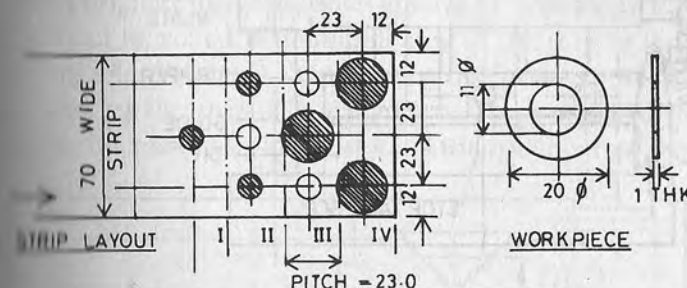


Fig. B38 Progressive tool for washers

B6.21 Stage Stops

When a new strip is taken, the first stage stop is pushed against the spring and the strip end is held against the stage stop to pierce one central hole

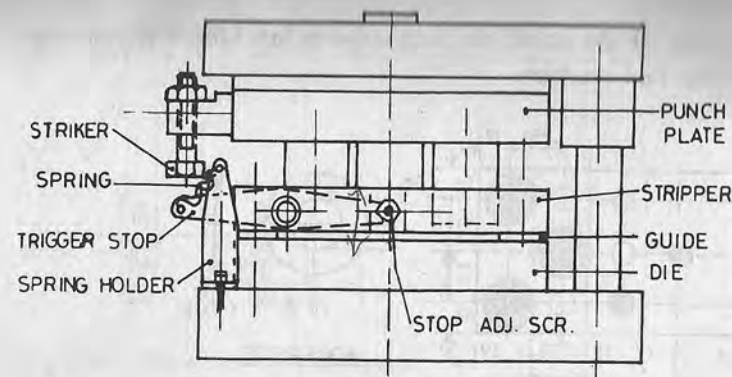


Fig. B39 End view of tool in Fig. B38 in direction 'P'

in the strip (Fig. B40a). In the second stage, the strip is fed up to the second stage stop which too must be held pressed against the spring during the second stage feeding. The strip assumes the shape shown in Fig. B40b. Similarly the third stage stop is used for the third stage to get

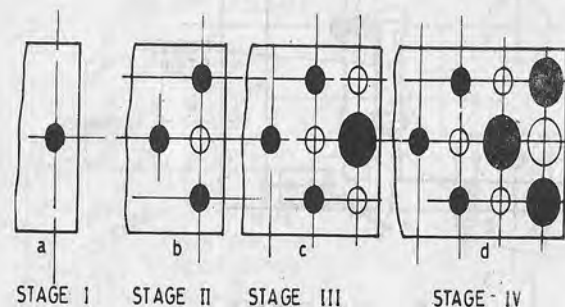


Fig. B40 Strip shape in various stages of progressive tool for washers

the shape of the strip shown in Fig. B40c. The last stage uses the trigger stop to obtain the strip shown in Fig. B40d. The trigger stop is used for blanking the following pieces in the remaining length of the strip.

The shank should be placed at the centre of pressure. We must also ensure positive disposal of all the piercing scrap and the blanks through the press table hole.

The two outer blanking punches with pilots centralize the pierced holes accurately for blanking. The trigger stop should be adjusted for feeding the strip about 0.1 mm more than the pitch so that the pilots can pull back the strip slightly for accurate positioning. Depending upon the press tonnage, the scrap disposal hole size in the press table, and the requirement of washers, any number of staggered rows can be arranged to obtain number of washers per stroke.

88.30 Piloting Workpiece without Holes

If the workpiece has got no holes suitable for a simple pilot, additional pilot holes can be added in unutilized area of the strip to facilitate accurate feeding. Fig. B41 shows a four-stage progressive tool with additional holes for piloting the strip. The chamfer on the workpiece corners permits placing the pilot holes in the wasteful triangular part of the strip.

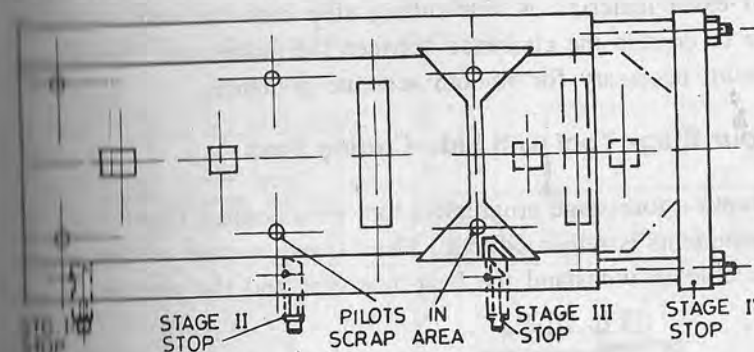


Fig. B41a Four-stage progressive tool

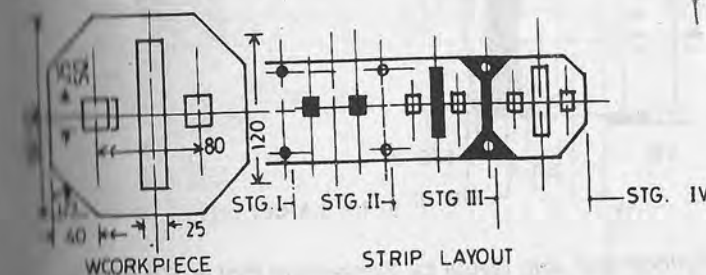


Fig. B41b Workpiece and strip layout for four-stage tool in Fig. B41a

A new strip is fed to the first stage stop to pierce two 20 dia pilot holes. In second stage, two square holes are pierced. The cropping punch above the third stage stop is slotted to provide space for the third stage strip. The pilots in the top tool engage with the pilot holes in the strip to rectify any feeding errors before a 25 mm × 120 mm slot is pierced and the 40 × 45° chamfer is cropped. Stage four uses a bridge stopper similar to one used in shearing and cropping tools (Figs B4, B5). This stop should be adjusted to permit some pull back of the strip by the pilots.

88.31 Number of Pilots

Two pilots position strip precisely. Strips for blanking tools are rarely cut accurately. It is also necessary to provide some clearance between the

guides and the strip for easy movement of the strip during feeding. This clearance allows the strip to tilt and shift marginally between the guides. A single pilot rectifies the error to some extent whereas two pilots position the strip perfectly. However very few components shapes permit use of additional pilots without wasting more material.

Nonetheless for accurate multistage progressive tools the error resulting from the variation in the strip width must be rectified even at the cost of extra material. A side-cutting stop cuts the strip width to correct size to contain the clearance between the guides and the strip to bare minimum necessary for smooth accurate guidance.

B6.40 Four-Stage Tool with Side-Cutting Stop

Fig. B42 shows a four-stage progressive tool for a pointer. Blanking such slender components is rather difficult. The 1.0 mm section of the punch will not be able to withstand the heat-treatment and the profile of the

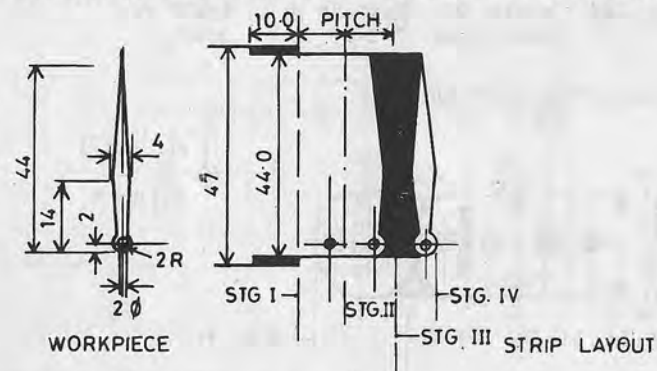


Fig. B42a Workpiece and strip layout for three-stage tool in Fig. B42b

workpiece will make finishing of punch after hardening rather costly. It is more convenient to sacrifice the strip material and make sturdy punches and dies which can withstand heat-treatment, and run troublefree for long time. The tool depicted in Fig. B42 utilizes less than one-third of the raw material, but runs troublefree and produces uniform, precise components.

B6.41 Side-Cutting Stops

This tool uses two side-cutting stops for controlling the pitch during feeding. It is necessary to use a wider strip (47) which reduces material utilization. The side-cutting stops use two punches which shear the strip width accurately to 44.0 mm so that the variation in the strip width is removed, and it can be guided precisely. The width between the guides before the side-cutting punches is about 47.6 – 47.55 mm so that even

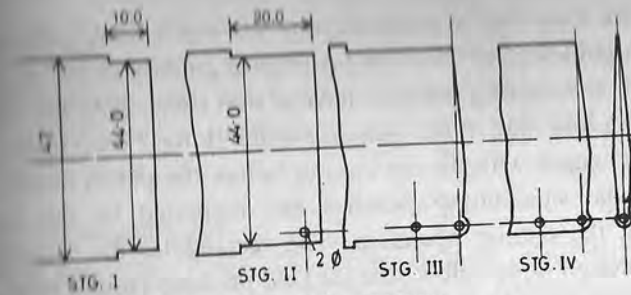
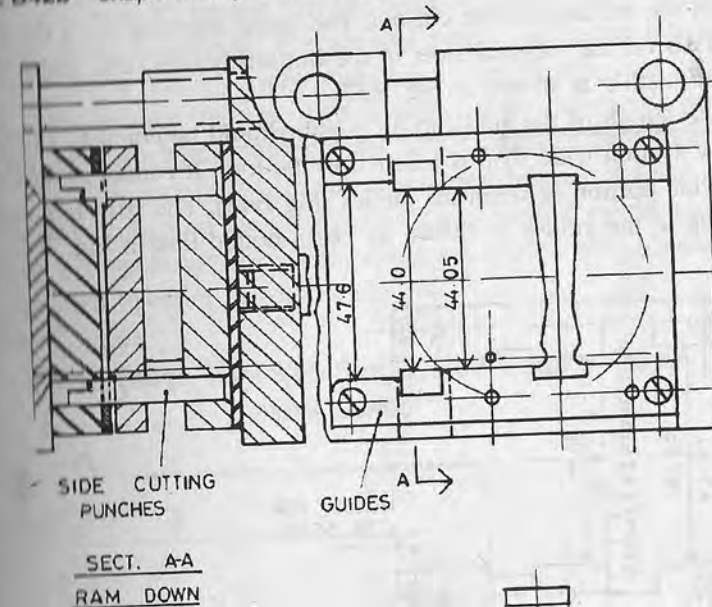


Fig. B42b Shape of strip in four stages



SECT. A-A
RAM DOWN

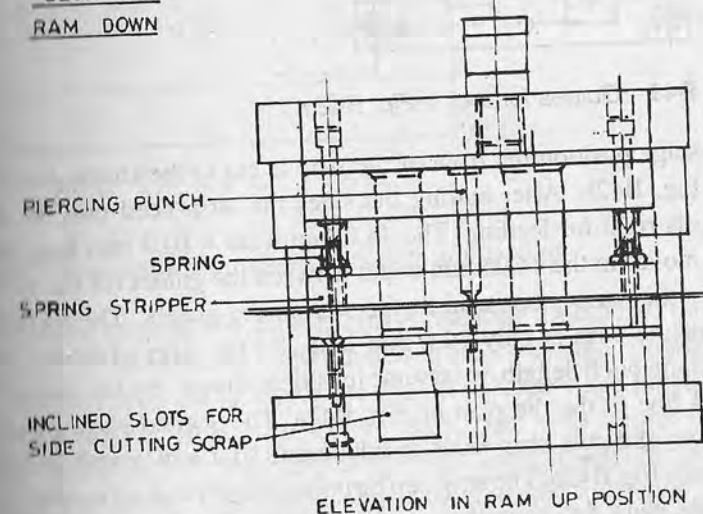


Fig. B42c Progressive tool for pointer

0.5 mm oversize strip can be used. Beyond the side-cutting punches the width between guides is 44.05/44.08 for precise guiding of the 44.0 mm wide strip. The side-cutting punches have a step [Sect. AA, Fig. B42c]. The non-cutting rear side of the punch is made longer than the cutting side so that it engages with the die cut-out before the punch commences cutting. Thus the side-cutting punches are supported by die against bending during the cutting operation. The rectangular die cut-out has got $1\frac{1}{2}^\circ$ fall through taper below straight land on three cutting sides. The side-cutting punch should be slide fit with the fourth, straight non-cutting side of the rectangular die cut-out. The scrap resulting from the side-cutting falls on the inclined slots in the bottom bolster, and slides down to the press table as shown in Fig. B37.

The length of the side-cutting punch should be equal to pitch (10.0). A new 47 mm wide strip is inserted in the tool. It cannot enter the 44.05 mm wide portion between the guides (Fig B43). The strip is pushed up to the step in the guides as shown by chain-dotted line in Fig. B43. In this

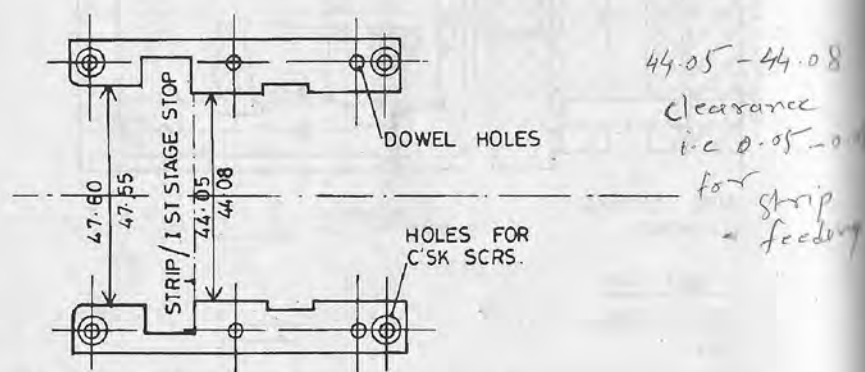


Fig. B43 Guides for tool in Fig. B42c

first stage position the front of the strip is cut to the shape shown in stage I in Fig. B42b. After cutting the sides the strip need only to be pulled towards right for feeding. The 44.0 mm wide $\times$ 10.0 mm long part of the strip moves in the 44.05 mm width between the guides till the 47 mm wide part of the strip stops against the step in the guides. The 44.0 mm wide part of the strip is only 10.0 mm long. So the strip advances exactly by 10.0 mm pitch length to assume position shown by the stage II chain-dotted line in the die plan of Fig. B42a. The second stage pierces a two dia hole and cuts strip sides to additional 10.0 mm length to shape it as shown in Fig. B42b. The strip can be pulled blindly to feed another 10.0 mm towards right for stage three to shape strip as shown in Fig. B42b. The front of the strip is cropped to obtain the profile of the pointer on right

hand side. Stage four crops the other side and cuts off the finished pointer. The finished blanks are pushed ahead towards right automatically during feeding, and can be conveyed by an inclined chute to a receptacle. The chain-dotted circle in the die plan [Fig. B42c] shows the hole in the press table.

B4.42 Spring Stripper

The top tool also holds the spring stripper. The stripper should be provided with steps on sides. The depth of the steps should be more than the guide thickness to ensure that the stripper cannot touch the guides on top surface during operation. The stripper height should be adjusted in such a way that it projects a few mm below the piercing and cropping punches. This ensures that the strip is held flat by the spring pressure before cutting commences. (Press tools using sheets/strips thinner than 1.5 mm should be provided with spring strippers instead of fixed ones.)

The side-cutting stop facilitates rapid blind feeding of the strip. No stage stops are necessary for commencing production with a new strip. So an unskilled operator can be employed.

B4.60 Three-Stage Tool with Single Side-Cutting Stop

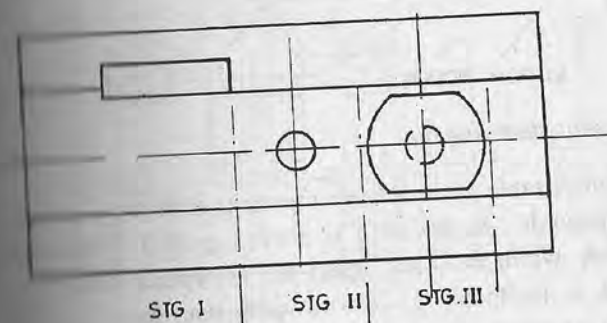


Fig. B44a Three-stage progressive tool with single side

The side-cutting stop can be used in single blanking tools also. For less accurate work or in blanking tools fitted with pilots a single side-cutting stop can be used. Fig. B44a shows die plan of a three-stage progressive blanking tool with a single side-cutting stop. The stop length should exceed the pitch by 0.1 mm for press tools using pilots for precise positioning. The single side-cutting stop cannot rectify the variation in the strip width. It is used mainly to facilitate rapid, blind feeding by an unskilled operator.

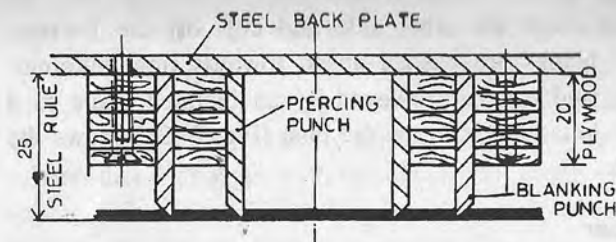


Fig. B44b Single element steel rule die

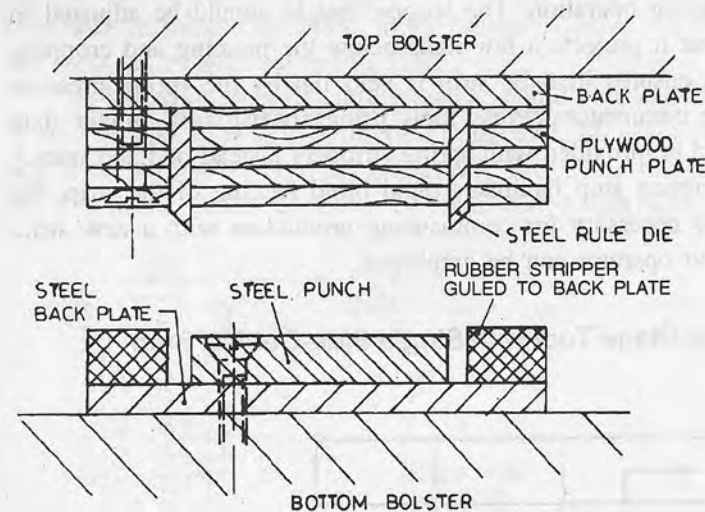


Fig. B44c Two element steel rule die

However if the press table is inclinable the strip slides, by gravity, towards the rear strip guide. As the strip is always guided by the rear guide, variation in strip width does not affect the workpiece precisions. So if the press table is inclinable to 30° towards rear even a single side-cutting punch is as good as two side-cutting stops on a non-inclinable press.

B6.60 Spring-Loaded Roller Guides

Spring roller guide (Fig. B44d) can be used conveniently for precise lateral guidance of strip even on non-inclinable presses. The tension spring pulls the bell-crank lever to swivel roller anticlockwise around the shoulder screw pivot. This pushes the roller and the strip towards the rear strip guide. Thus the strip engages with the rear guide and spring

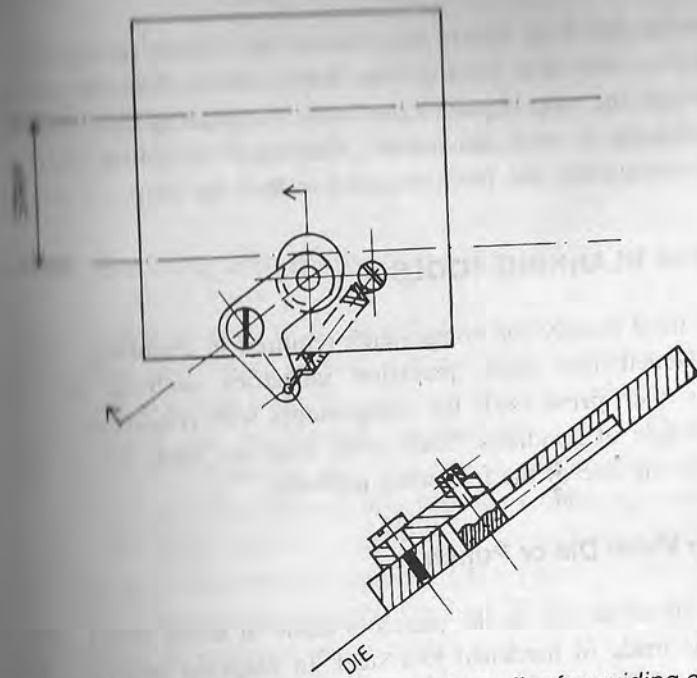


Fig. B44d Stripper with spring loaded roller for guiding strips

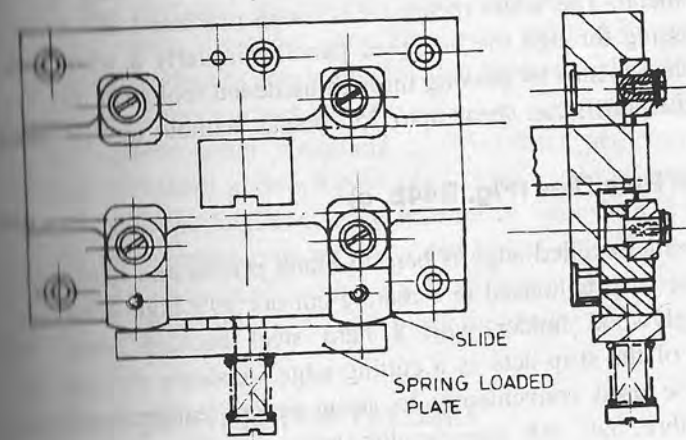


Fig. B44e Spring roller guides for inverted tools

roller at front, and is guided precisely, even if the strip width varies by as much as 1–1.5 mm.

Fig. B44e shows a spring roller guide suitable for inverted tools with punch and spring stripper on the bottom tool. Note that the strip is guided at both, rear and front sides by rollers. But the rear rollers are

fixed whereas the two front rollers are actuated by a single spring which pushes the rollers and strip towards rear fixed rollers. Thus inspite of variation in width, the strip is guided precisely. Assembling the rollers in unhardened stripper is very convenient. Guidance by rollers reduces friction and consequently the force required to Pull the strip.

B7.00 CHEAP BLANKING TOOLS

Press work is used mainly for components required in quantities above 50000 Nos. Nonetheless some precision industries such as aircraft manufacturers use press tools for components with requirement no more than a couple of hundreds. Such press tools are made as cheaply as possible by using one of the following methods.

B7.10 White Metal Die or Punch

In this system either the die or the punch is made of white metal while the other part is made of hardened tool steel. In blanking generally the die is made of tool steel while the punch is made of white metal. On the other hand in piercing, the punch is made of hardened tool steel and the die of white metal. The white metal die is rough machined and finished to size by passing through the hardened punch. Similarly a white metal punch is finished to size by passing through hardened tool steel die. Such white metal die/punch can shear upto 250 blanks without any problem.

B7.20 Steel Rule Dies (Fig. B44b, c)

A steel strip with bevelled edge is bent to blank profile and hardened to RC 50-52. The strip is housed in a mating cut-out in a high grade resin impregnated plywood holder with a hard steel backing plate. The bevelled edge of the strip acts as a cutting edge. A single element steel rule die can be used conveniently to shear paper, leather, cardboard, rubber, and fibre, i.e. soft non-metallic materials. The worksheet is placed on soft material like wood while using single element steel rule die.

A two element steel rule die uses a hardened tool steel punch and a steel rule die. These can be used for blanking and piercing metallic sheets too. Fig. B44c shows a two-element steel rule die for blanking and piercing. The tool steel punch is usually 5-8 mm thick. It is mounted on a steel backing plate. An 8-10 mm thick rubber pad around the punch serves as the stripper.

Standard bevelled tool steel strips of 23-24 mm height are fitted in 12-10 mm thick plywood casing. The steel rule bevelled edge pulls the worksheet against the hardened steel punch edge to effect fracture.

Steel rule dies cost about 25% less than conventional dies, and run trouble free upto a couple of thousands of blanks.

B7.30 Blanking with Rubber Dies (Fig. B44f)

If the blank edge need to be shaped only roughly, to be finished to size later, rubber pad can be used as a universal die. Rubber dies produce an edge which is a little better than a sawn edge. Aluminium sheets upto 0.8 mm thickness can be blanked satisfactorily using a rubber die. For working with a rubber die, the hole size should be more than 50 mm.

The rubber pad is housed in a pot-like retainer to contain spreadout on the sides. The retainer cavity is slide fit with the punch holder. The hardened tool steel punch is mounted on a punch holder. It is necessary to provide a locking bead at approximately 30 mm from the punch cutting edge. During downstroke of the rubber pad die, the worksheet is held in position by the locking bead. The rubber is forced into the space between the locking bead and the punch cutting edge. The worksheet is pushed, squeezed, and stretched against the punch edge to effect fracture of the worksheet to sever the blank from the parent sheet at the punch edge.

For blanking thicker sheets, the locking bead is replaced by a gripper which is at much lower level than the punch cutting edge. This level difference effects better stretching of worksheet and facilitates easy fracture of worksheet at punch edge. A 3° - 5° inward shear angle on the punch vertical edge facilitates easy fracture of worksheet. The hardened punch can be mounted even on a wooden block with an integral gripper and stretching channel. The locking bead and gripper wastes 40 mm worksheet material all around the blank periphery.

B8.00 AUTOMATIC STRIP FEEDING

If the strip is available in a large coil of required width, double roll feed can be used conveniently for automatic strip feeding (Fig. B45). Double roll feed uses two pairs of feed rollers on left and right hand side of the sheet. The gap between upper and lower feed rolls can be adjusted to suit the strip thickness used. Top end of the drive rod is attached to the roller mounted on the press crank. The drive rod position on the flange can be varied to change the eccentricity of the rod end with respect to the axis of the flange. This facilitates the adjustment of the feed stroke.

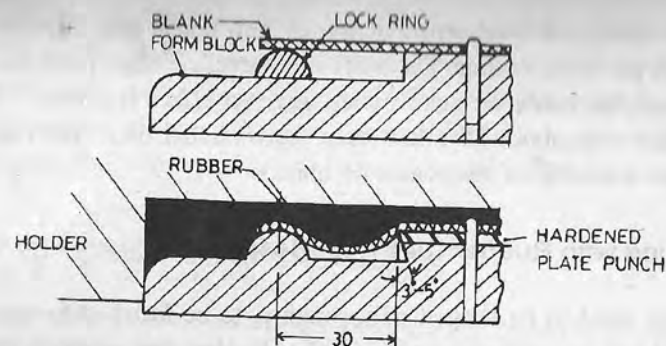


Fig. B44f Blanking with rubber die

The lower end of the drive rod is attached to the ratchet and pawl mechanism. This constrains the lower feed roller rotation to clockwise direction only. During upstroke of the press, the drive rod rotates the ratchet in anticlockwise direction. This rotates the lower feed rollers in clockwise direction. The amount of rotation and the feed stroke depends upon the eccentricity of the top end of the drive rod. During downstroke of the press the top feed rollers are lifted clear of the strip. They do not hold the strip. So the strip remains free during the downstroke of the press. The pawl returns to the starting position on the ratchet. The right hand feed roller [lower] is synchronized with the left hand roller by connecting the drive ratchets on both sides of press table by a connecting rod.

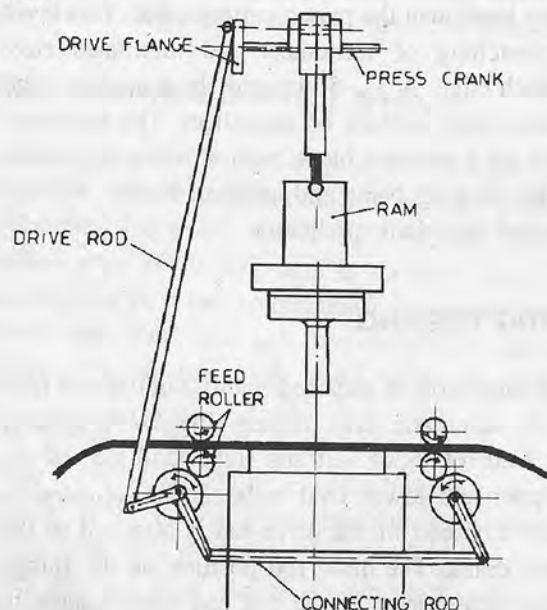


Fig. B45 Double roll feed

Double roll feed needs a decoiler on left hand side and a recoiler on the right hand side.

The accuracy of the feed is not very high. As such double roll feeds are used for jobs where some inaccuracies can be tolerated. The feed accuracy can be enhanced by using pilots in the top tool. The feed stroke should be set 0.1–0.2 more than the pitch when pilots are used.

Double roll feeds can increase productivity immensely. For the press can be run at high speeds (80–120 strokes/min). High speed presses can be run at 250–400 strokes per minute. Furthermore, as the press operation is fully automated one operator can run two or more presses.

88.10 Single Roll Feeds (Fig. B46)

The strip can be fed by using a single set of rollers only on one side of the press. In push type of feeding there is only one set of feed rollers on the left hand side of the press. Like double roll feed system the feed rollers are actuated by the press crank through the drive rod. The feed stroke

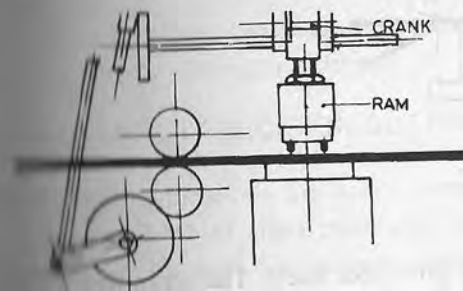


Fig. B46 Single roll feed

can be varied by adjusting the eccentricity of the top end of the drive rod on the flange coupled to the press crank. In pull type operation the feed rollers are fitted on the right hand side of the press and the strip is pulled by the feed roller to effect the strip feed.

88.20 Gripper Feed (Fig. B47)

Two gripper pads are mounted on a slide actuated by a pneumatic cylinder. The feed pitch can be set accurately by adjusting the positive stopper. A dwell is provided at the end of the feed stroke to facilitate engagement of tool pilots with the pilot hole in the strip. During pilot engagement the gripper pads do not hold the strip leaving it completely free during the cutting part of the press stroke. The gripper pads return to feed commencing position to repeat the cycle.

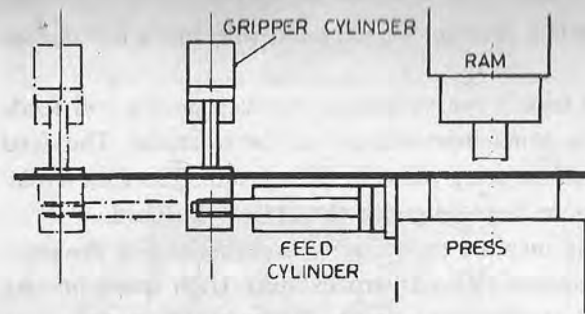


Fig. B47 Pneumatic gripper feed

B8.30 Scrap Cutters (Fig. B48)

The right hand side of the press can be fitted with scrap cutters to shear used strip to smaller pieces to simplify handling. The cut pieces can be collected in bins and compacted further by briquetting. The scrap cutter

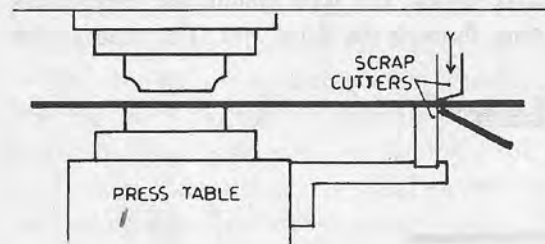


Fig. B48 Scrap cutters

can also be made integral with the press tool itself. The scrap then falls down the incline in the bottom bolster of the tool and is collected in the bin placed on the right hand side of the press.

B8.40 Decoilers and Recoilers (Fig. B49)

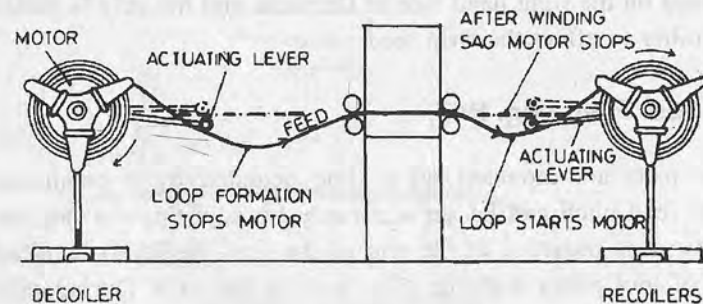


Fig. B49 Decoilers and Recoilers

Automatic strip feeding calls for automated strip unwinding and winding arrangement: decoilers and recoilers. Decoilers ensure ample supply of strip length to press tool by forming a loose loop due to sagging of free strip. When the sagging loop is fed through the press the strip becomes straight. This moves the actuating lever anticlockwise till the set limit when the electric motor of the decoiler is energized. The rotation of the motor rotates the strip coil mounted on the decoiler clockwise. The strip gets unwound and sags, and the actuating lever moves clockwise till the set limit. On reaching the limit, the motor is de-energized to stop rotation and unwinding of the coil. The cycle repeats when the sagged length of the strip is consumed.

Recoilers wind the wasted strip into rolls to simplify handling. The recoiler is also provided with an actuating lever. The lever moves anticlockwise as the used up strip sags at the right hand of the press. Reaching the sagging limit the recoiler motor is energized to wind the sagged strip into a roll. When the sagged strip is wound straight, the actuating lever de-energizes the recoiler motor to stop rotation and winding.

Coilers permit handling of strip and waste in bulk, reduce handling time, and promote productivity.

B8.00 HIGH PRECISION CUTTING TOOLS

Electrical laminations are made from 0.5 mm thick magnetic silicon steel. At 2.5% of sheet thickness, the die clearance should be 0.0125 mm/side. This calls for precision manufacture of press tools. The press tools should be designed to facilitate profile grinding of dies and punches. Very small punches call for special assembling methods such as mounting in tapered dovetail slots. Electrical laminations (or stampings) cutting tools warrant special considerations for precision manufacture.

Some parts of radio and televisions, typewriters, sewing machines, and watches have small sizes, and intricate profiles which are difficult to manufacture and machine. Sprockets, ratchets and gears should have edge square with the faces. Such components warrant fine blanking to obtain the requisite surface finish on the edge. The following pages describe methods for accomplishing high precision in cutting work in press tools.

B8.10 Fine Blanking

Impact shearing used in conventional blanking and piercing tools described earlier produces an edge with only one-third blank thickness square with the blank face. Impact shearing subjects worksheet material

to ultimate shear stress and fractures it well before the punch penetrates through worksheet. Consequently the one-third square portion of blank edge is connected to the farther face of blank by the rough bevelled band.

Control of important blanking parameters such as punch entry speed into worksheet, elimination of die clearance, and containing flow of worksheet materials surrounding punch can produce a smooth square edge, as good as machined face.

Fine blanking provides an edge which needs no further machining except deburring, by controlling above parameters.

B9.11 Blanking with Round Edge Die

In fine blanking the worksheet is partly extruded through die. The fine blanking punch is kept sharp-edged while the die edge is provided with a radius. The radius pushes the worksheet/material around die bell mouth into the die bore (Fig. B50). The blank edge gets compressed and

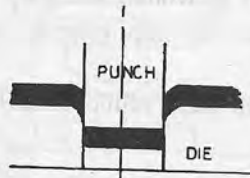


Fig. B50 Fine blanking with round edge die

burnished as it passes through the radiused die. Consequently the edge is smooth and square to blank face. The same cannot be said about the cut-out left behind by the blank. For worksheet flows and flanges into the bell-mouth of the radiused die, consequently, radiused die design is unsuitable for fine-piercing.

B9.12 Piercing with Rounded Edge Punch

If the hole must have square smooth surface the die edge should be sharp and the punch corner should be rounded (Fig. B51). The radiused punch

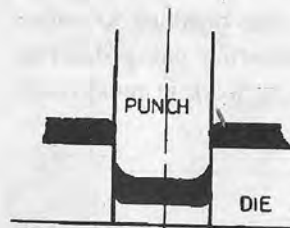


Fig. B51 Fine piercing with round edge punch

pulls material around it, compresses and polishes it as it penetrates through the worksheet. The sharp edge of the die ensures squareness of hole with worksheet faces.

B9.13 Containing Material Flow with 'V' Grippers

If the material surrounding blank/hole profile is held firmly during cutting, a smooth square edge/hole can be produced (Fig. B52). The 'V'

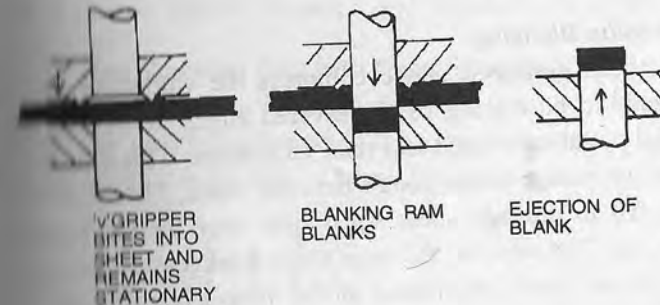


Fig. B52 'V' grip fine blanking tool

'V' grippers hold the worksheet firmly before the cutting commences. 'V' grippers also push the worksheet material towards blanking/piercing punch. Thus the worksheet is under lateral compressive stress before punch commences cutting. This state produces holes/blanks with fine finish on edges.

B9.14 'V' Size Shape and Position

The 'V' angle ranges from 60° for harder materials to 90° for softer materials (Fig. B53). The 'V' bites into worksheet from 20% – 40% of its

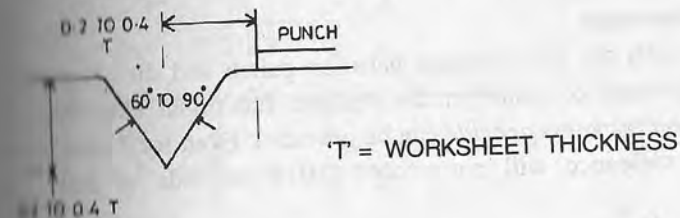


Fig. B53 'V' design

thickness. Height of 'V' should be $1/5$ to $1/2.5$ of worksheet thickness. The 'V' should be placed at about same distance as its height ($1/15, T/5$) from the punch cutting edge. The gripper (or pressure) plate is turned/milled around the cutting periphery to produce the gripping 'V'. The pressure plate is hardened and tempered to RC 50/55 to

enhance strength and contain wear. For the gripping pressure can be as high as 60 kgf/mm^2 of the blank area.

B9.15 Fine Piercing with 'V' Grippers

When worksheet is held with force $50\text{--}60 \text{ kgf/mm}^2$ of hole area it is possible to punch as small a hole as one-third worksheet thickness. The punch must however be guided incessantly throughout the piercing stroke.

B9.16 Compression Blanking

All the three methods described above compress the worksheet before it is cut. This leads to burnishing of the severed edges. Moreover fine blanking is carried out at ram speed less than 15 mm/sec . This eliminates impact shear fracture and resultant rough bevelled band. The worksheet material is subjected to ultimate shear stress only near the sharp edges of punch and/or die. The rest of the worksheet thickness is gradually deformed. The punch speed is reduced at the time of entry into the worksheet to effect gradual penetration.

B9.17 Fine Blanking Presses

Hydraulic presses are preferred to mechanical presses. For it is possible to vary the speed of hydraulic press during part of the stroke. Stepless variation of speed and tonnage can also be effected.

A triple action press is desirable. For 'V' grippers, punch, and ejector each call for separate rams with independent motions. Alternatively a double action press is fitted with a die cushion to effect ejection.

As there is little clearance between die and punch all the rams must be aligned precisely. High precision ram guidance system is necessary.

B9.18 Die Clearance

There is practically no die clearance between punch and die. Nonetheless to make passage of punch in die possible functional clearance of 0.5% of worksheet thickness per side can be provided. Even for 3 mm thick worksheet the clearance will not exceed 0.015 per side or 0.03 on diameter.

B9.19 Fine Blanking, Gripping, and Stripping Forces

Forces required are considerably higher than conventional blanking.

Fine Blanking Force is $15\text{--}25\%$ more than the force required for conventional blanking.

Gripper Force depends upon the blank area: $500\text{--}600 \text{ N/mm}^2$. Gripper force can be as high as 2.5 times the blanking force.

Ejection and Stripping Force is $12\text{--}15\%$ of the blanking force. Lesser clearance between severed piece and die, and the compressive stress in the severed piece and blanked out strip increase the stripping/ejection force.

B9.20 Fine Blanking Tools

Fine blanking tools are designed much more rigidly than conventional blanking tools. The die ring is usually provided with 6° included angle conical seat on outside diameter, and screwed into a very strong bolster.

B9.21 Fine Blanking Tool with Fixed Pressure Plate

Fig. B9.21 shows a fine blanking die with pressure plate screwed to top bolster. The punch is screwed to the inner ram of press. The bottom ram is used mainly for ejection of blank from die.

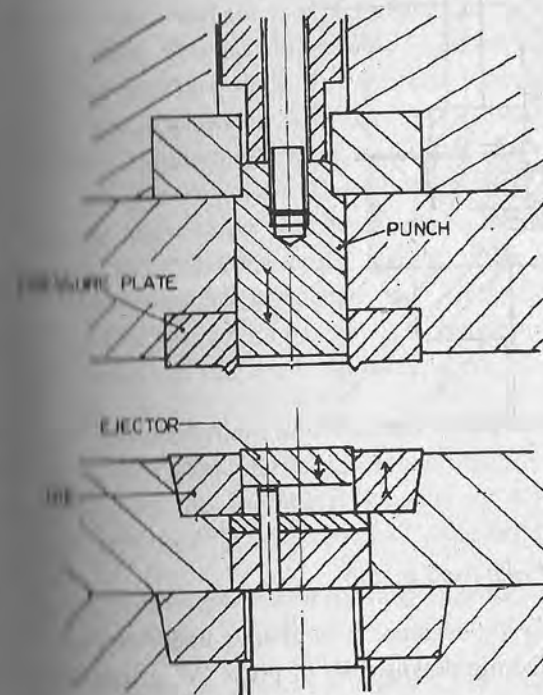


Fig. B9.21 Fine blanking tool with fixed pressure plate

During operation the outer ram of the press brings down the pressure plate to grip the worksheet rigidly. Then the inner ram descends to hold the worksheet (blank portion) sandwiched between the ejector and the punch. Slow penetration and further downward stroke of the inner ram pushes the punch through the worksheet and die to separate the blank from the parent sheet.

During upstroke of press the inner (punch) ram overtakes the outer (pressure plate) ram to strip the punch off the worksheet. The bottom ram pushes up the blank out of the die for manual unloading.

Note the tapered die and solid bolster plates.

B9.22 Fine Blanking Die with Fixed Punch

In the tool shown in Fig. B55 the blanking punch is screwed to top bolster while the pressure plate is actuated by the inner ram of the press. The bottom ram is used for ejection.

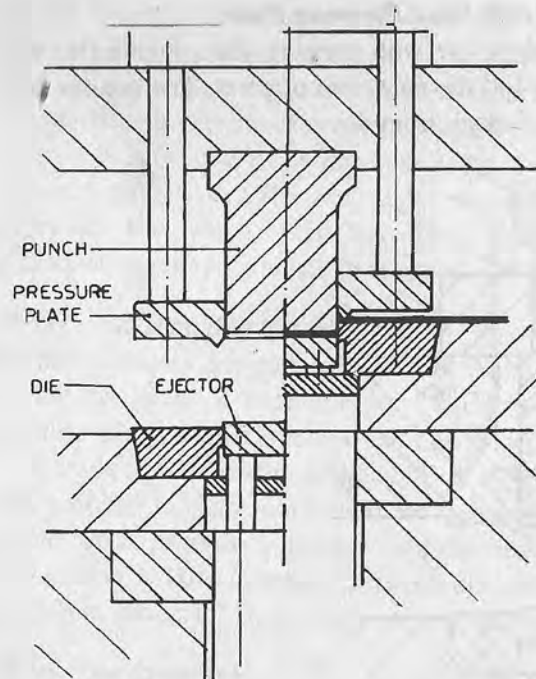


Fig. B55 Fine blanking tool with fixed punch

The outer ram acts like a die-cushion. It is always under certain hydraulic downward force. During downstroke of press 'V' gripper bites into worksheet first. Further downstroke pushes the pressure plate up the punch down onto worksheet. The worksheet is held between the punch face and the ejector fitted to bottom ram. The punch moves further down into the die to sever blank from parent sheet. The ejector is pushed downwards by punch and blank. During upstroke, the punch ram overtakes the pressure plate ram to effect stripping. The bottom ram ejects the blank from the die. Like the tool in Fig. B54 the die ring is tapered and the bolsters are massive.

B9.30 Press Tools for Electrical Laminations

Fig. B56 shows laminations used for rotor and stator of an electrical motor. These are made from 0.5 mm thick magnetic silicon steel. The inside diameter of rotor is provided with six dovetailed slots for rivetting which assemble a number of laminations into a thick stator pack. The stator is provided with 36 equispaced slots which are connected by a 1 mm wide slot to the stator bore. These slots house magnetic coils of the stator field. The stator outside diameter is provided with a key-way to facilitate alignment of the coil slots. The key-way is provided with a circular building mark placed offset with the centre line of the key-way. The building mark is used for aligning the rotor stampings. During offset, the building mark ensures that a stamping reversed by error is immediately detected. This ensures that burrs of all stampings are on the same side and there is a face to face contact between stampings in spite of burr. It is just impossible to deburr thousands of stampings with numerous intricate slots. So electrical laminations are carefully stacked, aligned, and transported with burr of all stampings on one side.

The rotor stamping is provided with a precision bore for the motor shaft and two key-ways, one of them with a building mark. The rotor stamping is provided with eight ventilation holes for cooling. There are 28 slots for coils/conductors which provide the rotor magnetic field. In the cast rotors the conductor slots are filled with aluminium by die casting. Die cast rotors have closed conductor slots as shown in Fig. B56. The 28 slots in the rotor are equispaced.

B9.31 Requirement and Method of Manufacture

When a new stamping is developed quickly, or requirement is less than 500000. Now the following sequence of manufacture can be used for minimizing tooling cost, and tool manufacturing time.

Sequence of Operations for Requirement less than 500000 (Fig. B57)

- (1) Blank combined rotor and stator with key-ways, holes, dovetails and building marks but without coil and conductor slots (Fig. B57a).
- (2) Pierce (notch) 36 coil slots, one/stroke, on a notching press with a standard indexing ring (Fig. B57b).
- (3) Separate rotor ring from stator on a piercing tool (Fig. B57c).
- (4) Pierce (notch) 28 conductor slots, in rotor stamping, one/stroke, on a notching press with an indexing ring (Fig. B57d).

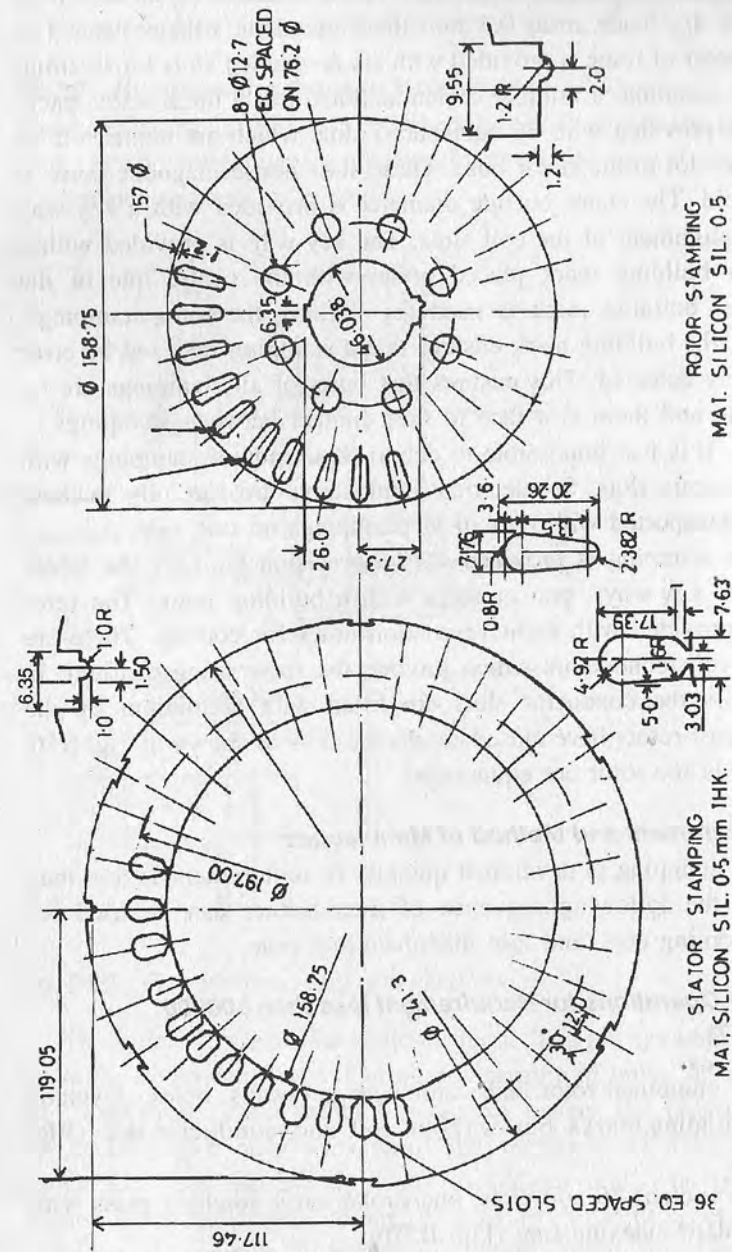


Fig. B56 Stator and rotor laminations of electrical motor

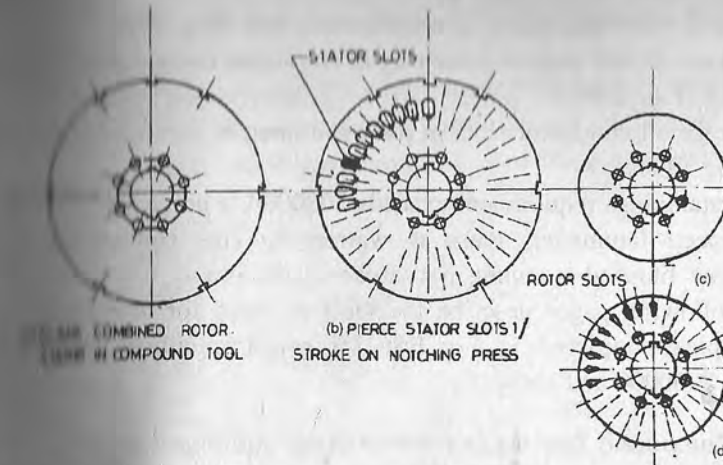


Fig. B57 Sequence of operations for requirement less than 500000

For requirements above 1000000 stampings notching presses, piercing only one coil slot per stroke, will turnout to be too slow (3000-4000 stampings per shift). It would be advisable to use a costly gang-slotting tool to pierce all rotor/stator slots in a single stroke of a big press. Even operation of rotor and stator stampings can be accomplished in the first operation itself.

Sequence of Operations for Requirement above 1000000 (Fig. B58)

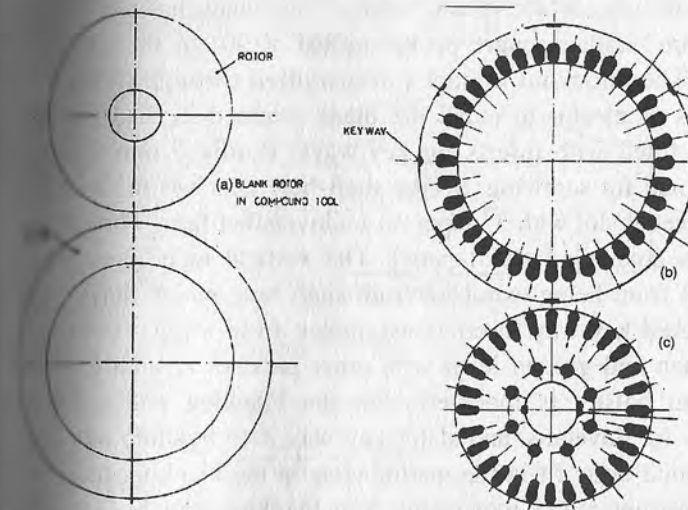


Fig. B58 Sequence of operations for requirement above 1000000 Nos/Year

- (1) Blank rotor and stator in a compound tool (Fig. B58a).
- (2) Pierce all coil slots in stator ring in one stroke using a gang-slotting tool (Fig. B58b).
- (3) Pierce all conductor slots in rotor stamping in a gang-slotting tool (Fig. B58c).

If the stampings requirement exceeds 5000000, a progressive tool set and a high speed lamination press is warranted. This combination can produce one finished stamping per stroke of the press.

The following pages describe the tools required for manufacture of the stampings depicted in Fig. B56 for requirements ranging from 500000 – 5000000 and above.

B9.32 Compound Tool for Combined Rotor and Stator Blank

The blanking die for outside diameter of the stator is screwed and dowelled to the top bolster (Fig. B59). The die carries dovetail punches located in slots in die screwed to the top bolster. Both die as well as inserts are topped by a hardened backing plate. The piercing punches for shaft hole, and ventilation holes in rotor too are fitted to the top bolster in a separate punch plate, backed by a hardened backing plate. The piercing punch plate sub-assembly is located in a counterbore in top bolster and screwed and dowelled to it. The top tool also houses blank knockout ejector with socket head screws. The screws are adjusted to protrude ejector slightly below die level; and locked in set position by check nuts. The ejector is actuated by four thrust pins with a thrust plate and knockout pin above. The square thrust plate reciprocates in a square pocket milled on top surface of top bolster. The shank has got a flange which seats into another square pocket milled at 90° to the pocket for thrust plate. The knockout impact is transmitted through thrust plate and thrust pins to ejector to expel the blank jammed in die. The shaft hole punch is fitted with inserts for key-ways. Hardly 6 mm wide, the insert is too small for screwing. So the shaft-hole punch is milled with a 3 mm deep dovetail slot with 3° taper on undovetailed face. The key-way insert is made dovetailed and tapered. The vertical taper prevents the key-way insert from being extracted from shaft hole punch during stripping. The tapered key-way insert is assembled from top, collar side, of shaft hole punch and ground level with other punches at both ends.

The bottom bolster is mounted with the blanking punch housing flanged inserts for dovetails, and stator key-way with building mark. The inserts are ground close fit in the mating slots in the blanking punch and dowelled to prevent radial movement. The blanking punch also serves as the piercing die for shaft and ventilation holes, key-ways and building

Note that the fall through taper for die is limited to 15° (1/4°).

The bottom tool is provided with a spring stripper to extract punch from the strip. The stripper houses a spring-loaded pin which acts as a support. The spring-loaded pin eliminates need for a weakening hole in

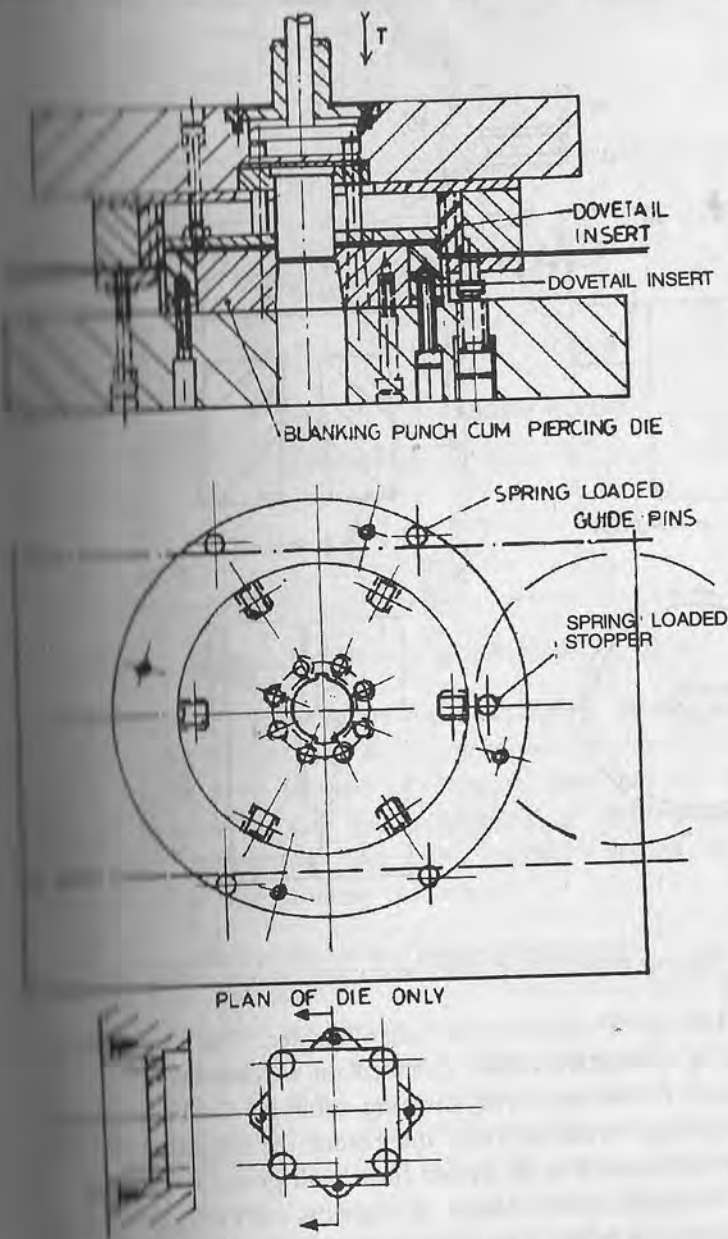


Fig. B59 Compound tool for combined rotor and stator

blanking die. The stripper is fitted with dovetail-shaped inserts for better stripping in the dovetailed part.

B9.33 Tooling Notching Presses

Tooling comprises of a single notch punch with punch plate and die inserts. Fig. B60a shows stator-slotting punch assembled in a round

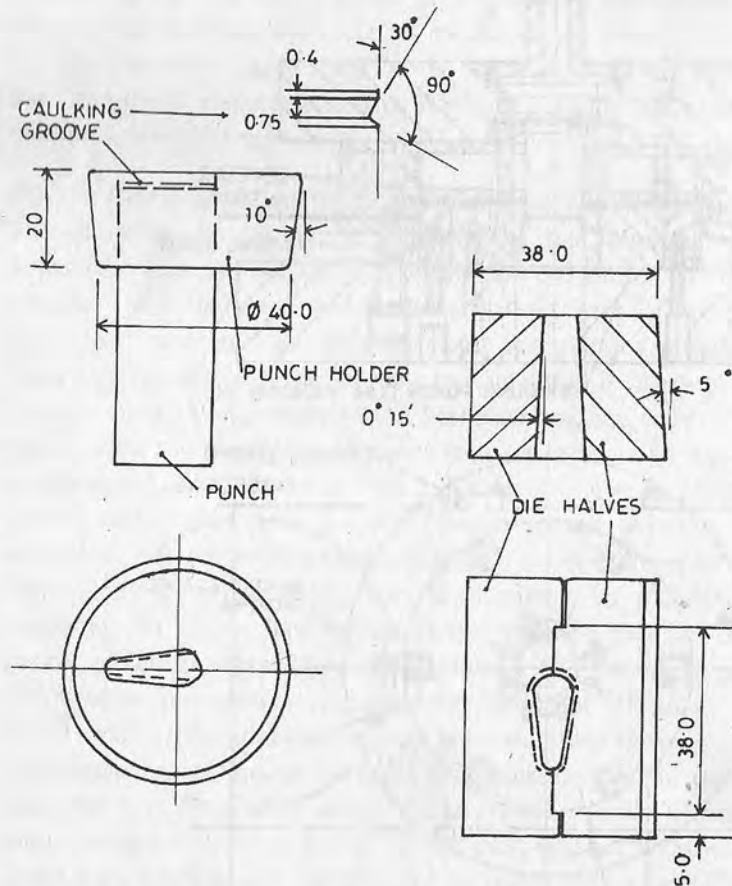


Fig. B60a Tooling for notching stator stamping on a notching press

punch holder with 10° taper on outside diameter. The tapered punch plate is held in a standard holder mounted on a common die set. The notching punch is provided with caulking grooves. Caulking prevents punch from getting extracted from the holder during stripping. After caulking, the punch top face is ground flush with punch holder.

The die comprises of two halves of segments with a locating tongue for alignment of both halves. One of the halves is provided with 5° angle

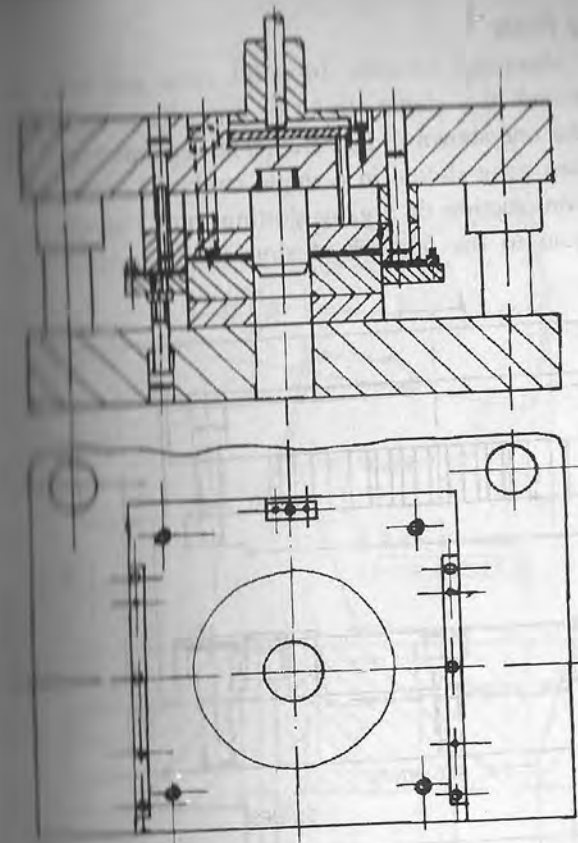


Fig. B60b Separation tool for rotor and stator in Fig. B56

on one side. This angle is used for clamping the inserts on a common bolster (See Fig. B23b). The die segments are provided with no straight lead on cutting face. But the fall through taper angle is only $1/4^\circ$ to minimize increase in size due to grinding of die top surface during resharpening. Segmental construction permits grinding of two halves accurately on profile grinding machines.

B9.34 Separation of Rotor and Stator Stampings

The separation tool (Fig. B60b) is like a simple inverted blanking tool with a spring stripper on bottom bolster, and knockout ejector in the top end. The top bolster is also fitted with a pilot which engages with the rotor shaft hole in the blank, and centralizes it precisely before stator and rotor are separated. Note that the mounting diameter of pilot mates with a hardened bush pressed in the top bolster. This ensures that the pilot is reassembled precisely after die resharpening. The flanged shank is provided with a counterbored pocket for knockout thrust plate.

B9.35 Gang-Slotting Tools

When requirement of stampings exceeds 1000000, rotor and stator are blanked out, and separated in a single stroke of press by using a compound tool similar to the one shown in Fig. B29. The separated rotor and stator stampings are then gang-slotted in a single stroke of press.

Fig. B61a shows construction of a gang-slotting tool. The die comprises of segments equal to the number of slots to be pierced. Each

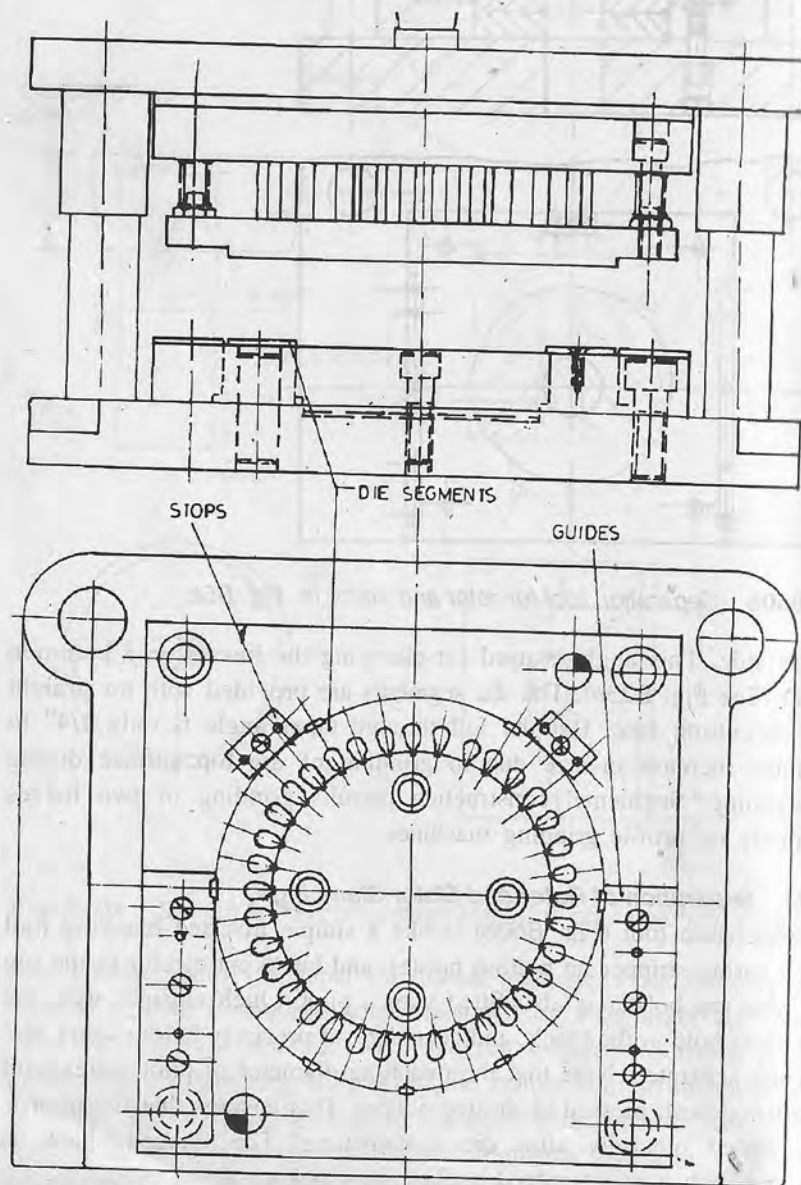


Fig. B61a Stator gang-slotting tool with segmental die

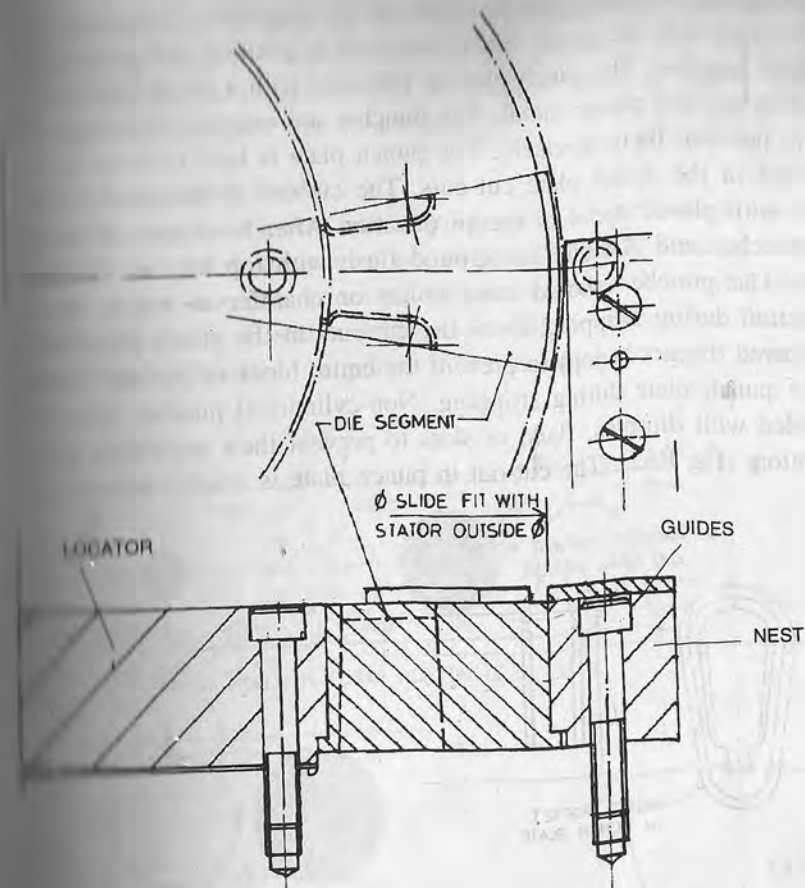


Fig. B61b Die segment for stator gang-slotting tool

segment is bound on two sides by radial lines with 'included angle' = $\frac{360^\circ}{\text{No. of slots}}$. The segments have flanges on the outside diameter. The segments are held together by the nest with a counterbore for segment flange. The flange and the counterbore prevent the segments from coming out of the nest during stripping. There is a central locator which holds down the segments on the inner periphery. As the stator slots open into the stamping bore the locator is provided with slots for piercing punches which protrude into the bore of stator ring. Locator and nest plate together hold the segments clamped down on bolster, as both nest plate and the locator are screwed down and dowelled to the bottom bolster.

Aligning 36 slotting punches with the die segment is not easy task. It is convenient to use plastic metal (araldite) to position and assemble the slotting punches. The punch plate is provided with a rough clear cut-out for punches and plastic metal. The punches are engaged with segmental die to position them precisely. The punch plate is held with the slotting punches in the punch plate cut-outs. The cut-out in the punch plate is filled with plastic metal to secure punches. After hardening of Araldite the punches and Araldite are ground flush with top face of the punch plate. The punches should have collar or chamfer at top to prevent extraction during stripping. Even the cut-outs in the punch plate should be tapered (bigger at top) to prevent the entire block of Araldite coming out of punch plate during stripping. Non-cylindrical punches should be provided with dimples, flats, or slots to prevent their movement during operation. (Fig B62). The cut-out in punch plate is usually non-cylindrical.

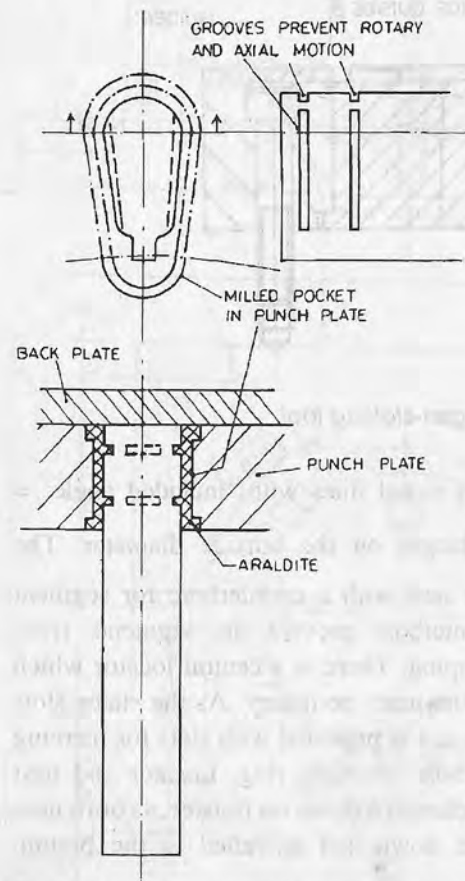


Fig. B62 Assembly of punches in gang slotting tools

This prevents rotation of the Araldite block and punches during operation. In fact, the inside edge of the cut-out is left rough. The Araldite enters the rough cavities to prevent rotary or linear motion between Araldite block and punch plate.

Progressive Tools

Progressive tool combines a number of press tools into a single long tool producing one finish component per stroke. The pitch, distance between various stages, must be precisely equal; otherwise the shaft hole and outside diameters of stator and rotor will be eccentric. This is accomplished by provision of pilots. If the stamping does not have holes

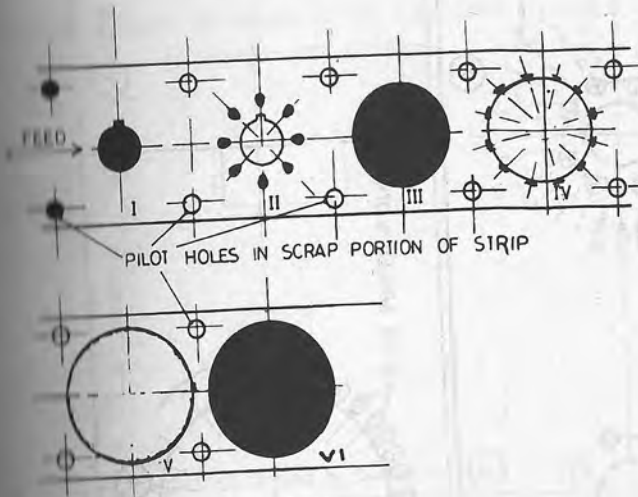


Fig. B63 Provision of pilots in scrap portion of strip

available for piloting, the scrap area between the two stampings is utilized to provide two pilot holes to ensure accurate feeding of strip.

Fig. B64 shows the die plan for a progressive tool for stamping shown in Fig. B56. In the first stage, the shaft hole, pilot holes and ventilation holes in rotor are pierced. In the second stage the rotor slots are pierced by gang-slotting. The third stage blanks down the slotted rotor. The fourth stage pierces stator in a gang-slotting tool. The fifth stage is left idle so that blanking die for stator should have good margin and strength. The sixth stage blanks stator with dovetails and key-ways. The rotor blanking stage pilots on the shaft hole at centre for concentricity. Stator blanking is also done with a large pilot in the bore of the slotted stator.

Each stage tool can be manufactured separately, and assembled precisely on a common die set. It is however convenient to combine rotor

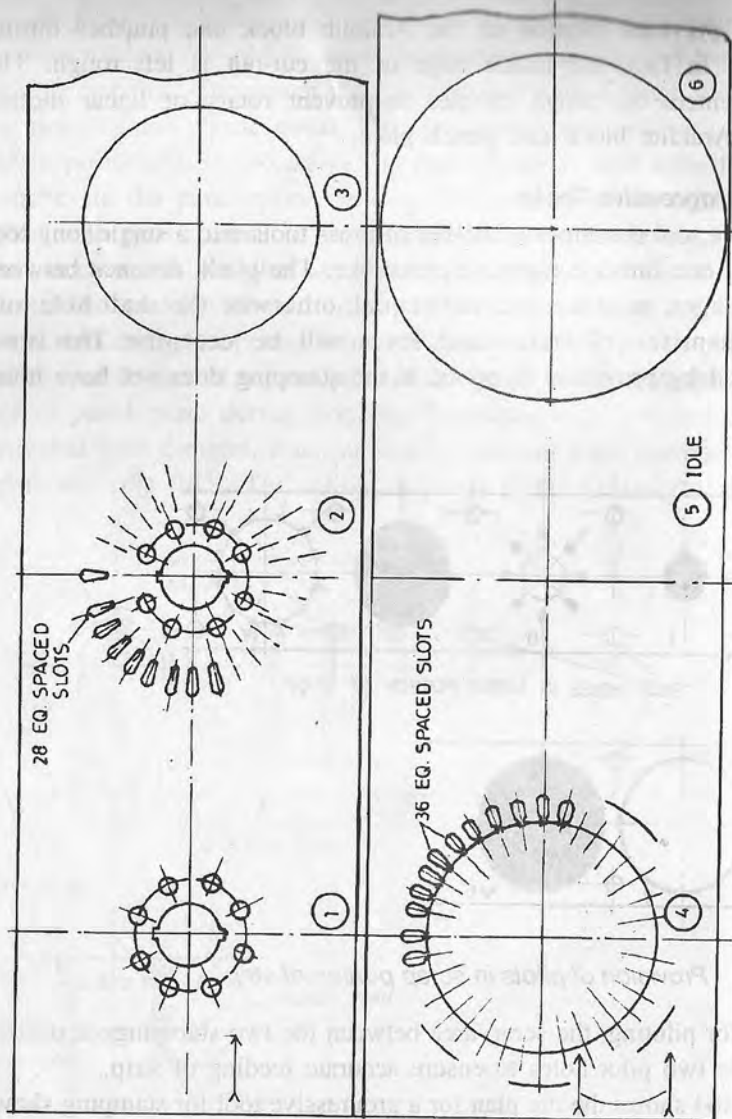


Fig. B64 Strip layout for progressive tool for rotor and stator

blanking and stator gang-slotting tools in a single die steel plate. After manufacture, the centre distance between rotor blanking die hole and stator gang-slotting tool is measured accurately. Gang-slotting tool for rotor, piercing tool for shaft and ventilation holes, and blanking tool for stator can be set at distances which are exact multiples of the centre distance between stator gang-slotting and rotor blanking stages. After setting, the stage tools are dowelled to the common bolster of the long pillar die set.

Fasteners
Neutral axis
B. force calcul.
Double bends in two stages
Edge bending
prog. die

C

Bending Tools

Bending changes the shape of the flat blank to make it angular, curved, or both (Fig. C1) along a straight line.

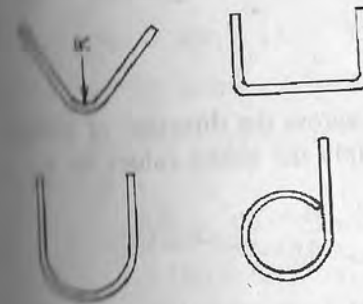


Fig. C1 Shapes obtained by bending

01.00 BEND RADIUS

The minimum radius to which a blank can be bent without cracking depends upon the blank material and its hardness (temper). This minimum inside radius also depends upon the direction of rolling. The strips should be cut in such a way that the bend line lies at right angles to the grain direction (Fig. C2a), for a sheet can be bent to lesser radius across the rolling direction. A sheet is more vulnerable to cracking in bends along the grain direction. So the minimum radius of bending without cracking along grains, is about four times the minimum radii for bends across the grain direction. The following table states the minimum radii for bending various materials across the direction of grains. Generally the direction of grains (rolling) is parallel to the longer side of the full uncut sheet.

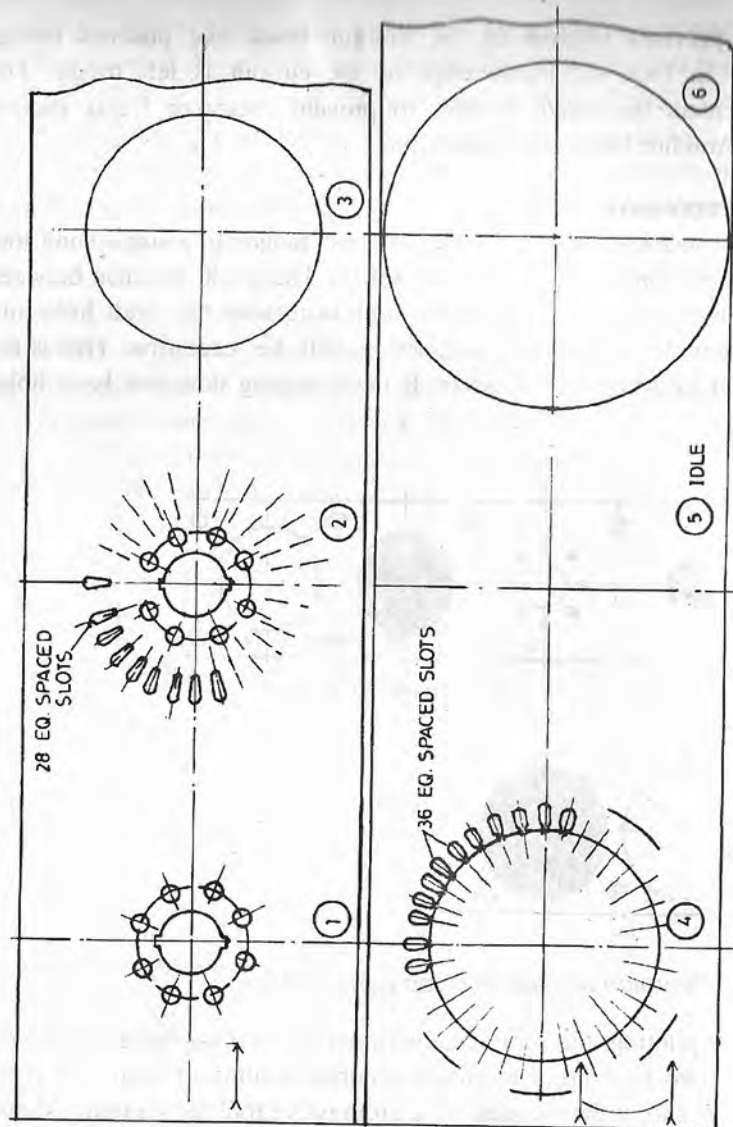


Fig. B64 Strip layout for progressive tool for rotor and stator

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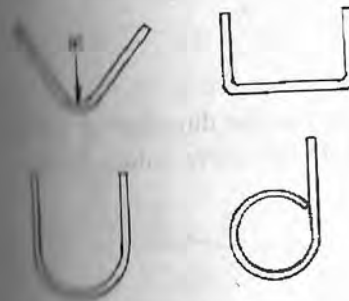


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Table C1 Minimum Bend Radius (Inside) for Various Materials for Sheet Thickness T

Condition	Aluminium	Brass	Copper	Steel
Dead Soft	$0.25 T$	$0.55 T$	T	$0.5 T$
1/4 Hard	$0.5 T$	T	$1.5 T$	T
1/2 Hard	$0.8 T$	$1.5 T$	$2 T$	$2 T$
3/4 Hard	$1.5 T$	$3 T$	$3 T$	$4 T$

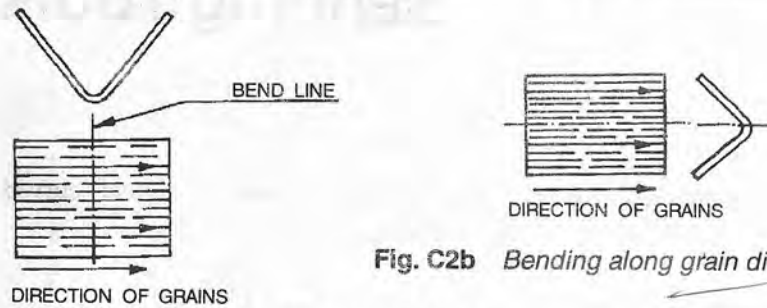


Fig. C2b Bending along grain direction

Fig. C2a Bending across grain direction

where T = Thickness of sheet to be bent.

Table C1 shows the radii for bending across the direction of rolling (for bends along the rolling direction multiply the above values by 4).

C2.00 DEVELOPED LENGTH

Calculate Bend Allowance

A component is usually blanked (or sheared or cropped) before bending. Consequently it is necessary to calculate the length before bending or the developed length of the workpiece before the blanking tool can be designed. During bending the metal layers adjacent to the inner surface are compressed (Fig. C3) whereas the metal layers near the external surface are stretched. The plane (layer) which is neither compressed nor stretched is called the neutral plane. The neutral plane lies along the middle of the sheet thickness for radii exceeding twice the thickness. For radii less than twice the sheet thickness the neutral plane lies approximately at one-third thickness from the inner surface of the bend. This shifting of the neutral plane should be taken into account while calculating the developed length. The developed length should be calculated along the neutral plane.

This can be summarized in the following formulae

$$L = \frac{\pi}{180} \cdot A \cdot (R + 0.5 T) \quad \text{When } R \geq 2T \quad [\text{Eqn C1}]$$

$$L = \frac{\pi}{180} \cdot A \cdot (R + 0.33 T) \quad \text{When } R < 2T \quad [\text{Eqn C2}]$$

A = Angle of bend in degrees T = Sheet thickness

R = Bend inside radius L = Development length

Example C1 Calculate the developed length for the component shown in Fig. C3.

Solution The developed or unbent length of the blank consists of 3 parts: the straight l_1 and l_3 and the curved part l_2 .

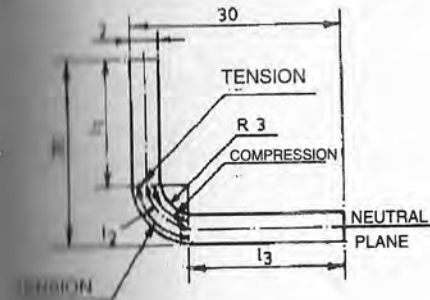


Fig. C3 Stresses in bending

$$l_1 = 20 \text{ mm} - (2 + 3) \text{ mm} = 15 \text{ mm}$$

$$l_3 = 30 \text{ mm} - (2 + 3) \text{ mm} = 25 \text{ mm}$$

As the inside radius of the bend is less than 4 (twice the sheet thickness)

$$l_2 = \frac{\pi}{180} \times 90 \times (3 + 0.33 \times 2) = 5.749 \approx 5.75 \text{ mm}$$

$$L = 15 + 5.75 + 25 = 45.75 \text{ mm}$$

Example C2 Find the developed length for the component shown in Fig. C4.

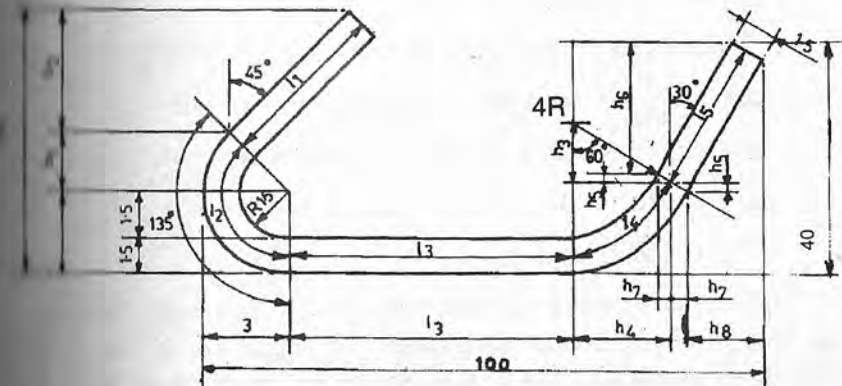


Fig. C4 Developed length calculations

Solution The external radius for the 45° bend

$$= \text{inside radius} + T = 3 \text{ mm}; \text{ Inside radius} = 3 - 1.5 = 1.5$$

$$h_1 = 3 \sin 45^\circ = 2.12 \text{ mm}$$

$$h_2 = 50 - 2.12 - 3 = 44.88 \text{ mm}$$

$$l_1 = \frac{h_2}{\cos 45^\circ} = \frac{44.88}{0.7071} = 63.47 \text{ mm}$$

$$R = 1.5 < 3 (2T)$$

$$l_2 = \frac{\pi}{180} \times 135 \times (1.5 + 0.33 \times 1.5) = 4.7 \text{ mm}$$

h_3, h_4, h_5, h_6 must be calculated for finding l_5

$$h_3 = (4 + \frac{1.5}{2}) \sin 30^\circ = 2.375 \text{ mm}$$

$$h_4 = 4.75 \cos 30^\circ = 4.15 \text{ mm}$$

$$h_5 = \frac{1.5}{2} \sin 30^\circ = 0.375 \text{ mm}$$

$$h_6 = 40 - (4 + 1.5) + h_3 - h_5 = 40 - 5.5 + 2.375 - 0.375$$

$$= 36.5 \text{ mm}$$

$$l_5 = \frac{h_6}{\sin 60^\circ} = \frac{36.5}{0.866} = 42.15 \text{ mm}$$

$$h_7 = \frac{1.5}{2} \cos 30^\circ = 0.65 \text{ mm}$$

$$h_8 = l_5 \cos 60^\circ = 42.15 \times 0.5 = 21.08 \text{ mm}$$

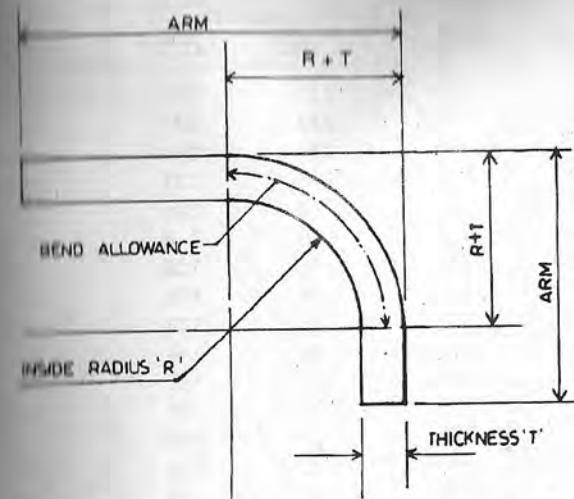
$$l_3 = 100 - 3 - h_4 - h_7 - h_8 = 97 - 4.15 - 0.65 - 21.08 = 71.12 \text{ mm}$$

As inside radius of the right-hand bend exceeds 3 (2T)

$$l_4 = \frac{\pi}{180} \times 60 \times (4 + 0.5 \times 1.5) = 4.97 \text{ mm}$$

$$\begin{aligned} \text{Developed length } L &= l_1 + l_2 + l_3 + l_4 + l_5 \\ &= 63.47 + 4.7 + 71.12 + 4.97 + 42.15 \\ &= 186.41 \text{ mm} \end{aligned}$$

Right angle 90° bends are used frequently in press work. To minimize the time required for calculating developed lengths for 90° bends tables have been compiled. These give 'set backs' or bend allowances for various thicknesses of sheets for different radii.



$$\text{SET BACK } S = 2 \times \text{ARM} (R + T) - \text{BEND ALLOWANCE}$$

$$\text{BEND ALLOWANCE} = 2(R + T) - S$$

Fig. C5 Set back

Set Back Tables [Fig. C 5] for 90° Bend

Bend radius (mm)	Sheet Thickness/SWG					
	0.46/27G	0.51/25G	0.56/24G	0.61/23G	0.71/22G	0.81/21G
0.75	1.0	1.08	1.16	1.23	1.38	1.52
1.00	1.05	1.12	1.19	1.26	1.48	1.63
1.25	1.10	1.16	1.22	1.28	1.59	1.74
1.50	1.20	1.265	1.32	1.38	1.51	1.84
2.0	1.42	1.48	1.54	1.60	1.72	1.84
2.5	1.63	1.69	1.79	1.81	1.93	2.06
3.0	1.74	1.80	1.86	1.92	2.04	2.16
3.5	1.95	2.01	2.07	2.15	2.26	2.38
4.0	2.06	2.12	2.18	2.25	2.36	2.47
4.5	2.28	2.34	2.40	2.46	2.58	2.70
5.0	2.49	2.55	2.61	2.67	2.79	2.91
5.5	2.595	2.655	2.72	2.78	2.90	3.02
6.0	2.70	2.76	2.82	2.89	3.01	3.13
6.5	2.81	2.865	2.93	3.00	3.12	3.24
7.0	3.01	2.98	3.03	3.11	3.23	3.34
7.5	3.22	3.20	3.24	3.33	3.45	3.56
8.0	3.43	3.41	3.45	3.55	3.66	3.77
8.5	3.64	3.63	3.66	3.77	3.88	4.00
9.0	3.85	3.85	3.81	3.99	4.09	4.21
9.5	4.06	4.07	4.08	4.21	4.31	4.43
10.0	4.48	4.51	4.50	4.65	4.75	4.87
11.0	5.86	6.17	5.34	6.30	5.63	6.31
12.5	6.52	6.83	6.00	6.96	6.29	6.97

Inside rad (mm)	Sheet Thickness mm/SWG				
	0.91/20G	1.02/19G	1.22/18G	1.42/17G	1.63/16G
0.75	1.68	1.83	2.13	2.43	—
1.00	1.78	1.94	2.23	2.53	—
1.25	1.88	2.05	2.34	2.64	2.95
1.5	2.00	2.16	2.45	2.75	3.06
2.0	1.96	2.37	2.67	2.96	3.27
2.5	2.18	2.31	2.56	3.18	3.49
2.75	2.29	2.42	2.66	3.28	3.60
3.0	2.39	2.53	2.77	3.01	3.70
3.5	2.61	2.74	2.98	3.23	3.48
4.0	2.83	2.95	3.20	3.44	3.70
4.5	3.05	3.16	3.41	3.66	3.93
4.75	3.16	3.26	3.52	3.76	4.02
5.00	3.27	3.36	3.62	3.88	4.12
5.25	3.38	3.47	3.73	3.98	4.23
5.5	3.49	3.58	3.84	4.09	4.34
6.0	3.71	3.78	4.06	4.31	4.57
6.5	3.93	4.00	4.27	4.54	4.79
7.0	4.15	4.21	4.48	4.76	5.02
7.5	4.37	4.42	4.70	4.99	5.24
8.0	4.59	4.63	4.93	5.21	5.47
9.5	5.25	5.26	5.15	5.88	6.15
11.0	5.91	5.89	5.83	6.55	6.82
12.5	6.57	6.52	6.51	7.22	7.50

Inside rad (mm)	Sheet Thickness mm/SWG				
	1.83/15G	2.03/14G	2.34/13G	2.64/12G	2.95/11G
1.5	3.36	—	—	—	—
2.0	3.57	3.87	—	—	—
2.5	3.78	4.08	4.28	—	—
2.75	3.89	4.19	4.65	5.09	—
3.25	4.11	4.40	4.86	5.31	5.76
3.5	4.21	4.51	4.97	5.41	5.87
4.0	3.94	4.72	5.18	5.63	6.09
4.25	4.05	4.29	5.29	5.73	6.19
4.75	4.26	4.50	4.88	5.95	6.41
5.25	4.48	4.72	5.09	6.16	6.62
5.75	4.69	4.94	5.31	6.38	6.83
6.0	4.80	5.05	5.42	6.49	6.94
6.5	5.02	5.26	5.63	6.71	7.15
7.0	5.23	5.48	5.85	6.93	7.37
7.5	5.45	5.69	6.06	7.15	7.58
8.0	5.66	5.91	6.28	7.37	7.80
9.5	6.31	6.56	6.93	8.03	8.44
11.0	6.96	7.20	7.57	8.69	9.09
12.5	7.60	7.85	8.22	9.35	9.74

Inside rad (mm)	Sheet Thickness (mm)				
	3.25/10G	3.66/9G	4.06/8G	4.47/7G	4.88/6G
1.5	6.32	6.92	7.52	8.12	8.73
2.0	6.53	7.14	7.73	8.33	8.95
2.5	6.74	7.34	7.94	8.54	9.17
3.0	6.96	7.57	8.16	8.75	9.38
3.5	7.17	7.78	8.39	8.97	9.58
4.0	7.38	7.99	8.61	9.18	9.79
4.5	6.74	8.20	8.81	9.40	10.00
5.0	6.96	8.42	9.01	9.62	10.22
5.5	7.18	7.66	9.22	9.84	10.45
6.0	7.40	7.88	9.44	10.05	10.67
6.5	8.06	8.52	10.04	9.50	11.33
7.0	8.72	9.16	10.66	10.15	10.65
7.5	9.38	9.81	11.30	11.79	11.29

If the bend radius is zero the developed length is equal to sum of the arms in a right angle. For the component shown in Fig. C3.

Developed length $L = 20 + 30 = 50$ mm for zero radius

Increase in the bend radius reduces the developed length. Set back can be defined as the difference between the developed lengths with zero radius and the specified inside radius. Fig. C5 states the set backs for various thicknesses and inside corner radii.

Example C3 Calculate the developed length for the component shown in Fig. C6a : Add the arms of the right angle bend to obtain developed length for zero radius bend.

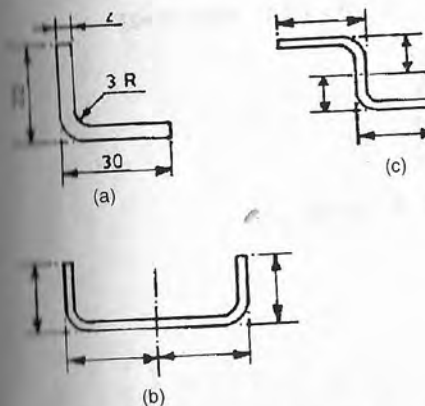


Fig. C6 Calculations of developed length

Solution

$$\begin{aligned}\text{Sum of arms} &= 22 + 30 \\ &= 52 \text{ mm}\end{aligned}$$

$$\text{Set back for 2.0 mm thick sheet and 3 mm inside radius} = \frac{4.19 + 4.40}{2}$$

$$\begin{aligned}\text{Developed length} &= \text{sum of arms} - \text{set back} \\ &= 52 - 4.295 \\ &= 47.70 \text{ mm}\end{aligned}$$

Channel and Z sections can be divided into two right angle bends (Fig. C6b) to calculate the developed length from the set back tables.

Tables of bend allowance, the developed length for a right angle bend, are also available (Fig. C7). For using these tables the straight lengths and the curved length must be separately calculated and added as in examples C1 and C2 in this chapter.

For a right angle bend shown in Fig. C6 (a) the straight lengths would be $(22 - 5)$ and $(30 - 5)$. The bend allowance for 3 mm radius on 2.0 mm thick sheet is 5.765 mm (Table C7).

$$\begin{aligned}\text{Developed length} &= 17 + 5.765 + 25 \\ &= 47.77 \text{ mm}\end{aligned}$$

This developed length is only 0.07 mm more than the developed length (47.70 mm) obtained from the set back tables in Fig. C5.

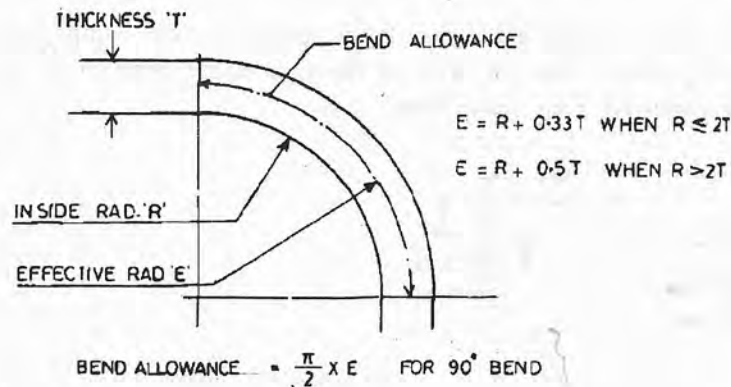


Fig. C7 Bend allowance tables

Fig. C7 Bend allowance tables

Worksheet Thickness mm	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50
0.21/35 G	0.50	0.95	1.28	1.74	2.07	2.52	2.91	3.31	3.70	4.09	4.48	4.88	5.27	5.66	6.06	6.45	6.84	7.23
0.31/30 G	0.65	0.95	1.42	1.81	2.21	2.60	2.99	3.39	3.78	4.17	4.56	4.96	5.35	5.74	6.13	6.53	6.92	7.31
0.35/29 G		0.97	1.45	1.85	2.24	2.63	3.02	3.42	3.81	4.20	4.60	4.99	5.38	5.77	6.17	6.56	6.95	7.34
0.38/28 G		0.98	1.38	1.87	2.26	2.65	3.05	3.44	3.83	4.23	4.62	5.01	5.40	5.80	6.19	6.58	6.98	7.37
0.42/27 G		1.00	1.39	1.90	2.29	2.69	3.08	3.47	3.86	4.26	4.65	5.04	5.44	5.83	6.22	6.61	7.00	7.40
0.46/26 G		1.02	1.42	1.93	2.32	2.72	3.11	3.503	3.896	4.29	4.68	5.07	5.47	5.86	6.25	6.64	7.04	7.43
0.51/25 G		1.04	1.44	1.84	2.36	2.757	3.15	3.54	3.935	4.33	4.72	5.11	5.51	5.90	6.29	6.68	7.08	7.47
0.56/24 G	0.66	1.07	1.46	1.84	2.40	2.796	3.19	3.58	3.975	4.37	4.76	5.15	5.55	5.94	6.33	6.72	7.12	7.51
0.61/23 G		1.10	1.49	1.89	2.44	2.84	3.23	3.62	4.01	4.41	4.80	5.19	5.585	5.98	6.37	6.76	7.16	7.55
0.71/22 G		1.15	1.54	1.94	2.33	2.91	3.31	3.70	4.09	4.49	4.88	5.27	5.663	6.06	6.45	6.84	7.234	7.63
0.81/21 G		1.20	1.60	1.99	2.38	2.78	3.386	3.78	4.17	4.56	4.96	5.35	5.74	6.35	6.53	6.92	7.31	7.706
0.91/20 G		1.25	1.64	2.04	2.44	2.82	3.22	3.86	4.25	4.64	5.035	5.43	5.82	6.213	6.61	7.00	7.39	7.78
1.02/19 G		1.31	1.71	2.10	2.49	2.88	3.28	3.67	4.336	4.73	5.12	5.51	5.906	6.30	6.69	7.085	7.478	7.87

(Contd.)

Worksheet
Thickness
mm

Corner Radius (Inside) mm (Fig C7)

	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.75	5.00	5.25
1.22/18 G	1.81	2.20	2.60	2.99	3.38	3.77	4.17	4.88	5.28	5.67	6.06	6.457	6.85	7.24	7.635	8.42	8.81	9.206
1.42/17 G	1.91	2.307	2.70	3.09	3.485	3.88	4.27	4.66	5.06	5.83	6.22	6.61	7.01	7.40	7.79	8.577	8.97	9.36
1.63/16 G		2.416	2.81	3.20	3.59	3.987	4.38	4.77	5.16	5.56	6.386	6.76	7.17	7.56	7.957	8.74	9.135	9.53
1.83/15 G		2.52	2.91	3.305	3.70	4.09	4.48	4.876	5.27	5.66	6.05	6.447	7.33	7.72	8.11	8.90	9.29	9.68
2.03/14 G		2.62	3.016	3.41	3.80	4.19	4.587	4.98	5.37	5.765	6.16	6.55	6.94	7.336	8.27	9.057	9.45	9.84
2.34/13 G			3.176	3.57	3.96	4.355	4.75	5.4	5.53	5.926	6.32	6.71	7.10	7.50	7.89	9.30	9.69	10.086
2.64/12 G			3.725	4.12	4.51	4.90	5.296	5.69	6.08	6.474	6.867	7.26	7.65	8.045	8.83	9.22	9.616	
2.95/11 G			3.886	4.28	4.67	5.06	5.457	5.85	6.24	6.635	7.03	7.42	7.81	8.206	8.99	9.38	9.777	
3.25/10 G				4.43	4.827	5.22	5.61	6.005	6.40	6.79	7.18	7.576	7.97	8.36	9.147	9.54	9.93	
3.66/9 G					5.04	5.43	5.82	6.217	6.61	7.00	7.396	7.79	8.18	8.57	9.36	9.75	10.145	
4.06/8 G					5.247	5.64	6.03	6.425	6.82	7.21	7.60	7.996	8.39	8.78	9.567	9.96	10.35	
4.47/7 G						5.85	6.24	6.637	7.03	7.42	7.816	8.21	8.60	8.99	9.78	10.17	10.565	
4.88/6 G							6.457	6.85	7.24	7.636	8.03	8.42	8.81	9.207	9.99	10.38	10.777	

08.00 SPRING BACK *2 methods for overbending*

A metal piece generally opens up slightly after bending. This elastic recovery is called spring back. The spring back increases with (i) tensile strength [toughness] of the material bent as well as (ii) bend radius. Spring Back value also depends on the angle of bend and material hardness. The following table gives spring back angles for a few radii and tensile strengths for 90° bend angle.

Table C2 Spring Back Angles for 90° Bend

Bend Radius	Tensile Strength	
	400 N/mm ²	600 N/mm ²
R = T	4°	7°
R = 5T	6°	12°

A test piece of the blank material can be bent and its angle measured to find out the spring back accurately. Some trial and error adjustment is generally necessary for bending tools for workpieces with precision angular bends.

The workpieces should be bent to lesser angles than shown on the component drawing so that after spring back recovery, (Fig. C8) the bend angle will be equal to the angle stated on the drawing. For a right angle bend of a mild steel blank, having 460 N/mm² tensile strength, and inside

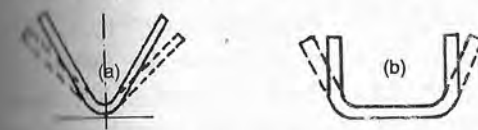


Fig. C8 Change in bend angle due to spring back

radius T , the press tool should bend the workpiece to approximately 85° so that after spring back the angle will increase to 90°. A channel can be bent in two operations by 'V' bending tool (Ref. para C5.31 and Fig. C12). The spring back can be controlled by bending each corner to a lesser angle so that after spring back the sides are square with the base. In single operation channel bending, the base can be made slightly convex (Fig. C9) so that after spring back the convex base springs back to compensate for the spring back on sides. Fig. C9 shows channel after spring back in dotted line.



Fig. C9 Compensating spring back

C4.00 AIR BENDING AND BOTTOMING

In air bending the entire bend length of workpiece does not come in contact with the punch or the die (Fig. C10a). So the die need not have a profile resembling the workpiece. The punch angle is less than the angle required on the workpiece. The workpiece bend angle can be reduced by taking the press ram further down whereas the angle can be increased by reducing the stroke of the press (Fig. C10b). Thus the workpiece bend angle can be varied by adjusting the stroke of the press. This adjustment can take care of the spring back. The punch as well as the die angles must be less than the bend angle required on the workpiece, as the bend angle of workpiece cannot be less than the angle on the punch or the die.

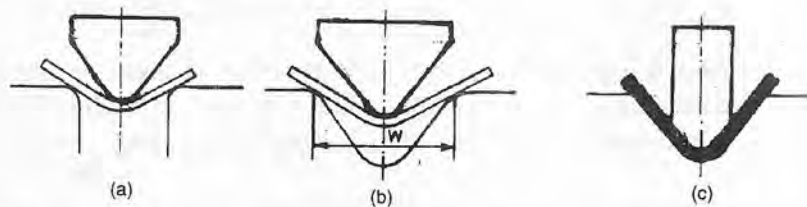


Fig. C10 Air bending and bottoming

Bottoming or solid bending hammers the workpiece from top as well as the bottom. The bent component is sandwiched and compressed between the punch and the die at the end of the downstroke (Fig. C10c). Consequently, the punch and die profiles should match the outer and inner faces of the bent piece before spring back increase in the bend angle. The press stroke should be set for the maximum blank thickness in view of the variation in sheet thickness. This will lead to air bending of the thinner sheets within the variation range. The bend angle will naturally be slightly more for the thinner sheets, which cannot be helped, for if the press ram is set for thinner sheets the ram will get jammed due to heavy compressive stresses when a thicker sheet is used. For the extra thickness of sheet obstructs the ram in effecting the full stroke, while the power drive of the press strives to push the ram down. The problem is particularly acute in crank-driven mechanical presses. These presses are vulnerable to obstruction in stroke. Kunckle-joint coining presses and hydraulic presses are not affected by obstruction of the stroke and are more suitable for bottoming or solid bending.

Bending tools must be set precisely for stroke. This can be facilitated by providing setting pins on the bolsters. Both bolsters are fitted with

along pins which touch face to face in the closed position of the tool. The pins also act as safety stops, and should have sufficient cross-section to transmit the entire tonnage of the press.

C6.00 'V' AND CHANNEL BENDING

C6.10 'V' Bend Parameters [Fig. C11]

Minimum bend inside radius R , minimum flange length a and desired width W of 'V' depend upon worksheet tensile strength f_t , worksheet thickness T and elongation limit of worksheet. The following equations can be used to determine the above parameters (Fig. C11)

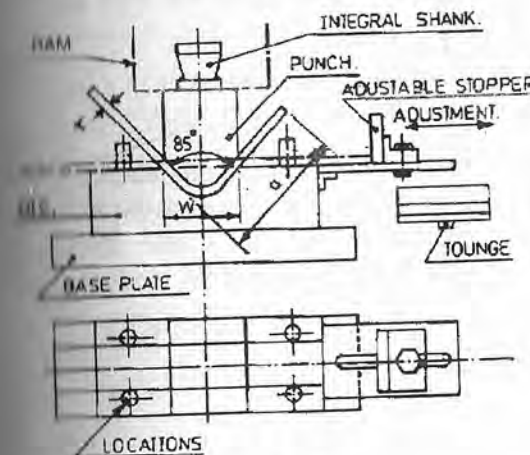


Fig. C11 'V' bending tool

$$\text{Min. inside radius} = R = \frac{f_t}{320} T \quad [\text{Eqn C3}]$$

$$f_t = \text{Tensile strength of worksheet (N/mm}^2\text{)}$$

$$\text{Min. flange length} = a = \frac{W - T}{1.41} \quad [\text{Eqn C4}]$$

$$\text{Width of 'V'} = W = 8 \text{ to } 10 T$$

$$\text{Elongation} = e = \frac{T}{2R + T} \quad [\text{Eqn C5}]$$

Elongation limits for various materials can be found from Table M 1.10 in appendix. It ranges from 26% for low carbon (0.08 Max) deep drawing steel to 18% for structural medium carbon (0.4 steel) and 10% for aluminium bronze to 35% for pure (99.8%) aluminium without any temper.

C5.20 Bending Force — factors reqd. (4) force calⁿ

Bending force depends upon 'V' width W , workpiece thickness T and tensile strength f_t , as well as the length L to be bent to 'V' shape.

C5.21 'V' Bending Force

$$\text{Bending Force} = V_{bv} = \frac{1.33LT^2f_t}{W} \quad [\text{Eqn C6}]$$

L = Transverse length of the bend, i.e. width of the blank in mm

T = Thickness of the blank in mm

f_t = Tensile strength of the blank material in N/mm^2 from Table B1. This can be taken 600 N/mm^2 for mild steel

W = Width of 'V' at top (Fig. C10b)

W should not be less than 6 times blank thickness, ' T ', preferred range = 8 to 10 T

Example C4 Find minimum inside bend radius, minimum flange length, and force required for 'V' bending of workpiece having ultimate tensile strength 360 N/mm^2 and elongation limit 23% if sheet thickness is 2 mm and length of 'V' to be bent is 50 mm. Width of 'V' die is 20 mm.

Solution From Eqn C3

$$R = \frac{360}{320} \times 2 = 2.25$$

From Eqn C5

$$e = \frac{T}{2R + T} \quad \therefore R = 1/2 \left(\frac{T}{e} - T \right)$$

$$\therefore R = 1/2 \left(\frac{2}{0.23} - 2 \right) = 3.34$$

Taking higher of the two values, $R = 3.34$

$$\text{Min. flange thickness} = a = \frac{W - T}{1.41}$$

$$\therefore a = \frac{20 - 2}{1.41} = 12.76$$

$$\text{Bending Force} = V_{bv} = \frac{1.33LT^2f_t}{W}$$

$$\therefore V_{bv} = \frac{1.33 \times 50 \times 2^2 \times 360}{20}$$

$$= 478 \text{ N} \approx 0.05 \text{ tonnes}$$

C5.22 Channel Bending Force

Force required for channel bending V_{bc} can be found from the following formula

$$V_{bc} = \frac{2.66LT^2f_t}{W} \quad [\text{Eqn C7}]$$

L = Transverse length of the bend (mm)

T = Thickness of blank (mm)

f_t = Tensile strength of blank (N/mm^2)

W = Width of channel (mm)

V_{bc} = Channel bending force (N)

Example C5 Find the force required for bending the channel shown in Fig. C14 if tensile strength of blank = 400 N/mm^2 .

Solution Referring the component in Fig. C14

$$L = 22$$

$$T = 3$$

$$W = 60$$

$$f_t = 400 \text{ N (given)}$$

$$V_{bc} = \frac{2.66LT^2f_t}{W} = \frac{2.66 \times 22 \times 3^2 \times 400}{60}$$

$$= 351.2 \text{ N} \approx 0.04 \text{ tonnes}$$

C5.30 'V' Bending Tools

Fig. C11 shows a simple, open, 'V' bending tool. The shank has been made integral with the punch. The punch as well as the die have been given 85° angle leaving 5° for spring back opening. The die has been provided with four location pins for transverse location. The longitudinal location has been provided by a stop which can be adjusted to vary the arm length a of the bend. The stop is mounted on a bracket screwed to the die. The longitudinal slot in the bracket locates the adjustable stop by a slide-fit tongue, and facilitates clamping by the hexagonal head bolt and a nut. It is a good practice to draw the press ram in downstroke position as shown by chain-dotted line. This ensures that there is adequate clearance between the bent piece and the ram at the end of the downstroke.

C5.31 Channel Bending with 'V' Tool

'V' die can be used for forming a channel by bending the other end of the 'V' bent workpiece. It is however necessary to make another punch (Fig. C12) with a slot for the previously bent arm. The workpiece should be drawn in both ram down and up and positions to make sure that no part of the workpiece hits the punch during bending.

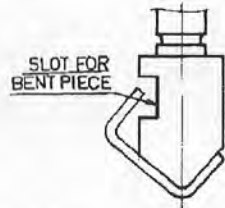


Fig. C12 Bending channel with 'V' tool

Open 'V' tools can be used without pillars and guide bushes because the female 'V' in the die acts like a lead and centralizes the wandering punch as it approaches the end of the downstroke. It is however necessary to prevent rotation of the punch due to loosening of the shank on threads. The loosening can be prevented by fitting a cross-pin dowel passing through the punch and the threaded part of the shank (Fig. C13).

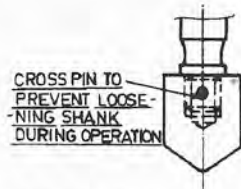


Fig. C13 Prevention shank loosening on threads

C6.00 CHANNEL BENDING TOOLS

Channels can be bent in single operation as shown in Fig. C14. This tool bends two workpieces per stroke. A designer should always consider possibility of gang bending number of components in a single stroke of the press. The number will depend upon the press tonnage as well as the table area.

The punch is anchored into the top bolster and screwed to it. Two side dies are anchored into the bottom bolster. The dies have been screwed and dowelled to prevent transverse movement during operation. The top of the side dies have been provided with location pin for transverse location of blank.

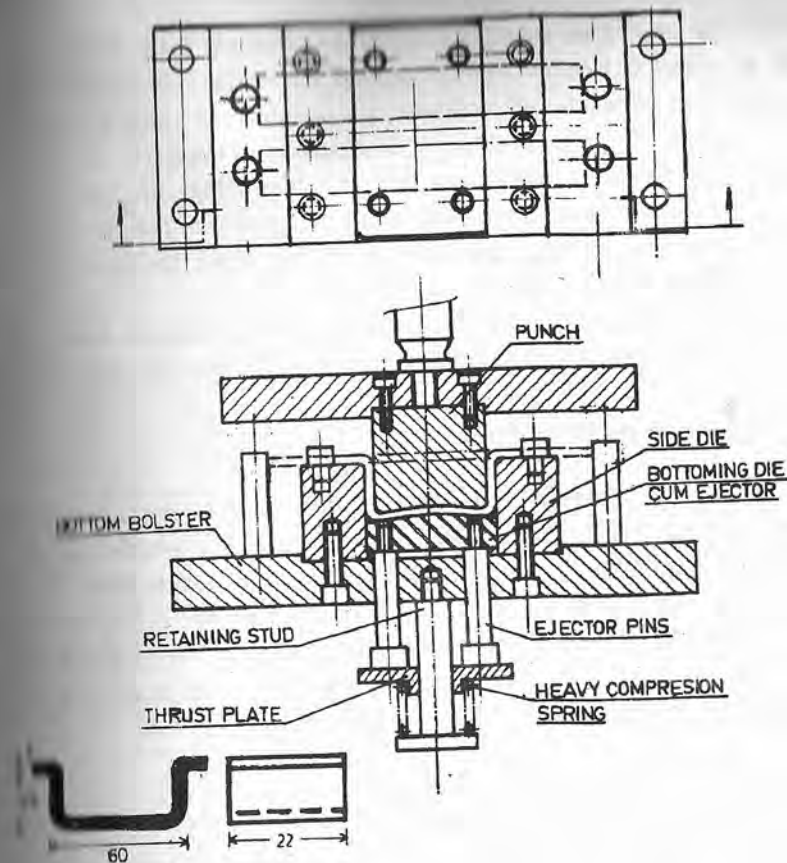


Fig. C14 Channel bending tool

The location pins on bottom bolster position the blank longitudinally for bending. The side dies should be provided with a generous radius (3 R T) on the inner top corners for smooth passage of the blank during bending.

C6.10 Bottoming and Ejection

The bottoming die is made convex and the bending punch has got a corresponding concave radius to compensate for the spring back opening up of the sides (see Figs C8, 9). The bottoming die also serves as a spring actuated ejector. The underneath of the bottom bolster is fitted with a retaining stud which holds the heavy compression spring in position as the bent channel gets jammed between the side dies and requires heavy force for removal from the dies. A thrust plate transmits the force of the spring to the bottoming die-cum-ejector.

When the press ram is up, the compression spring holds the bottoming die up, about 0.5 mm below the top surface of the side dies. The flat blank is loaded between the location pins as shown in chain-dotted line in the elevation of Fig. C14. During downstroke of the press, the blank is sandwiched between the punch and the bottoming die. The blank moves down getting bent in the process till the press ram reaches the end of the downstroke. During the last part of the stroke the base of the channel is bent curved and bottomed.

As the punch rises in an upstroke the compression spring ejects the jammed channel upwards till it reaches the level of the side dies top surface.

C6.20 Ejection by Knockout

Another method of ejection of the jammed channel is to use an inverted tool with a knockout operated ejector (Fig. C15). The position of the blank before bending is shown by dotted line in the elevation. Each blank rests on the punch and is located by 4 transverse and 2 longitudinal location pins. Three blanks are located longitudinally and transversely by 14 location pins. The side dies are provided with holes for the transverse location pins as shown in the elevation of Fig. C15.

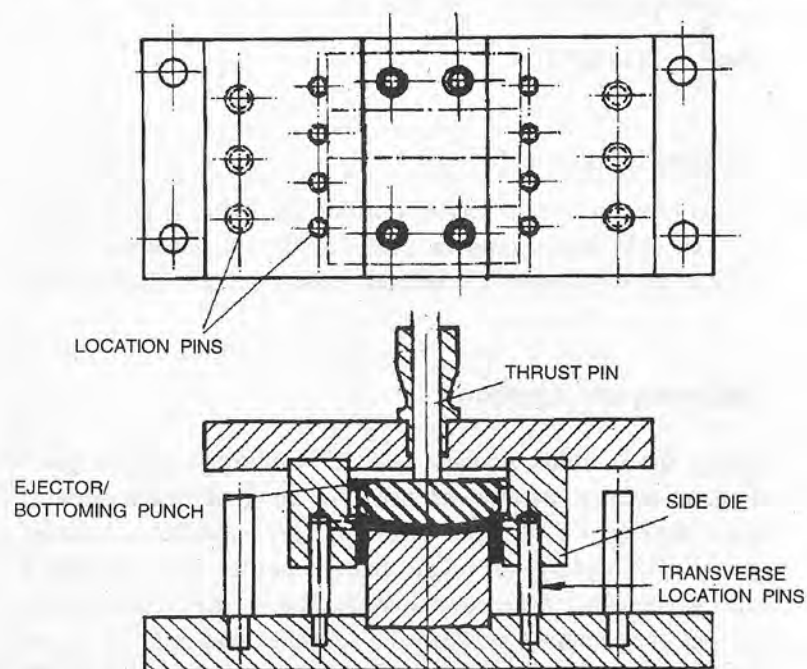


Fig. C15 Inverted channel bending tool

The ejector functions in the same manner as the ejector described in the inverted blanking tool depicted in Fig. B26.

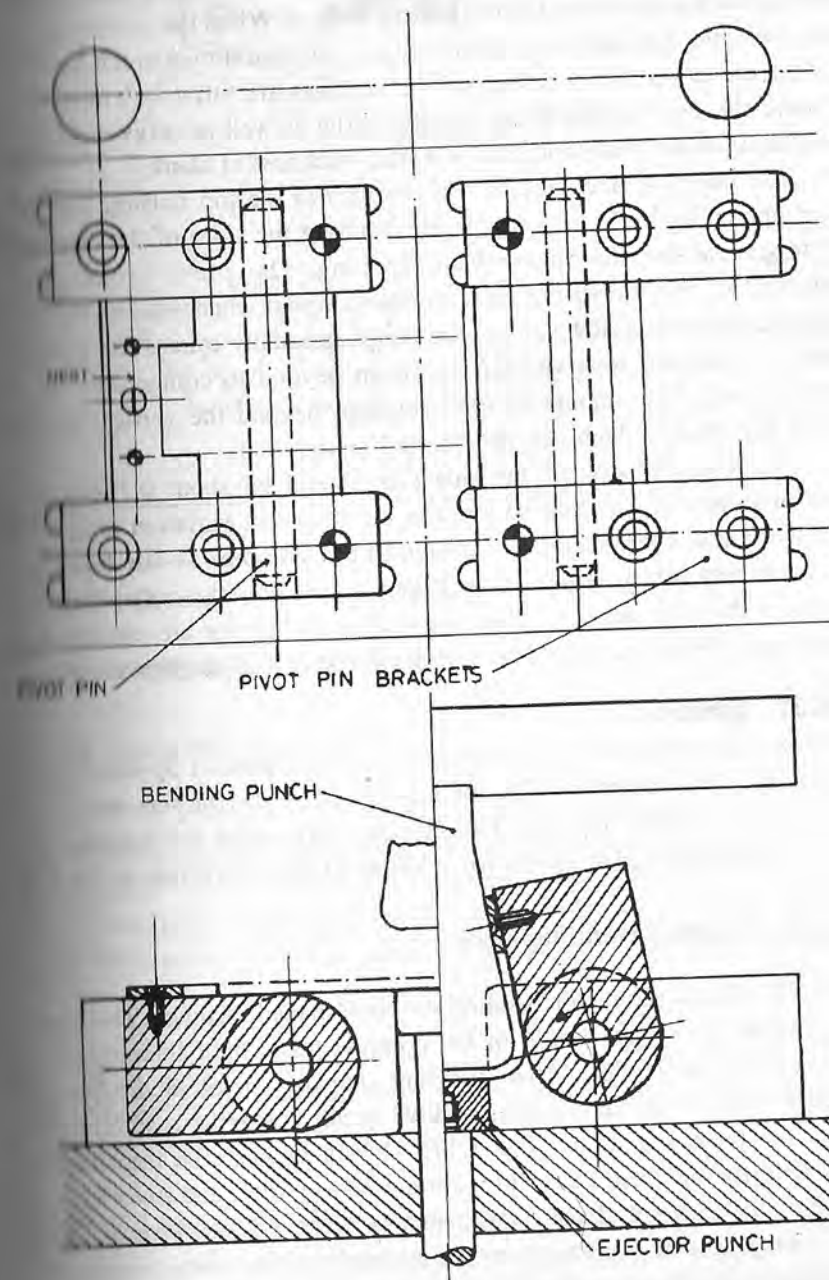


Fig. C16 Channel bending with pivoted dies

C6.30 Channel Bending Tool with Pivoted Dies

Fig. C16 shows a channel bending tool with swinging side dies. The swinging side dies can pivot around the strong pins housed in solid brackets anchored in and screwed to the bottom bolster. When the press ram is up the swinging dies fall under gravity to the position shown in left hand half of the elevation. The top faces of the side dies are fitted with nests which locate the ends of the blank longitudinally as well as transversely. The thickness of the nest should be less than thickness of blank.

The punch is anchored in and screwed to the top bolster. The sides are tapered up by 5° to facilitate overbending the sides of the channel to compensate for the spring back opening. The press stroke can be adjusted to suit the spring back to obtain square channels. As the press ram descends in a downstroke, the punch gradually rotates the swinging dies to turn their tops vertical, and even beyond to compensate for the spring back. The amount of the overshoot beyond the vertical depends upon the stroke which can be adjusted as required.

The distance between the side dies should be about 0.1 mm more than required for the thickest sheet in the thickness variation range. This does not affect the frictional rotation of the side dies as the blank gets jammed between the side dies as it bends, and provides rotary frictional drive to the side dies. The blank as well as the ejector are pushed down against the heavy compression spring till the end of the downstroke.

C6.31 Ejection

The spring pushes the ejector and the bent component upwards as the punch rises in an upstroke. The frictional force rotates the side dies to turn the bending faces horizontal. The side dies turn under gravitational moment to rest in the position shown in left end half of elevation in Fig. C16.

C6.40 Dovetail Bending Tool

Fig. C17 shows a tool for bending dovetail shaped channel. The punch, resembling the inside profile of the component, is in light interference fit in the vertical punch plate. Two swinging side dies pivot in the brackets fitted to the top bolster. A compression spring keeps the side dies open when the press ram is up (Fig. C17). During downstroke the side dies bear with two inclined cams fitted on the bottom tool; and pivot inwards to bend the channel shaped workpiece to acute angled dovetail shape. The swinging side dies open up automatically under force of the compression spring between them as the ram goes up. The bent piece is slid out forward for unloading from the punch.

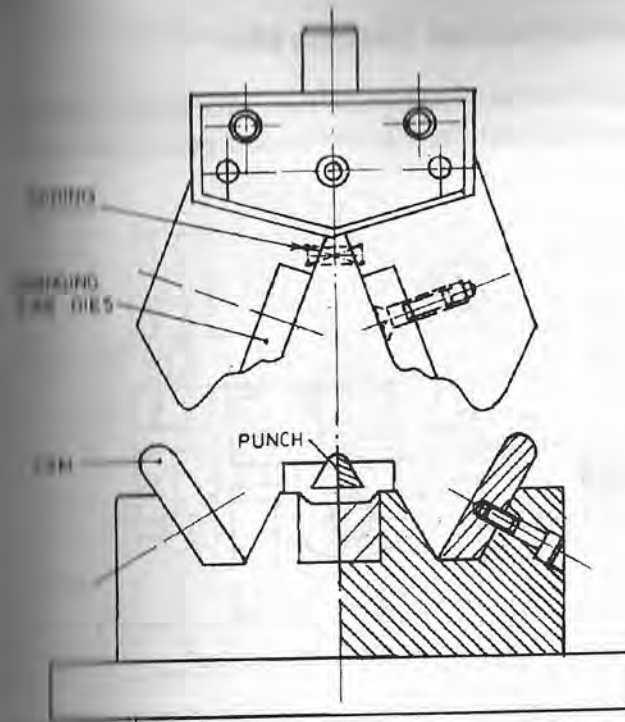


Fig. C17 Dovetail bending tool with pivoted dies in top tool

C7.00 TUBE BENDING TOOLS

C7.10 Ring Bending Tool

Fig. C18 shows a tool for bending a ring from a flat blank. The pivoted side dies are normally held in open position by torsion springs when the press ram is up. The top tool is fitted with a bracket which holds a removable punch (mandrel). During downstroke the punch pushes the blank downwards. The side dies swing inwards to bend the blank to

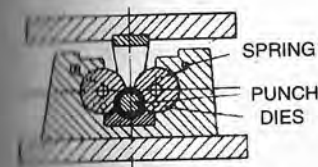


Fig. C18 Ring bending tool with pivoted dies in bottom tool
cylindrical shape around the punch. The punch mandrel is supported at both ends in sturdy brackets. So it is necessary to remove the punch mandrel from the brackets for removal of the finished tube.

C7.20 Tube Bending Tool with Swinging Dies

Fig. C19 shows another tool for bending tube from a flat blank. The blank rests above the punch mandrel fitted in the vertical punch plate at the

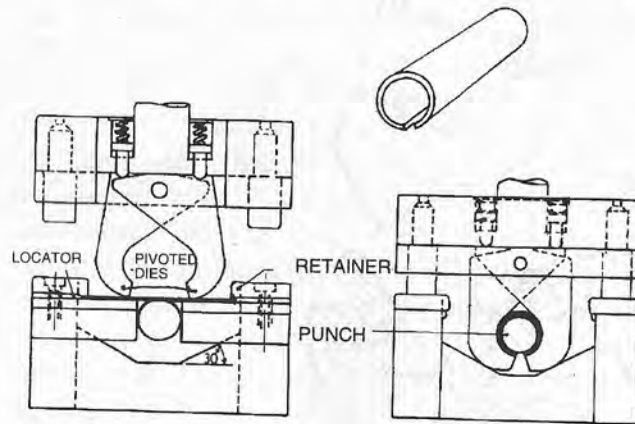


Fig. C19 Tube bending tool with pivoted dies on top tool

rear of the tool. Two swinging dies pivot about pins fitted in the brackets on the top tool. The swinging side dies push the blank down against the punch mandrel. The side dies bear against the angular cams on the bottom tool, and wrap the flat blank around the punch mandrel. The compression springs above the two side dies open them as the press ram rises in an upstroke.

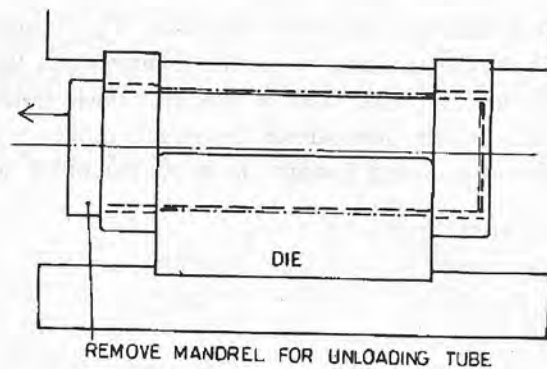


Fig. C20 Removable punch mandrel for bending long tubes

If the tube length is long, it is necessary to support the punch mandrel at both ends. The mandrel, should be removable for unloading of the finished tube (Fig. C20).

C7.30 Tube Bending Tool with Mandrel in Top Tool

Fig. C21 shows a tube bending tool with a mandrel in the top tool. The lower half of the die is fixed to the bottom bolster, whereas the upper

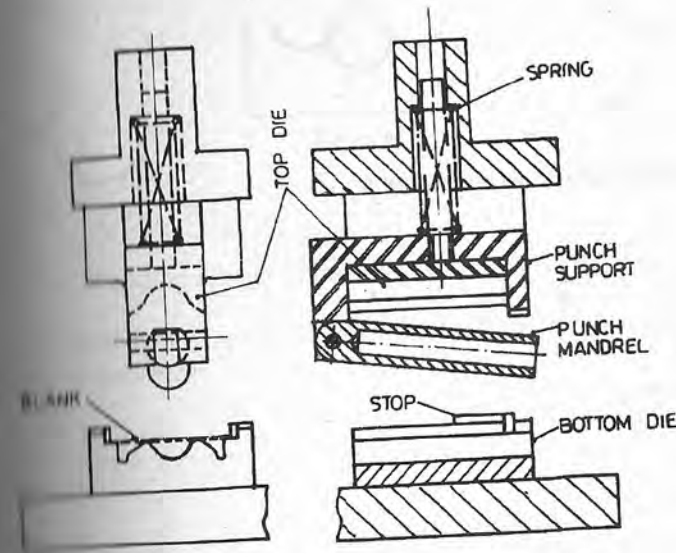


Fig. C21 Tube bending tool with punch mandrel on top tool

half is fixed to the top bolster. The flat blank is located by two guides dowelled and screwed to the lower half of the die. It is advisable to draw the workpiece in four equidistant positions of the stroke to determine the profile for the top and the bottom halves of the die. The mandrel carries the finished tube up during the return stroke of the press. It is necessary to swing off the mandrel from supporting bracket for unloading the finished tube.

C7.40 Bending Tube in Two Operations

Fig. C22 shows a method of bending a tube in two operations. The second stage uses a narrow-neck mandrel supported in the top bolster. Another method of tubular bending in two operations is depicted in Fig. C23. In this method the sheet is bent to deep 'U' shape in the first operation. For the second operation, the 'U' shaped piece should be loaded upside down on the mandrel in the top tool instead of the usual practice of providing location and loading on the stationary bottom tool. The finished tube goes up with the mandrel during the upstroke.

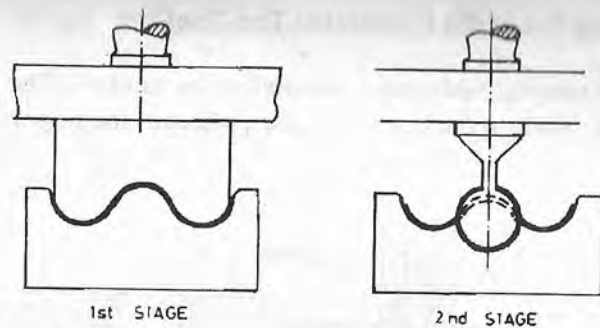


Fig. C22 Bending tube in two operations

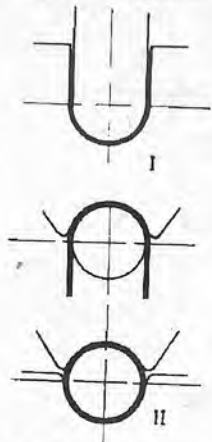


Fig. C23 Bending tube in two operations

Fig. C24 depicts a deep 'U' die for tubular bending in a single operation. The mandrel housed in the top tool carries the finished tube up in the return stroke. Naturally the mandrel must be removed for unloading the finished tube.

C8.00 MULTI-ACTION BENDING TOOLS

C8.10 Double Action Tool for Felt Holder

Fig. C25 shows a dual action bending tool for the component drawn in right hand top corner. The top tool is fitted with two punches and two side cams. The cams bear with side bending dies which move inwards during the downstroke. The side dies wrap the blank gradually around the punches as shown in the elevation. The cams are provided with hardened wear pieces which simplify rectification of errors during manufacture and economical replacement after wear. The top tool is



Fig. C24 Bending tube in single operation by deep 'U' die

also provided with a spring stripper which holds the blank firmly before bending commences.

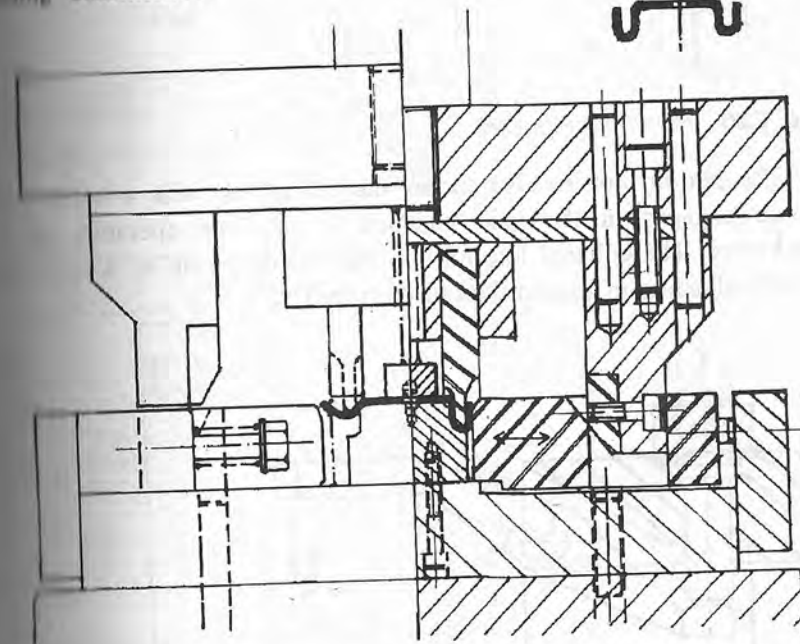


Fig. C25 Double action bending tool for felt

Note the stepped design of the punch in Fig. C26. The punch section is reduced down to the required shape for minimum length necessary for bending the workpiece. The reduced part is joined to the strong, bigger section above by generous radii. This enhances that strength of the punch and reduces breakage. When the press ram is up, the sides

bending dies are held open by compression springs provided with retaining bolts. The sides bending dies have location tongues for guidance in the slots milled in the bottom bolster.

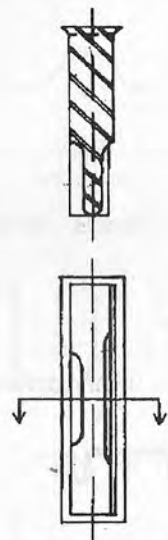


Fig. C26 Punch for Fig. C25

The bottom bolster also carries the central die with a location pin which engages in the hole punched in previous operation on the workpiece. The collared location pin can be moved up by a ejector for quick unloading of the finished piece (Fig. C27).

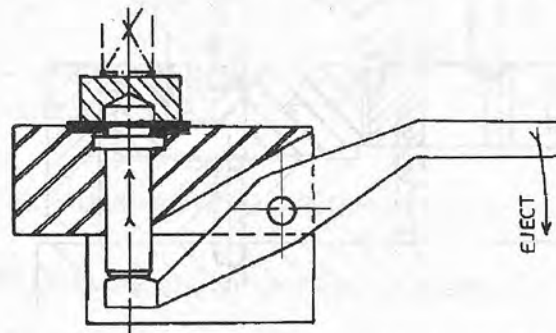


Fig. C27 Ejection arrangement for tool in Fig. C25

The die is fitted with a guide at rear to position and hold the workpiece square with the bending punches. The central die must be screwed and dowelled to the bottom bolster. Designed by the author the above tool was very much appreciated by shop personnel and eventually by the top management for its ingenuity.

The automobile industry uses sophisticated multi-action tools with many bending, piercing, or forming punches operating from different sides of a workpiece. The punches are well guided and generally operated by cams carried by top or bottom tools.

69.00 CURLING TOOLS *of pre curling* ⑥

Fig. C28 shows a curling tool for hinges. The hardened punch is sandwiched between top guides anchored in the top bolster. The guides should have generous radius (lead) at the entry point for the blank. This facilitates correction of misalignment resulting from thickness variation in blanks.

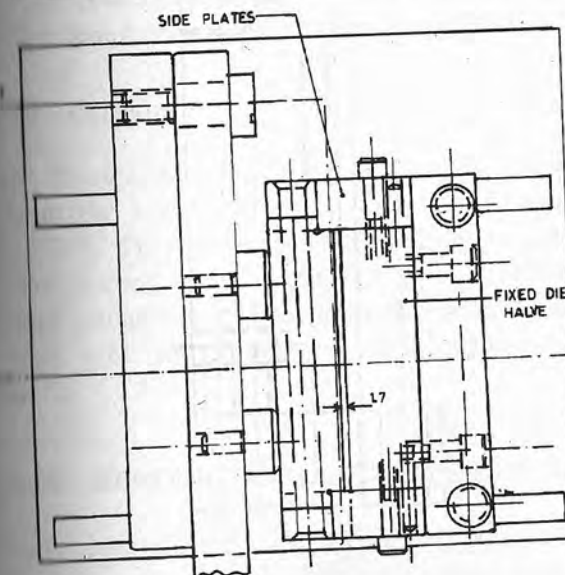
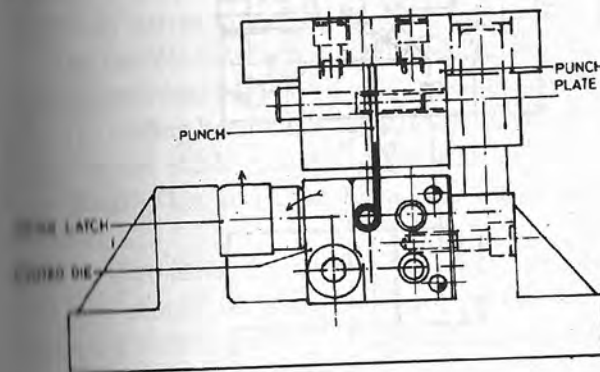


Fig. C28a Curling tool for hinge

C9.10 Unloading Curled Piece

The die consists of two halves to facilitate unloading of the curled hinge. The fixed half is anchored in and screwed to the bottom bolster. This half carries a pivot pin for the swinging half. The swinging half is turned aside while unloading the finished workpiece. During

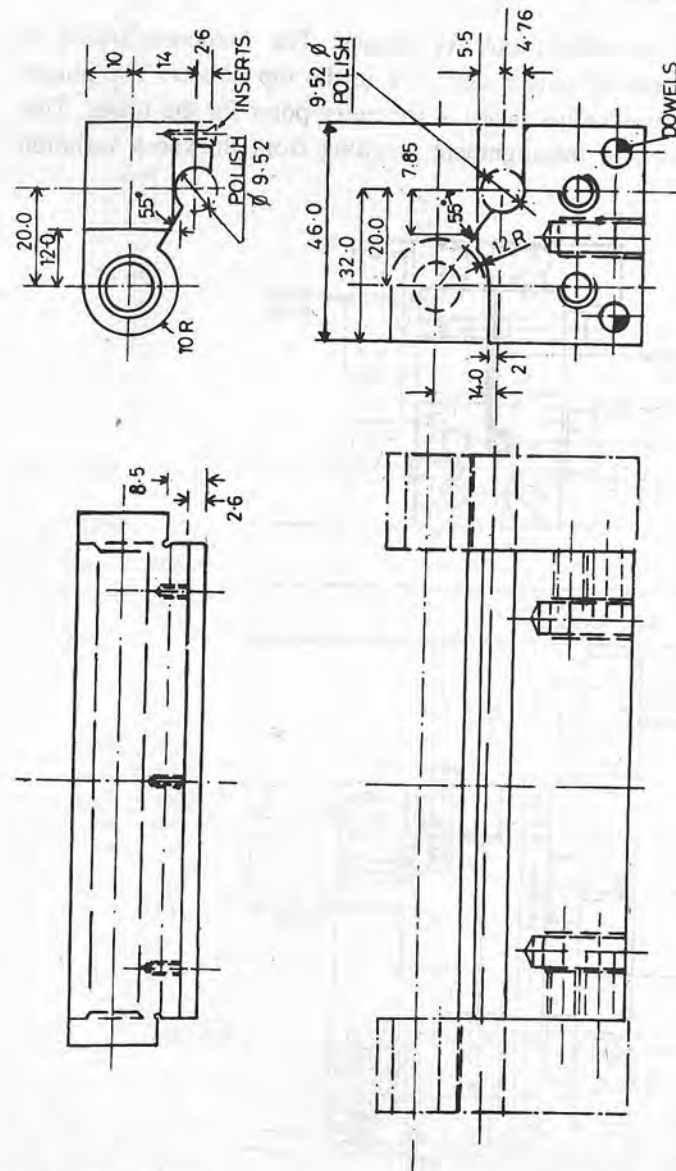


Fig. C28b Curling die halves for tool for Fig. C28a

curling operation this half is held in position by two thrust pins fitted in the pivoted lever. The lever transmits the thrust developed during operation to the sturdy angle plate-like part of the bottom bolster. The lever is swung off the path of the swinging die at the time of unloading, as the curled piece gets jammed in the closed die. The finished piece cannot be removed from the die till the two halves are opened up after swinging off the lever.

The opening (1.7) between the die halves should be about 0.1 mm more than the maximum thickness of the blank to be curled. This causes excessive clearance for the thinnest blank. The blank face will tilt slightly from the vertical. The radius at the entry point of the top guides makes the blank faces vertical before the punch pushes the blank down into the closed die halves to curl it.

The two die halves must blend well at their mating faces (at 55°) and must be polished/ground for easy, smooth movement of the blank in the die. The curling bore in the die halves is finished to size on assembly. The width of the blank should be close slide fit in the opening between the die halves. This keeps the blank side edges vertical and the top edge horizontal.

The die halves are subjected to severe abrasion at the curling faces. The die should be made of high carbon, high chromium steel and hardened to 56 to 62 RC hardness. Otherwise the curling faces will soon wear out. A die for aluminium blanks can be made out of mild steel and case hardened deeply (1.5 mm) to 45 to 50 RC.

C9.20 Lipping

A flat blank cannot be curled well in a single operation. It is necessary to bend the lower end of the blank slightly to the radius of curling (Fig. C29). This operation is called lipping. Lipping reduces abrasion on the curling faces of the dies. The curved end provides excellent bearing surfaces for commencing the curling. Fig. C29 shows a simple bending tool for lipping the blank for the component shown in Fig. C28a.

C10.00 BENDING TOOLS FOR PRESS BRAKES

Long sections of sheet metal are bent on press brakes. The long bending punches used on press brakes are provided with a location tongue all over the length instead of a round shank (Fig. C30a). The tongue is provided with a small projection at top to prevent gravitational fall. The

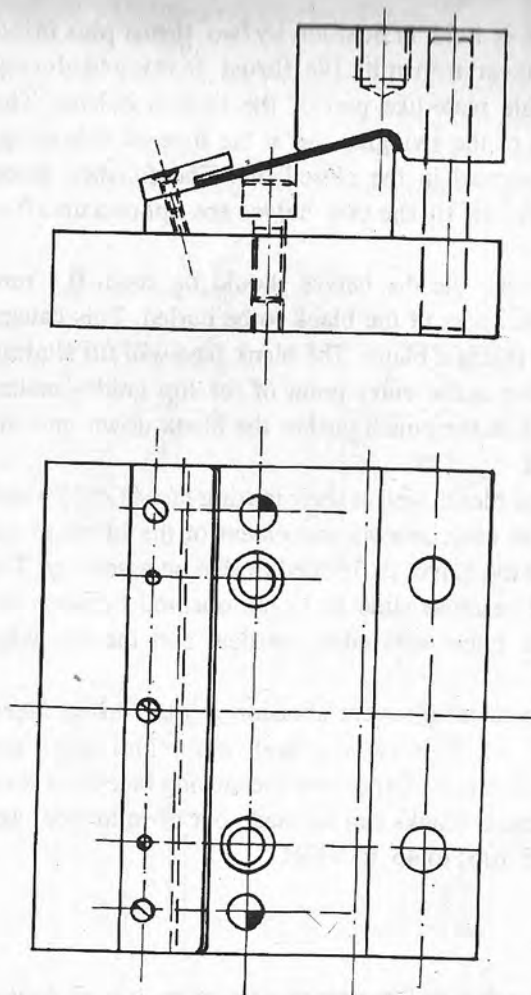
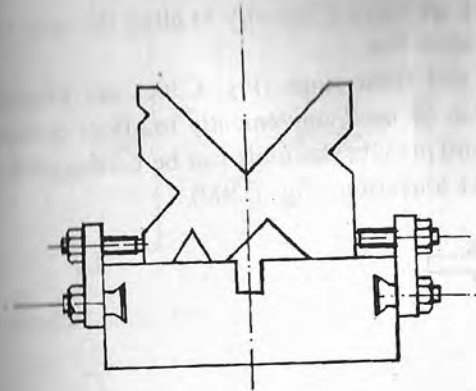


Fig. C29 Lipping tool for hinge

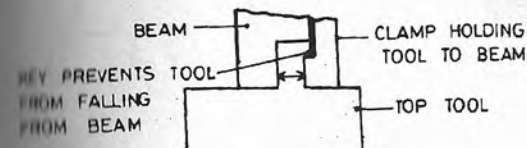
top punch locates on tongue face for lateral position, and is held rigidly by a number of clamps provided on the long ram face.

Even the die is usually provided with a locating tenon which is push fit with the location groove on press brake table. The dies are usually clamped by horizontal screws housed in the holders fixed in dovetail slots on both sides of press brake table.

As workpieces bent on press brakes are long (upto 6 m) tools are designed as narrow long blocks to effect material economy. A 'V' bending die is usually provided with more than one 'V' grooves to facilitate bending various sheet thicknesses and angles with the same die. 'V' die having different sizes of 'V's on the four sides is not provided with a location tongue. Such 'V' is set parallel to press ram by manipulating the



Die clamping arrangement for die with different sizes of 'V's on four sides



Shank for press brake tools

Fig. C30a Mounting tools on press brakes

clamping screws on both sides of press brake table (Fig. C30a). Alternatively the die is provided with different sizes of 'V's on one side

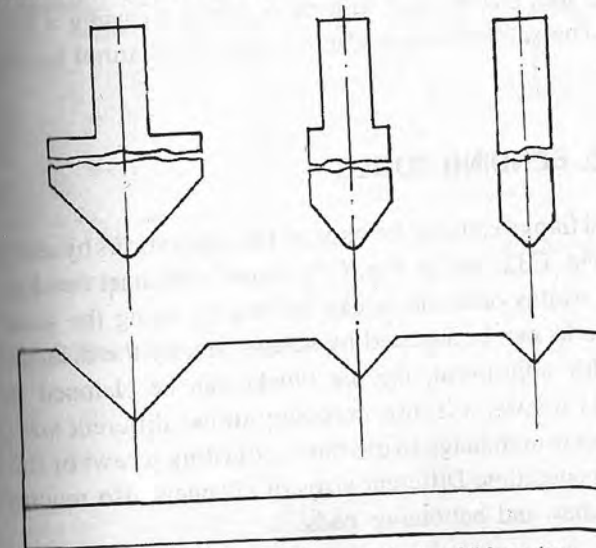


Fig. C30b Dies with different sizes of 'V' on top

only (Fig. C30b). Such dies are shifted laterally to align the required size with the ram/punch centre line.

Adjustable back stops and front stops (Fig. C30c) are available as machine accessories, and can be used conveniently to effect economy in tool cost. A variety of standard press brake tools can be used conveniently for corrugating, curling, and louvering (Fig. C30d).

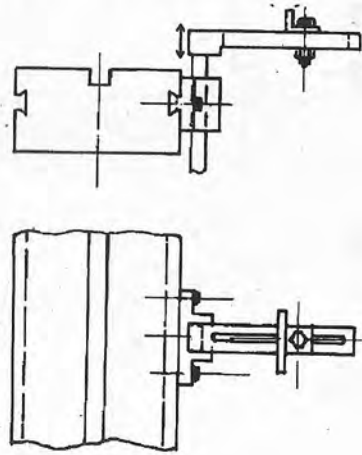


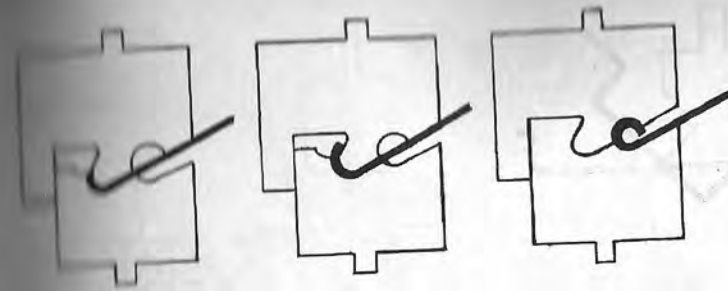
Fig. C30c Adjustable back stop

C11.00 VERSATILITY OF 'V' BENDING TOOLS

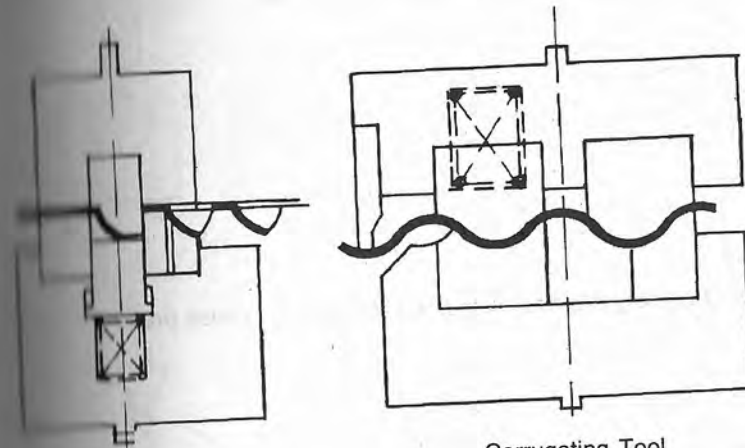
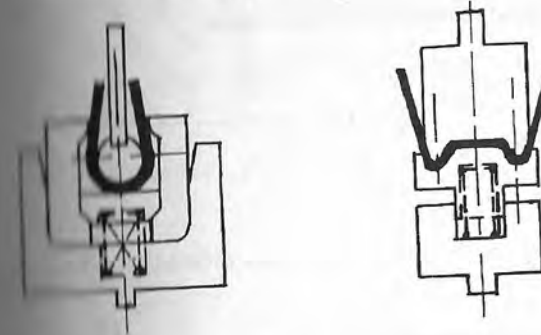
A simple 'V' bending tool can be used to form channels by using a long punch (Fig. C31b). The same tool can also be used for channel having inward flange (C31c).

C.12.00 CHANNEL BENDING TOOLS

A channel with inward flange can also be bent in two operations by using the tools depicted in Fig. C32a and b. Fig. C33 shows a channel bending tool in which various widths of channels can be bent by using the same die blocks. The die blocks can be adjusted by screws to vary the distance between two dies. After adjustment, the die blocks can be clamped in position by socket head screws. It is also necessary to use different sizes of packing pieces to prevent damage to die block adjusting screws or the die slipping off during operation. Different sizes of channels also require different bending punches and bottoming pads.



Standard Curling Tool



Louvering Tool

Corrugating Tool

Fig. C30d Press brake tools

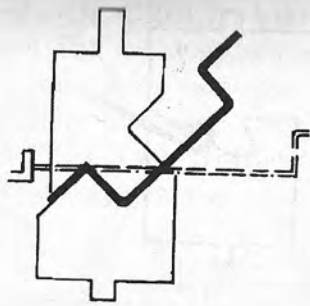


Fig. C31a *Bending flanged channel on press brake*

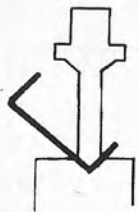
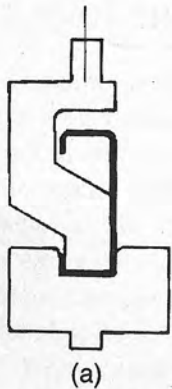


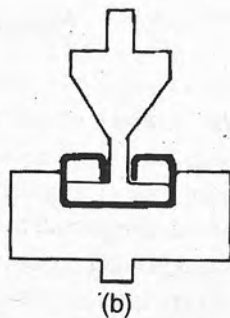
Fig. C31b *Bending channel with standard 'V' tool*



Fig. C31c *Bending channel with inward flange on press brake*



(a)



(b)

Fig. C32 *Bending channel with inward bends on presss brake*

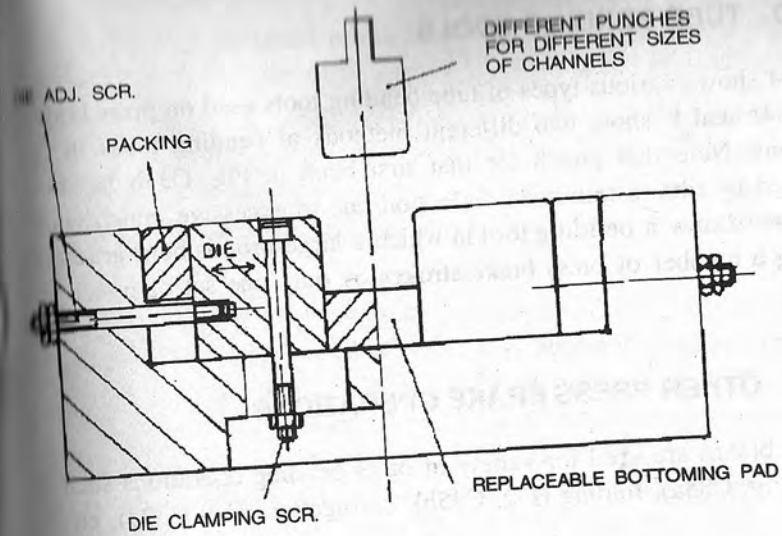
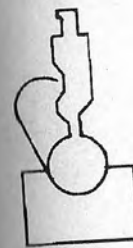
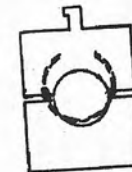


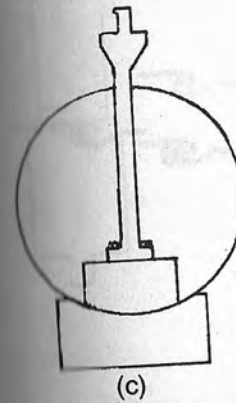
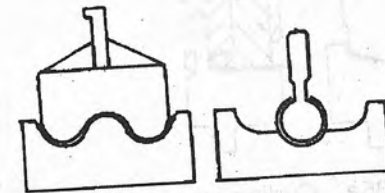
Fig. C33 *Adjustable width channel bending tool*



(a)



(b)



(c)

Fig. C34 *Bending tubes on press brake*

C13.00 TUBE BENDING TOOLS

Fig. C34 shows various types of tube bending tools used on press brakes. Figs C34a and b show two different methods of bending tubes in two operations. Note that punch for that first bend in Fig. C34b has been reinforced by ribs to minimize deflection due to excessive punch width. Fig. C34c shows a bending tool in which a large tube is bent gradually by using a number of press brake strokes by only one set of punch and die.

C14.00 OTHER PRESS BRAKE OPERATIONS

Press brakes are used for variety of other bending operations such as curling (Fig. C35a), folding (Fig. C35b), corrugation (Fig. C30d), etc.

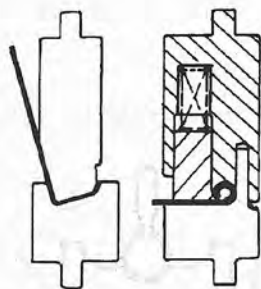


Fig. C35a Curling on press brake

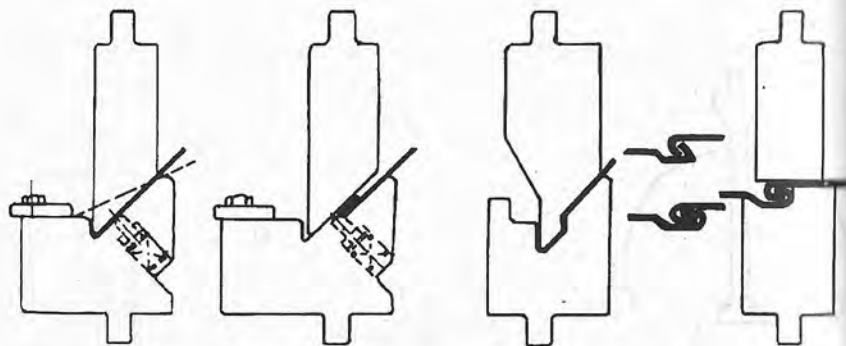


Fig. C35b Folding on press brake

Press brakes are often used for piercing holes and slots with unit tooling sets. (Ref. Para B3.20 and Figs B13b, c).

Although designed primarily for bending, long sections press brakes can be used like any other press keeping in mind the following points:

1. There is no fall through cut-out in table for scrap disposal. A special bolster with an inclined slot for automatic downslide of scrap (to table) is required. Alternatively the tooling should have built-in scrap disposal arrangement like the inclined slot in die holder of unit tooling piercing set.

2. The shank of press brake is narrow and long. If the top bolster of the press tool to be used is wide, it is necessary to have reinforcement ribs as shown in Fig. C34b, or the narrow shank section should be connected to top bolster of press by an angle for spreading the press brake force over wider area (Fig. C36a). Another method of distributing press brake energy over a wider area is to use a flanged shank which can be screwed to the top bolster (Fig. C36b). It is also convenient to make a common adapter/bolster with integral shank (Fig. C37) and use it for clamping wider press tools.

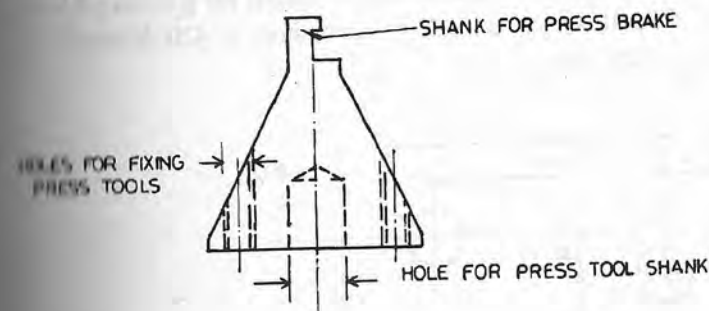


Fig. C36a Tapered shank for mounting wider press tools on press brake

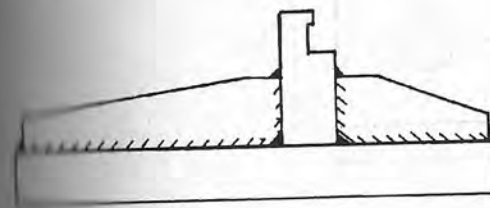


Fig. C36b

3. The shank (tounge) should be placed on the centre of pressure of the tool.

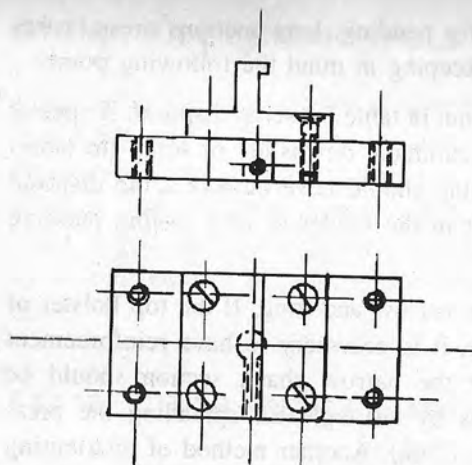


Fig. C37 Flanged shank for using wider press tools on press brake

4. The length of the narrow tounge (shank) should be long enough to transmit the force required for press tool operation.

Example C6 Find position of shank and its length for piercing 4 holes shown in Fig. C38 if shear strength of worksheet = 420 N/mm^2 and shank thickness = 16 mm.

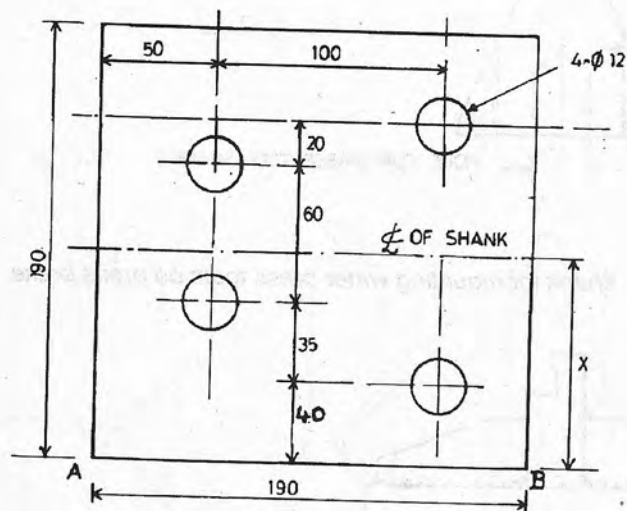


Fig. C38 Workpiece for Example C6

Solution Centre of pressure can be found by taking moments about the edge AB of workpiece. Assume that the centre of pressure is at distance X from AB.

Force for piercing one hole of 25ϕ in a 2 mm thick sheet with shear stress $420 \text{ N/mm}^2 = V$

$$V = \pi \times 25 \times 2 \times 420 = 65973 \text{ N}$$

Taking moments about AB

$$4 \times 65973 \times X = 40 \times 65973 + 75 \times 65973 + 135 \times 65973 + 155 \times 65973$$

$$\therefore X = 101.25$$

Taking design stress on shank equal to 8 kgf/mm^2 ,

$$\text{Shank length} \times 16 \times 8 = 4 \times 6597.3$$

$$\therefore \text{Shank length} = 206.16 \approx 210 \text{ mm}$$

FORMING TOOLS

Forming subjects the blanking material to higher stresses than bending. There is more material flow in forming than in bending (Fig. D1). For

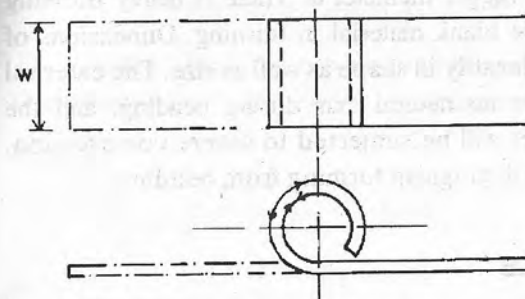


Fig. D1 Stresses in curl bending

example, curling a rectangular piece at one end compresses the inner surface and stretches the outer surface of the bend, but the width of the blank does not change. However, when we form a similar shape on the

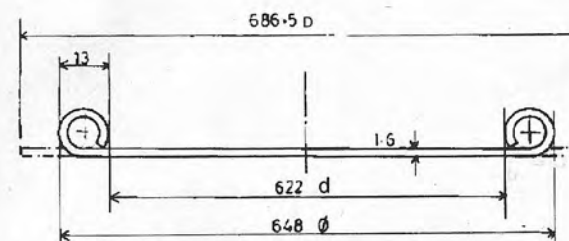


Fig. D2 Material flow in beading a flange

periphery of a circular blank there is substantial change in the blank at the outer periphery (Fig. D2). The outside diameter D of the blank is turned inwards to diameter d in *beading*. The circumference πD is reduced to πd resulting in much more severe stressing of the blank during the operation. For example if 1.6 mm thick 686.5 dia blank is curved to

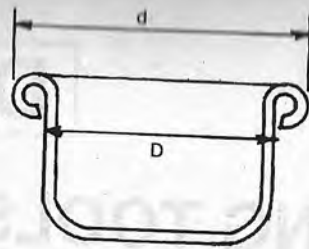


Fig. D3 Cup beading

13 dia bead, there is a reduction of 26 mm in diameter of material at the outer periphery of the blank, and the circumference of original blank is compressed by 81.68 mm (approx 4%). If we bead the top edge of a cup outwards (Fig. D3) the material at the top of the cup will be stretched from smaller diameter D to bigger diameter d . There is heavy stressing and much internal flow of the blank material in forming. Dimensions of the workpiece change considerably in shape as well as size. The external periphery of blank will have no neutral axis during beading, and the entire thickness of the sheet will be subjected to severe compression, and tension. These features distinguish forming from bending.

D1.00 FLANGING TOOLS

D1.10 Flanging Coefficient

Forming is not confined to circular components nor the external periphery only. Pierced holes in sheet metal are often flanged to elongate the bore length (Fig. D4).

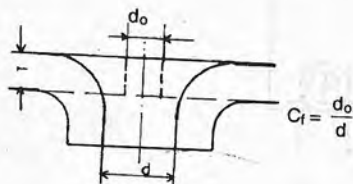


Fig. D4 Hole flanging coefficient

The ratio between the pierced hole size d_o and the finish flange hole size d is called 'Flanging Coefficient'

$$\text{Flanging Coefficient} = C_f = \frac{d_o}{d}$$

C_f depends upon the ratio between pierced hole size d_o and blank thickness T and ranges from 0.2 (for $d_o = T$) to 0.6 (for $d_o = 33 T$).

D1.20 Flanging Force

Flanging force V_f can be found from the following equation

[Eqn D1]

$$V_f = 1.5\pi (d - d_o) T f_t$$

V_f = Vertical flanging force ('N')

d = Hole size after flanging (mm)

d_o = Hole size before flanging (mm)

T = Blank (sheet) thickness (mm)

f_t = Ultimate tensile strength (N/mm²) of blank material (Fig. B4)

= 620 N/mm² for M.S.

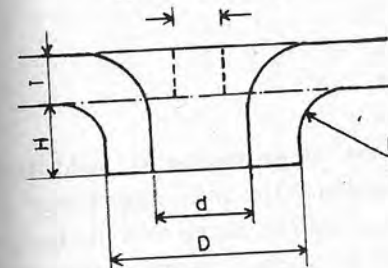
Example D1 Find force required for flanging 8 ia finish size hole in 1.5 mm thick sheet having ultimate tensile strength of 620 N/mm² if $C_f = 0.6$

Solution

$$C_f = \frac{d_o}{d} = \frac{d_o}{8} = 0.6$$

$$d_o = 5.4$$

$$\begin{aligned} V_f &= 1.5\pi (d - d_o) \times T f_t \\ &= 1.5\pi (8 - 5.4) 1.5 \times 620 = 11394.5 \text{ N} \\ &= 1.14 \text{ Tonne} \end{aligned}$$



$$\begin{aligned} R &= 0.25 T \text{ WHEN } T < 1.14 \text{ mm} \\ &= 0.33 T \text{ WHEN } T > 1.14 \text{ mm} \end{aligned}$$

$$d_o = \frac{TD^2 + 4Td^2 + 4Hd^2 - 4HD^2}{9T}$$

T	H	D
< 0.88	T	d + 1.25 T UPTO 1.14 T
0.88	0.7 T 0.8 T	
1.25	0.60 T 0.75 T	d + T

Fig. D5 Limitations in hole flanging

D1.30 Flanging Holes

Sheets thinner than 0.88 mm can be flanged to length H equal to sheet thickness (Fig. D5). However the possible flange depth H decreases rapidly for sheets thicker than 0.88 mm. Fig. D5 shows the constraints in hole flanging. Note that the die corner radius R is one-fourth of sheet thickness T for sheets thinner than 1.14 mm and is one-third of sheet thickness for sheets thicker than 1.14 mm. The flange outside D (the die bore) should be $(d + 1.25 T)$ for sheet thinner than 1.14 mm while D is lesser $(d + T)$ for thicker sheets.

The hole size d_o (Fig. D5) before flanging can be found from the following formula:

$$d_o = \frac{TD^2 + 4Td^2 + 4Hd^2 - 4HD^2}{9T} \quad [\text{Eqn D2}]$$

D1.31 Segmental Flanging

Hole flanging stretches parent material and is called stretch flanging. This method is also used for forming segmental flanges (Fig. D6). In open segmental flanges the flange length H is limited mainly by the maximum deformation possible for the blank material. The maximum deformation possible (without cracking) is higher for stretch forming than shrink forming (Fig. D6). Deformation can be calculated from the following formula:

$$\text{Deformation} = \left(\frac{R_2}{R_1} - 1 \right) \times 100$$

R_1 = Radius of blank before flanging (mm)

R_2 = Radius of the flange after forming (mm)

Fig. D6 gives the maximum possible deformation for mild steel and aluminium. The figure also tabulates the maximum flange H possible for stretch and shrink flanging. It can be noted that the flange length does not depend upon the blank thickness T in open segmental flanging. Furthermore deformation for shrink flanging mild steel is only 10%, i.e. one-fourth the deformation possible in stretch forming. Deformation necessary for flanging must be computed and checked for process capability before commencing the design of the flanging tool. Negative value of deformation is a clear indication that the workpiece requires shrink flanging. Fig. D6 shows the shapes of blanks before flanging in chain-dotted line. It can be observed that in stretch forming blank length l_1 is elongated to l_2 whereas in shrink forming the blank length l_1 is reduced to length l_2 .

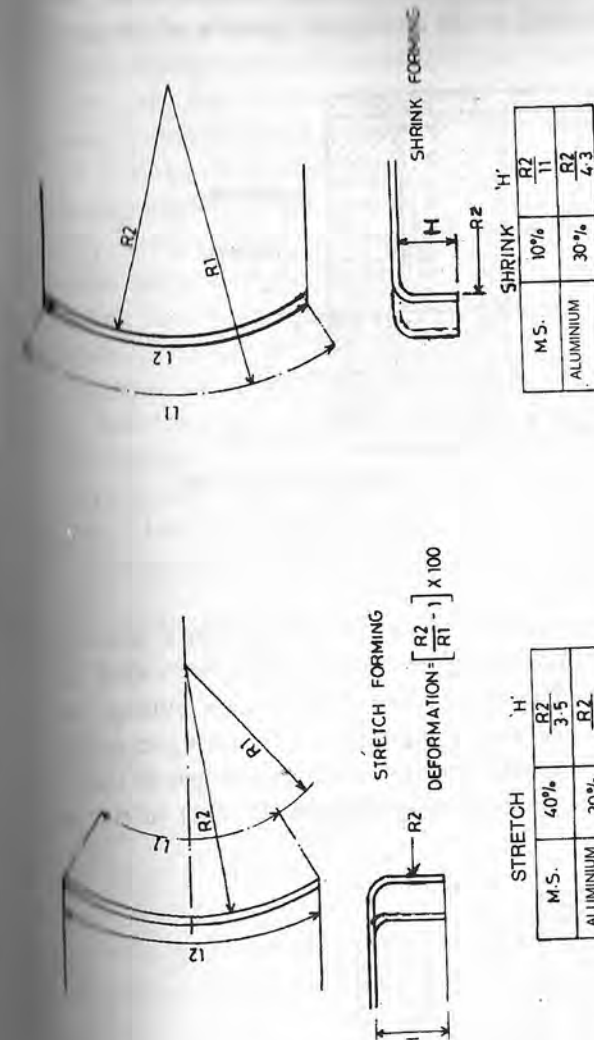


Fig. D6 Segmental flanges

Fig. D7 shows a hole flanging tool for a single flange. The chain-dotted line shows the blank before flanging. The die is provided with a counterbore for locating the circular blank. The inside corner radius of the die should not exceed one-third to one-fourth of the blank thickness. The flanging punch is provided with a generous radius at lower end. It acts as a lead and centralizes the blank hole d_o with the punch dia d before flanging commences. The punch has got a collar at the top to prevent its extraction from the punch plate during the upstroke. The top

tool is fitted with a spring stripper for automatic removal of the jammed workpiece from the flanging punch during the upstroke of the press.

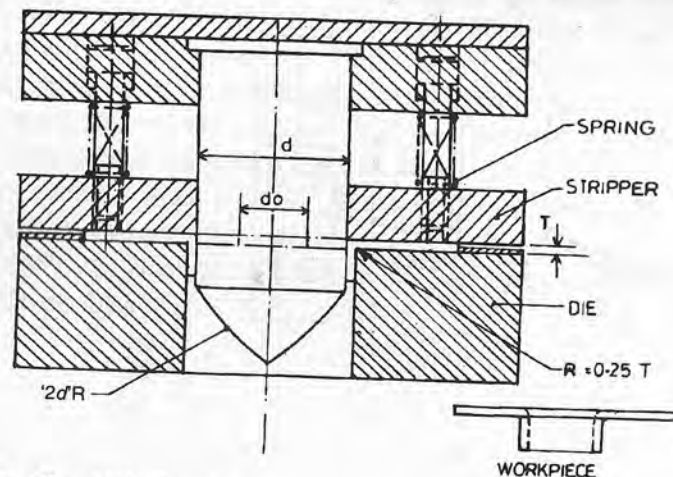


Fig. D7 Hole flanging die

Piercing and flanging operations can be combined in a single tool. Tools which combine cutting and forming operations are called Combination tools. (Compound tools combine two or more cutting operations only.) Fig. D8 illustrates a combination tool for piercing and forming a single flange. The flanging tool is of inverted type to facilitate automatic disposal of the piercing scrap through the hole in the press table.

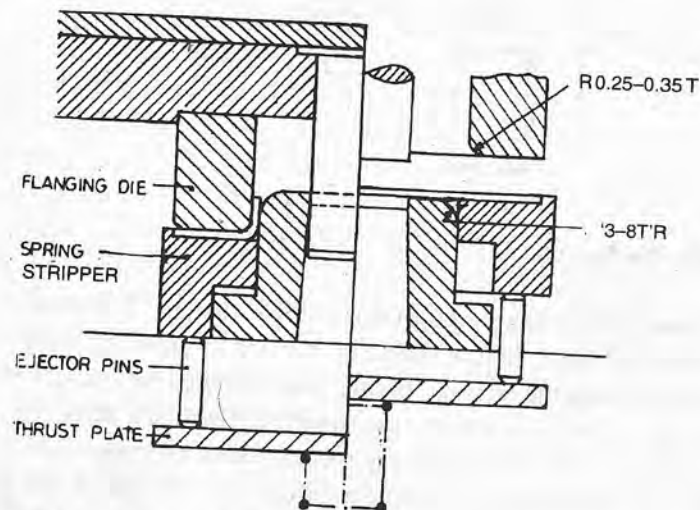


Fig. D8 Inverted hole flanging tool

The top tool carries the flanging die and piercing punch. The piercing punch should be slightly longer than the flanging punch so that the blank is pierced before flanging commences. The bottom tool holds the combination piercing die-cum-flanging punch. Note that the corner radius on the flanging punch should be three to eight times the blank thickness for smooth material flow. The bottom tool also carries a spring stripper for automatic removal of the jammed workpiece from the flanging punch. A heavy spring fitted at the bottom of the tool holds the stripper slightly above the top face of the flanging punch when the press ram is up.

During the downstroke the unformed part of the blank is held sandwiched between the flanging die and the stripper which is pushed down against the spring during the operation. As the ram goes up in a return stroke the spring pushes the stripper up through the thrust plate and the ejection pins.

Number of holes can be pierced and flanged simultaneously in a gang tool which holds two or more piercing punches and combination flanging punch-cum-piercing dies similar to one shown in Fig. D8.

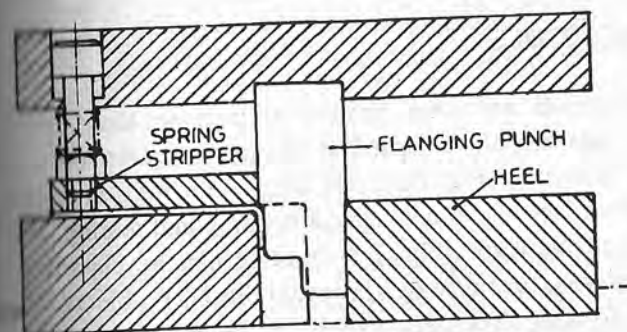
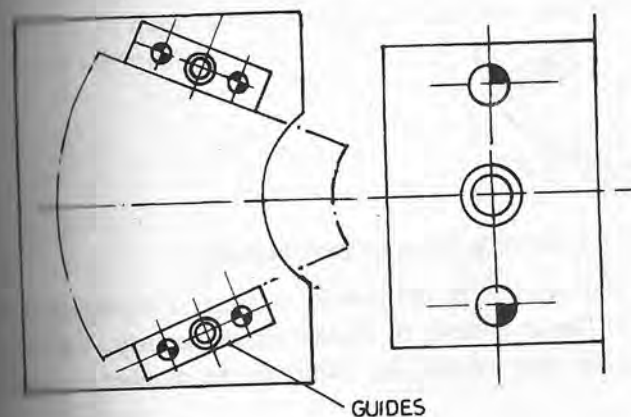


Fig. D9 Use of heel to minimize deflection in open flanging

As the flange length is generally less than blank thickness in hole flanging, and elastic recovery of the blank material reduces the outside diameter of the flanged workpiece, it rarely gets jammed in the flanging die.

The open form of segmental flanges eliminates the possibility of workpiece jamming on the flanging punch. Nonetheless it is advisable to use a spring stripper to hold the blank firmly in position during the operation. Punches for segmental flanging are subjected to bending due to eccentric loading. It is advisable to use a heel on the bottom bolster to prevent bending of the punch. Alternatively an even number of blanks can be formed in a single stroke by gang forming (Fig. D10). Placement of the blanks diametrically opposite to each other eliminates the

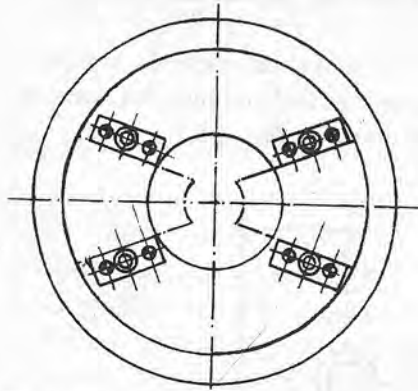


Fig. D10 Neutralizing bending force in open flanging

eccentric loading and bending of the punch, although a higher capacity press is required to flange number of blanks simultaneously. The press tool size and cost will also increase according to the number of blanks flanged.

D2.00 BEADING TOOLS

Sheet metal components are often beaded to increase their strength against bending. Cups are often beaded at top to strengthen the edges against bending and tearing (Fig. D3). Flat flanges for reels are usually beaded to make them less vulnerable against bending and tearing. When the edges are turned outwards (Fig. D3) beading can be classified as stretch forming whereas turning edges inwards (Fig. D2) subjects blanks material to shrink forming. The deformation can be calculated from the following formula

D2.10 Deformation in Beading

$$\text{Deformation} = \left(\frac{R_2}{R_1} - 1 \right) \times 100$$

R_1 = Radius of bead after forming

R_2 = Radius of blank before beading

The maximum value of R_2 should be used for calculations in stretch forming (Fig. D3) whereas the minimum value of R_2 should be considered in shrink forming (Fig. D2). The maximum deformation should fall within the values stated for segmental flanging (Fig. D6) because the maximum deformation depends upon the physical properties of the material to be formed and not merely on the shape resulting from forming.

D2.20 Shrink Beading Tool for Reel Flange

Fig. D11 shows a press tool for shrink beading of a reel flange. It is necessary to draw the flat blank to cup before beading it (See section E for drawing tools).

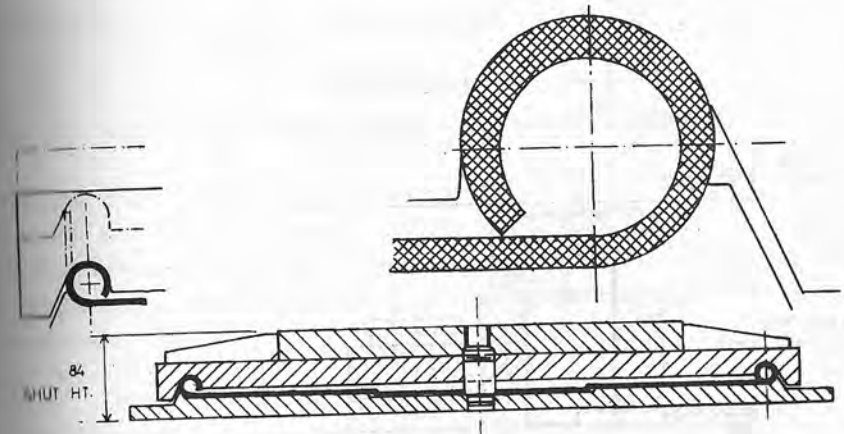


Fig. D11 Reel shrink flanging tool

The cup is located by a location pin engaging in the central hole pierced in earlier operations. The cup should be supported adequately on the external radius. (See the enlarged view). The top tool has got a form similar to a curling die. There should be a chamfer of approximately 60°

at the entry point. The chamfer as well as the radius of the top tool should be ground or polished well for smooth flow of the workpiece material during the operation. The beading radius and the chamfer in the top tool are subjected to severe abrasion, and should be hardened to enhance the tool life.

The top and bottom tools are aligned by the central location pin which should be precision running fit ($H7/f6$) in the top tool. For cups without a central hole it is necessary to provide two guide pillars in the bottom tool and guide bushes in the top tool for alignment of the tools. The component can be located on the external corner radius of the cup.

D2.30 Stretch Beading Tool for Cup

Fig. D12 shows a stretch beading tool for a cup. The cup is located on its outside diameter. The beading punch has got a pilot on the lower side. The pilot engages with the inside bore of the cup and centralizes it with the beading punch before the operation commences.

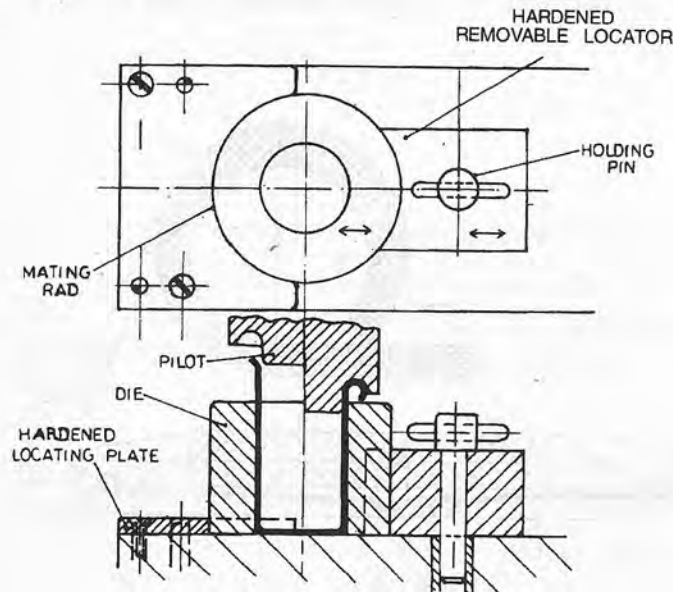


Fig. D12 Cup beading tool with removable die

It is necessary to lip the top edge of the cup in the previous operation to facilitate smooth flow of the material in beading. Dies for deep cups are generally slid out from the bottom bolster, clear of the top tool, for unloading the beaded cup and loading a fresh piece (Fig. D13). This

facilitates use of press having lesser open height and stroke. Such tools should be provided with an arrangement for locating the removable die for centrality with the beading punch and holding it in working position during the operation.

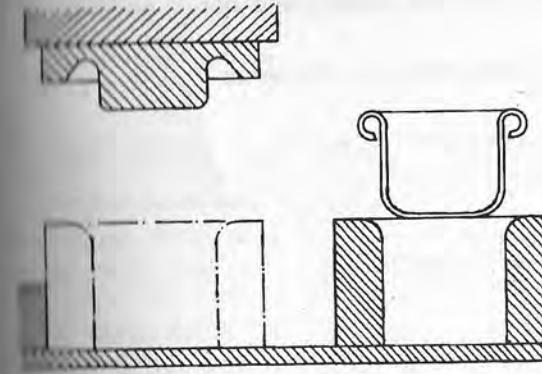


Fig. D13 Sliding die for loading and unloading deep cups

Referring to the plan in Fig. D12 it can be observed that the bottom bolster has been provided with a radius which bears the outside diameter of the removable die. The die is held in position by a removable locator and a close fit holding pin. The bottom bolster is fitted with a hardened plate to minimize the wear due to frequent sliding in and out of the die on the bolster.

D2.40 Strengthening Rectangular Parts by Beading

Beading is not confined to circular parts only. Even rectangular components are beaded to increase their depth, and strengthening them against bending (Fig. D15). These beads act like ribs enhancing the strength against bending. Beads in rectangular parts are generally closed on all sides. This imposes limitation on bead dimensions.

D2.41 Depth, Side Margin, and Pitch

The deflection due to bending load varies inverse to the moment of inertia of the cross-section. As the moment of inertia is proportional to the cube of the depth of the section it is convenient to decide the depth of bead first.

The maximum depth depends upon the tensile strength of worksheet, its thickness, and the forming pressure used.

$$\text{Max. depth} = d = \frac{0.4545}{P} \cdot 6t \cdot T \text{ for rectangular bead [Eqn D3]}$$

$$d = \frac{0.909}{P} \cdot 6_t \cdot T \text{ for circular bead} \quad [\text{Eqn D4}]$$

T = Worksheet thickness (mm)

6_t = Worksheet tensile strength (N/mm^2)

P = Forming pressure = 7–9.5 N/mm^2

Example D2 Determine the maximum bead depth possible for a rectangular bead in

(a) 1.5 mm thick M.S. Sheet with $6_t = 300 \text{ N/mm}^2$;

$P = 8 \text{ N/mm}^2$

(b) 2 mm thick aluminium sheet

$6_t = 110 \text{ N/mm}^2$; $P = 7 \text{ N/mm}^2$

Solution

$$(a) \quad d = \frac{0.4545 \times 300 \times 1.5}{8} = 25.56$$

$$(b) \quad d = \frac{0.4545 \times 110 \times 2}{7} = 14.28$$

Fig. D14a shows a graph for four bead depths ranging from 3 to 20 mm. The graphs can be used for determining side margins m for various bead depths. Note that side margin m ranges from four and a half to ten times depth d .

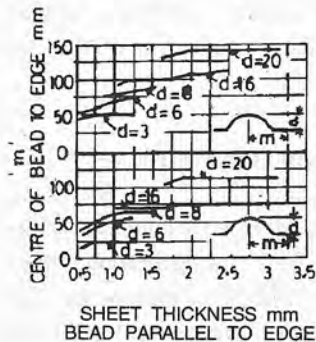


Fig. D14a Side margins for beads

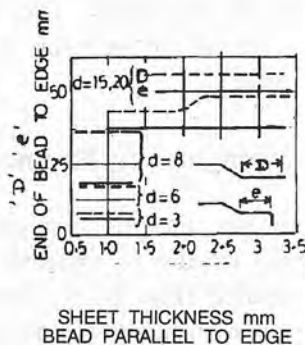


Fig. D14b End margins for beads

The pitch between two beads ranges from one and a half to two times the side margin m , but should not be less than eight times sheet thickness T .

D2.42 End Margins and Length

End margin e at the ends of a rectangular bead can be found from Fig. D14b. The depth to end margin ratio of a designed bead should fall in the shaded area shown in Fig. D14b.

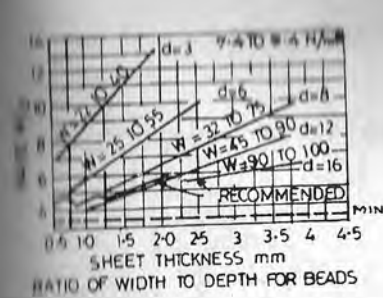


Fig. D14c Width : Depth ratio and radii of beads

The maximum length of the bead can be found by deducting margins at both ends of the bead from workpiece length. It can be noted that end margin varies from two to five and half times bead depth d .

D2.43 Bead Width

This can be found by referring Fig. D14c which plots 'Width : Depth' ratio of bead against sheet thickness. It can be noted that width of bead ranges from four to eight times the bead depth.

D2.44 Connecting Radii

Beads are connected to flat portion by ample radii. The following equations state the various radii in terms of bead depth d

- (1) Cross radius $R = 2.2 d$
- (2) Corner radius $R_c = 1.4 d$
- (3) Longitudinal radius $R_e = 10 d$

[Eqn D5]

Example D3 A 350 mm long and 160 mm wide panel made from 2 mm thick low carbon steel is to be strengthened against bending by a bead along the length. Determine the width, length and radii of the bead.

Solution If a single central bead is provided, the maximum side margin will be half the panel width

$$m = \frac{160}{2} = 80 \text{ mm}$$

Referring Fig. D14a upper graph for 80 mm side margin.

$d = 15 \text{ mm}$ Approx.

Referring Fig. D14b for 15 mm bead depth and 2 mm thick sheet end margin e should be between 45 to 50. Taking 45 margin

$$e = 45$$

$$\begin{aligned} \text{Bead length} &= 350 - 2e \\ &= 350 - 2 \times 45 \\ &= 260 \text{ mm} \end{aligned}$$

Referring Fig. D14c for sheet thickness 2 mm and $d = 15$ mm ratio $\frac{w}{d}$ should be 5.75.

$$\frac{w}{15} = 5.75 \quad \therefore w = 86.25 \approx 86$$

From para 2.44

Cross radius $R = 2.2 d = 2.2 \times 15 = 33$ mm

Corner radius $R_c = 1.4 d = 1.4 \times 15 = 21$ mm

Longitudinal radius $R_e = 10 d = 10 \times 15 = 150$ mm

Fig. D15 shows the bead shape.

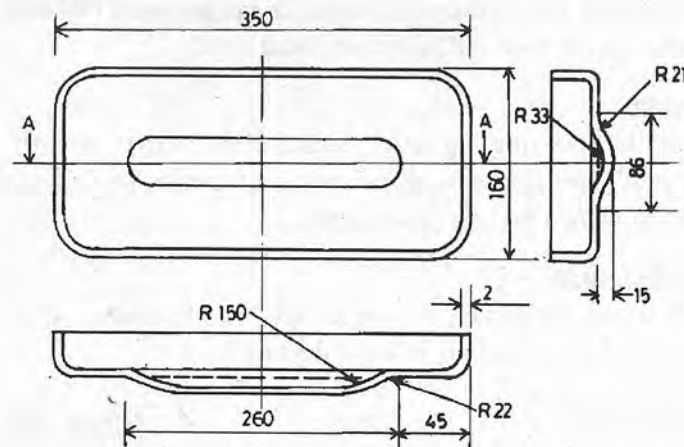


Fig. D15 Bead for Example D2

D2.45 Beading Tool for Rectangular Bead

Fig. D16 shows a beading tool for a rectangular bead. Although there is no risk of punch getting jammed in a formed bead it is convenient to provide a spring stripper to ensure wrinkle-free material flow. Top and bottom tools are aligned permanently by guide pillars and bushes.

D2.46 Beading with Rubber Dies

Hard-rubber pad (85–95A durometer) can be used instead of steel die. The rubber assumes the shape parallel to steel punch profile with the worksheet sandwiched in between punch and rubber. The hardened punch corresponds with the internal profile of the required bead.

In rubber die beading the worksheet is held between the punch end and the rubber block before forming commences. The contact area between punch, worksheet, and rubber increases gradually till the end

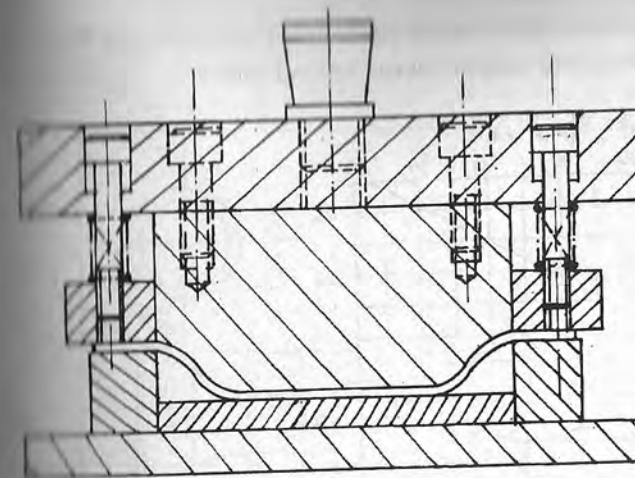


Fig. D16 Beading tool for rectangular workpiece

of the punch stroke. Progressive stretching of worksheet over a large area provides better strength than beads formed by metal die. However for deep beads more than one operations are necessary when a rubber die is used. Rubber block height should be three times the bead depth d .

D2.50 Annular Beads and Countersunk Buttons

D2.51 Annular Bead

Holes in worksheet can be strengthened around periphery by providing an annular bead (Fig. D17). The maximum depth of the bead depends upon the elongation limit of the worksheet material. Referring Fig. D6 elongation limits for mild steel and aluminium are found to be 40% and 70% respectively. Fig. D18 shows a graph for depression height d to width

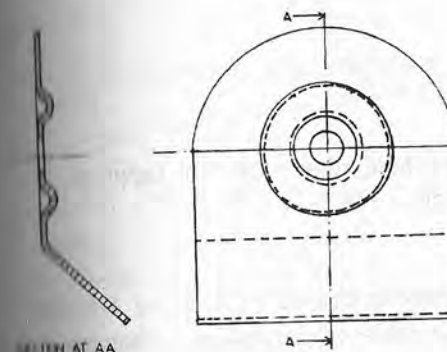


Fig. D17 Reinforcing ribs around holes in stampings

w ratio d/w for recesses with circular contours. This graph can be used conveniently for designing annular beads around holes.

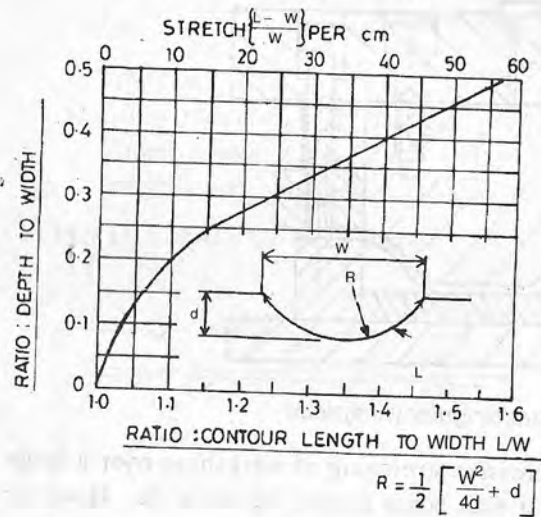


Fig. D18 Relation between average stretch and dimensions of a recess of a circular contour

Example D4 Design a circular bead for a 16 ϕ hole in 1.5 mm thick steel sheet with 30% elongation limit.

Solution From Fig. D18, for 30% elongation $\frac{d}{w} = 0.35$

If we take $d = 6$ mm

$$w = \frac{6}{0.35} = 17.14 \approx 17$$

$$R = \frac{1}{2} \left(\frac{w^2}{4d} + d \right) \quad [\text{Eqn D5}]$$

$$= \frac{1}{2} \left(\frac{17^2}{4 \times 6} + 6 \right) = 9.02 \approx 9$$

From Fig. D14a, the margin from hole edge = 50 mm (approx.)

$\therefore$ Mean ϕ of bead = $16 + 2 \times 50 = 116 \phi$

D2.52 Formed Bosses (Fig. D19)

Buckling resistance of worksheet can be increased by forming a depression in the sheet. The angular side wall of depression enhances the strength considerably. However the depression depth usually ranges between 1.25–2.5 times worksheet thickness T only. For diameter D to

depth d ratio of depression $\frac{D}{d}$ should not be less than 10 and can be as high as 30.

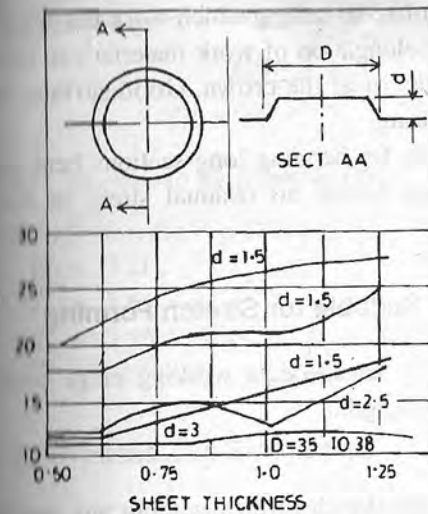


Fig. D19 Width : Depth ratio of formed bosses

D3.00 STRETCH FORMING

In stretch forming, the entire thickness of the section is subjected to tensile stress beyond yield point. For the neutral axis is well outside the blank thickness (Fig. D20a). In bending, the neutral axis is situated mid-thickness, and material on one side of neutral axis is subjected to compressive stress while the material on the other side is under tension (Fig. D20b).

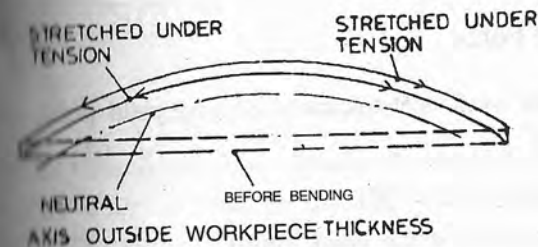


Fig. D20a Stretch forming

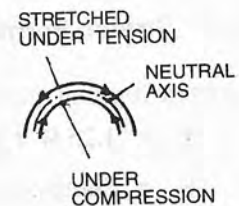


Fig. D20b Bending

As the entire thickness of workpiece is under tension the problem of spring back is eliminated completely. On the other hand stretch forming work hardens the entire cross-section of the workpiece thickness is higher tensile strength, quite unlike to rolling which work hardens only the surfaces. However excessive elongation of work material can tear the worksheet between jaws and die, or at the crown. Good surface finish on workpiece edges reduces tearing.

Stretch forming is used widely for bending long sections bent earlier on press brakes. Stretch forming leaves no residual stress in formed piece.

D3.10 Worksheet Materials Suitable for Stretch Forming

The worksheet material should have an adequate working range between yield strength and the ultimate strength.

D3.11 Steels

Low carbon steels (C10, C20) can be stretch formed without any problem. Stainless steel, can not be stretch formed in 'full hard' state, and needs to be annealed before stretch forming.

D3.12 Aluminium

Alloys of aluminium can be stretch formed even after heat-treatment eliminating the distortion inevitable in heat-treatment. If aluminium is stretch formed before heat-treatment, it is advisable to stretch form it again after heat-treatment to remove the process distortion.

D3.13 Magnesium Alloys

These need to be heated to facilitate stretch forming. Usually punch (or die) is heated from 200°C to 370°C by electrical heaters to impart heat to workpiece at working point. The jaws are not heated.

D3.20 Stretch Forming Force

As stretch forming stretches worksheet thickness beyond yield point,

$$S = 1.25 W T f_y \quad [\text{Eqn D6}]$$

S = Stretch forming force = [N]

W = Width (Transverse) of the blank (mm)

T = Thickness of blank (mm)

f_y = Yield strength of blank (N/mm²)

Example D5 Find stretch forming force for workpiece shown in Fig. D21 if the yield strength of the blank is 220 N/mm².



Fig. D21 Workpiece for Example D5

Solution Referring Fig. D21.

$$W = 700$$

$$T = 1.6$$

$$S = 1.25 \times 700 \times 1.6 \times 200 \\ = 30,8000 \text{ N} \approx 31 \text{ tonnes}$$

D3.30 Process and Equipment

The blank is held rigidly at two ends by jaws provided in the machine. It is then wrapped around the punch/die which stretches the blank material, reducing its thickness marginally. Holes in workpiece should be made after stretch forming to avoid distortion in stretching. The stretching can be effected by moving punch/die, or jaws.

D3.31 Moving Ram Stretch Forming Machine (Fig. D22)

The punch/die is attached to ram of a hydraulic cylinder. The stationary jaws hold blank firmly at the two ends while the ram presses into the blank and stretch forms it.

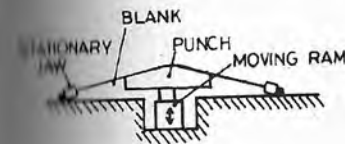


Fig. D22 Moving ram stretch forming machine

D3.32 Swivelling Jaws Stretch Forming Machine

The jaws are attached to the rams of two trunnion mounted hydraulic cylinders, while the punch/die is mounted on the machine table and remains stationary (Fig. D23). The rams are in outstroke position of hydraulic cylinders when the blank is loaded and clamped in the jaws at both ends.

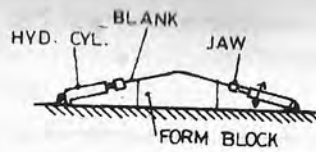


Fig. D23 Swivelling jaws stretch forming machine

During stretching, the rams withdraw into the cylinders in instroke. This also swivels the trunnion mounted cylinders downwards; stretching the blank over the punch/die.

In rotary arms machine (Fig. D24) the jaws are attached to the ram



Fig. D24 Rotary arms (jaws) stretch forming machines

of two rotary arms which move the cylinders around the die to wrap it around before stretching it by instroke of the cylinders.

D3.33 Rotary Table Stretch Forming Machine (Fig. D25)

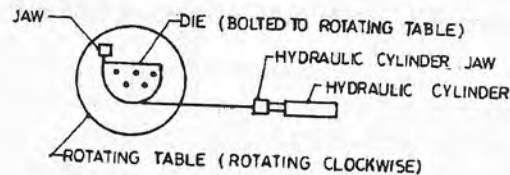


Fig. D25 Rotary table stretch forming machine

One of the blank holding jaws is mounted on a rotary table carrying the die. Rotation of the table wraps, and stretches the blank around the die. The fixed jaw is attached to ram of a hydraulic cylinder to facilitate stretching the blank.

D3.40 Tooling

Only the punch around which the blank is stretched needs to be manufactured. The punch (also called die) can be made of seasoned wood,

monite, plastic or even concrete. This reduces the material as well as manufacturing cost. A wooden die should be at least 100 mm thick and should have cast iron, or plastic, or zinc alloy inserts at wear points such as sharp shapes. Grey cast iron die, although costly to the machine, has a very long life. Plastic punches have high wear resistance and provide a smooth surface free from galling or other marks. Plastic punches should have solid phenolic work surface although the core can be of phenolic foam (Fig. D26). Plastic punches should be supported by a steel base with I beams. Otherwise the lower edges of punch are likely to chip off.

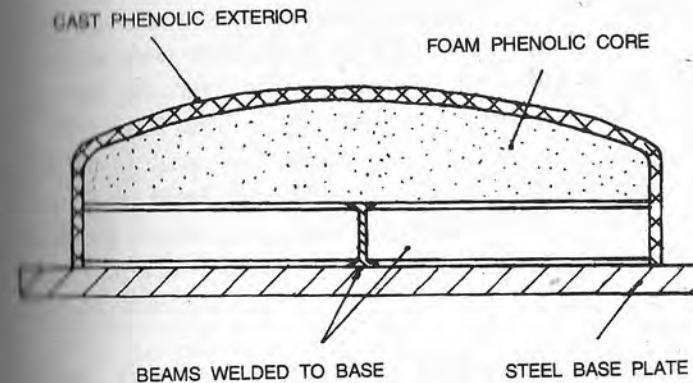


Fig. D26 Plastic punch for stretch forming tool

interstage annealing
minimises form defects - (8)

E

Effects of punch & die radii
Hydra. press preferred for deep draws.

Drawing Tools

Blank holder

air vent

Factors - Donaldson

(16M)
lubricants
die rad.
punch -
redn.
blank hold force

Drawing is a process of axial elongation through application of axial force. In sheet metal drawing a flat sheet is deformed into a deep cup. Drawing generates much more stress and material flow than forming.

The finish depth of the workpiece is sometimes so much that it is not possible to draw the component to the final shape in a single operation because the blank material will be stressed beyond its endurance and will crack up before the desired depth is attained. Drawing stresses the blank material a little more than the yield stress but much less than the ultimate strength.

E1.00 DRAWING FORCE FOR CIRCULAR CUP

The force required for drawing depends upon the yield strength of the material f_y , and the diameter and thickness of the cup.

$$\text{Drawing Force} = V_d = \pi d T \left[\frac{D}{d} - 0.6 \right] f_y \quad [\text{Eqn E1}]$$

D = Diameter of blank/cup before operation (mm)

d = Diameter of cup after drawing (mm)

T = Thickness of cup (mm)

f_y = Yield strength of cup/blank material [N/mm^2]

Example E1 Find the force required for drawing a 50 dia cup from a 70 dia 2 mm thick M.S. blank if yield strength of the material is 300 N/mm^2 .

$$\begin{aligned} \text{Solution } V_d &= \pi d T \left(\frac{D}{d} - 0.6 \right) f_y \\ &= \pi \times 50 \times 2 \left(\frac{70}{50} - 0.6 \right) \times 300 \\ &= 75400 \text{ N} = 7.54 \text{ tonnes} \end{aligned}$$

Example E2 Find force required for redrawing a 60 dia, 1.2 mm thick cup to 53 dia if $f_y = 260 \text{ N/mm}^2$

$$\begin{aligned}
 \text{Solution } V_d &= \pi d T \left(\frac{D}{d} - 0.6 \right) f_y \\
 &= \pi \times 53 \times 1.2 \left(\frac{60}{53} - 0.6 \right) 260 \\
 &= 27640 \text{ N} = 2.76 \text{ tonnes}
 \end{aligned}$$

E2.00 PRESS CAPACITY

The above force is spent in deforming the workpiece alone. Draw change in the shape of blank in drawing however necessitates additional force ranging from 20% to 40% of the drawing force for keeping the blank under blank-holder pressure to prevent the wrinkles in the drawn cup. So the press capacity should be about 40% more than the drawing force.

E3.00 MAXIMUM REDUCTION

When a flat blank of D dia is drawn to smaller dia d , the original periphery πD is reduced to a much smaller length πd . Consider a small sector of a cup (Fig. E1). The length L is reduced to length l . The material shown in the shaded portion of the sector is completely displaced with a maximum

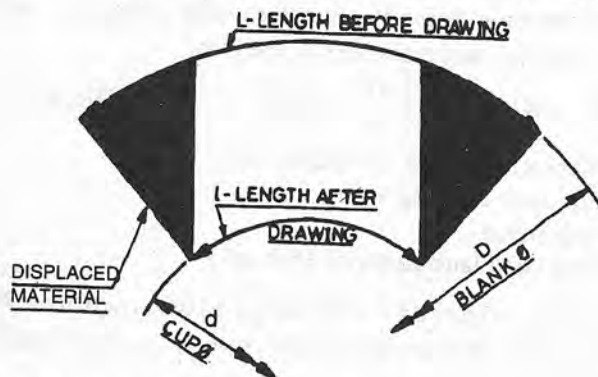


Fig. E1 Material flow in drawing

material flow at the external diameter. The reduction (deformation) effected in drawing can be computed from the following equation

$$\text{Reduction} = \frac{D - d}{D} \times 100 \quad [\text{Eqn 1}]$$

The maximum reduction which is possible without cracking depends upon the physical properties of the component material. The reduction

in the first draw is generally limited to approximately 45% for M.S. and aluminium whereas brass and bronze can be reduced by 50%. In other words a M.S. or aluminium blank can be drawn to a cup having 55% of the blank diameter in the first draw. Brass and Bronze blanks can be drawn to cups having half the diameter of the blank in the first draw. It should be remembered that the diameter d of the cup is measured at the centre of the thickness of the cup (Fig. E2).

E4.00 DIE CLEARANCE

The material flow in drawing renders some thickening of flange and thinning of walls of the cup inevitable. The thickening is highest (upto 20%) at the top edge and flange. The wall thickness decreases gradually to minimum at the bottom of the cup. The bottom of the cup thins down upto 15% of thickness if no cushion is used to hold the blank firmly during the operation.

The space for drawing is kept intentionally bigger by 7 to 15% the worksheet thickness. This additional gap over and above sheet thickness is called 'Die Clearance'. In addition to providing space for wall thickening, the clearance reduces friction between die sides and the workpiece. Table E1 below states die clearances for drawing mild steel cups.

Note that die clearance increases as thickness of worksheet increases. The redrawing dies have about 12% more die clearance than first draw dies. On the other hand, finishing (sizing) dies have about 60% less die clearance than first draw dies.

Table E1 Clearances for Drawing Dies

Sr. No.	Blank Thickness	First Draw	Redraws	Sizing Draw
1	up to 0.4	0.07 T 0.09 T	0.08 T 0.11 T	0.04 T 0.05 T
2	0.45 1.25	0.08 T 0.10 T	0.09 T 0.12 T	0.05 T 0.06 T
3	1.30 3.15	0.1 T 0.12 T	0.12 T 0.14 T	0.07 T 0.09 T
4	above 3.20	0.12 T 0.14 T	0.15 T 0.20 T	0.08 T 0.11 T

Notes: The above clearances are applicable for drawing mild steel workpieces having shear strength of 40 kgf/mm².

For materials having different shear strength.

$$\text{Clearance} = \frac{40 \times \text{clearance for M.S.}}{\text{workpiece shear strength}}$$

Example E3 Find die size for a cup with 80 mm inside diameter and from 0.71 mm thick (22 G) sheet if the cup is made of (a) mild steel having shear strength 400 N/mm²; (b) Aluminium having shear strength 280 N/mm².

Solution (a) From Table E1,

$$\begin{aligned}\text{Clearance for 1st draw} &= 0.08T - 0.1T \\ &= 0.08 \times 0.71 - 0.10 \times 0.71 \\ &= 0.0568 - 0.071\end{aligned}$$

$$\begin{aligned}\text{Clearance for redraws} &= 0.09 \times 0.71 - 0.12 \times 0.71 \\ &= 0.0639 - 0.0852\end{aligned}$$

$$\begin{aligned}\text{Clearance for sizing} &= 0.05 \times 0.071 - 0.06 \times 0.071 \\ &= 0.0355 - 0.0426\end{aligned}$$

$$(b) \text{ Shear strength ratio} = \frac{400}{280} = 1.43$$

$$\therefore \text{Clearance (1st draw)} = 1.43 \times 0.0568 - 1.43 \times 0.071$$

$$= 0.081 - 0.101$$

$$\begin{aligned}\text{Clearance (redraws)} &= 1.43 \times 0.0639 - 1.43 \times 0.0852 \\ &= 0.091 - 0.122\end{aligned}$$

$$\begin{aligned}\text{Clearance (sizing)} &= 1.43 \times 0.0355 - 1.43 \times 0.0426 \\ &= 0.0516 - 0.061\end{aligned}$$

E5.00 BLANK SIZE CALCULATIONS

The thickening of the cup is neglected in blank size computations. Most of the formulae for blank size calculations assume that the thickness of

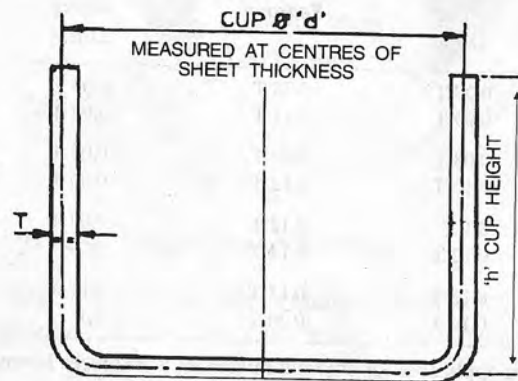


Fig. E2 Specifying dimensions for drawing computation

blank does not change in drawing. The blank size is calculated by equating the surface areas of the finished drawn cup with the area of the blank. For a cylindrical cup (Fig. E2) the surface area can be divided into two constituents: the cylinder and the bottom.

$$\begin{aligned}\text{Area of cup} &= \text{Bottom area} + \text{Cylinder area} \\ &= \frac{\pi}{4} d^2 + \pi dh \\ &= \frac{\pi}{4} (d^2 + 4dh)\end{aligned}$$

D is diameter of the blank

$$\text{Blank Area} = \frac{\pi}{4} D^2$$

Equating cup area with the blank area

$$\begin{aligned}\frac{\pi}{4} D^2 &= \frac{\pi}{4} (d^2 + 4dh) \\ D &= \sqrt{d^2 + 4dh}\end{aligned} \quad \text{[Eqn E3]}$$

Blank dia (mm)
Cup mean dia (mm)
Cup height (mm)

For quick oral calculations of approximate blank diameter the following formula can be used

$$D = d + h + \frac{d}{4} \quad \text{[Eqn E4]}$$

Example E4 Calculate the blank diameter for 80 mm inside dia, 2 mm thick and 60 mm high cup.

Solution d = mean (mid-thickness) dia of cup

$$= 80 + 2 = 82 \text{ mm}$$

$$\begin{aligned}D &= \sqrt{d^2 + 4dh} \\ &= \sqrt{82^2 + 4 \times 82 \times 60} \\ &= 162.49 \text{ mm}\end{aligned}$$

Oral calculation formula

$$\begin{aligned}D &= d + h + \frac{d}{4} \\ &= 82 + 60 + \frac{82}{4} \\ &= 162.50 \text{ mm which is only 0.01 mm more than the precise formula}\end{aligned}$$

Example E5 Find blank diameter for the cup shown in Fig. E3.

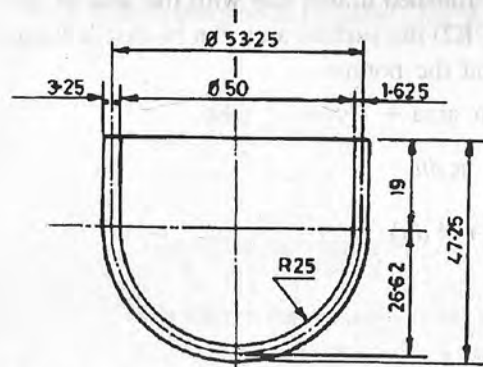


Fig. E3 Computation of blank ϕ

Solution The component area can be divided in two parts, the hemispherical bottom with 25 mm inside radius, and cylinder with 50 mm inside dia and 19 mm height.

$$\begin{aligned}\text{Mean diameter} = d &= 50 + 1.625 \times 2 \\ &= 53.25 \text{ mm}\end{aligned}$$

$$\begin{aligned}\text{Component area} &= \pi \times 53.25 \times 19 + \frac{\pi}{2} \times 53.25^2 \\ A &= 7632.60 \text{ mm}^2\end{aligned}$$

This should be equated with blank area

$$0.7854 D^2 = \text{Component area} = A$$

This can also be written as

$$\begin{aligned}D &= \sqrt{1.273 A} \\ &= \sqrt{1.273 \times 7632.60} \\ &= 98.57 \text{ mm}\end{aligned}$$

[Eqn E3]

For more accurate estimation of blank size the radius r joining the vertical cylinder to bottom of cup must be taken into account. It is enough to consider the ratio $d : r$ of the cup mean diameter d and corner radius r . If the ratio d/r is above 20, the corner radius can be neglected and [Eqn E3] can be used to calculate the blank size.

$$(i) \text{ When } 20 > \frac{d}{r} > 15$$

$$D = \sqrt{d^2 + 4dh - 0.5r}$$

[Eqn E4]

$$(ii) \text{ When } 15 > \frac{d}{r} > 10$$

$$D = \sqrt{d^2 + 4dh - r}$$

[Eqn E7]

$$(iii) \text{ When } \frac{d}{r} < 10$$

$$D = \sqrt{(d - 2r)^2 + 4d(h - r) + 2\pi r(d - 0.7r)}$$

[Eqn E8]

Example E6 Find blank diameter of a 80 mm outside diameter $\times$ 110 mm high $\times$ 1 mm thick cup with following corner radii (a) 10, (b) 7, (c) 5.

Solution (a) $d = 80 - 1 = 79$ mm

$$\frac{d}{r} = \frac{79}{10} = 7.9 < 10$$

$$\begin{aligned}D &= \sqrt{(d - 2r)^2 + 4d(h - r) + 2\pi r(d - 0.7r)} \\ &= \sqrt{(79 - 2 \times 10)^2 + 4 \times 79(110 - 10) + 2\pi \times 10(79 - 0.7 \times 10)} \\ &= \sqrt{3481 + 31600 + 4523.89} \\ &= 199.01 \text{ mm}\end{aligned}$$

$$(b) \frac{d}{r} = \frac{79}{7} = 11.28 < 15 \text{ but more than } 10$$

$$\begin{aligned}D &= \sqrt{d^2 + 4dh - r} \\ &= \sqrt{79^2 + 4 \times 79 \times 110 - 7} \\ &= 202.49 - 7 = 195.49 \text{ mm}\end{aligned}$$

$$(c) \frac{d}{r} = \frac{79}{5} = 15.8 \text{ which is more than } 15 \text{ and less than } 20$$

$$\begin{aligned}D &= \sqrt{79^2 + 4 \times 79 \times 110 - 0.5 \times 5} \\ &= 199.99 \text{ mm}\end{aligned}$$

Any cylindrical cup can be divided into suitable constituents for computation of surface areas at mid-thickness. Fig. E4 covers the various shapes encountered in drawing cylindrical cups.

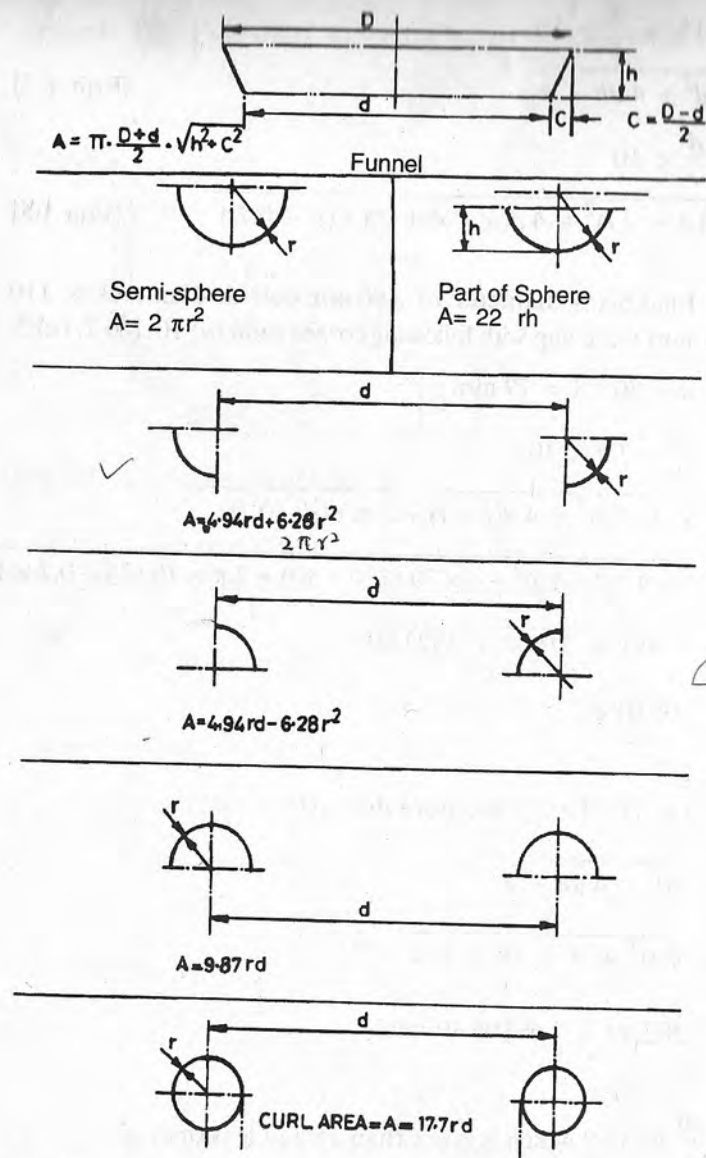


Fig. E4a Circular cups surface areas

Example E7 Calculate the blank size for the component shown in Fig. E5.

Solution The component areas can be divided as marked A1, A2, A3, and A4 in Fig. E5.



Fig. E4b Circular cups surface areas

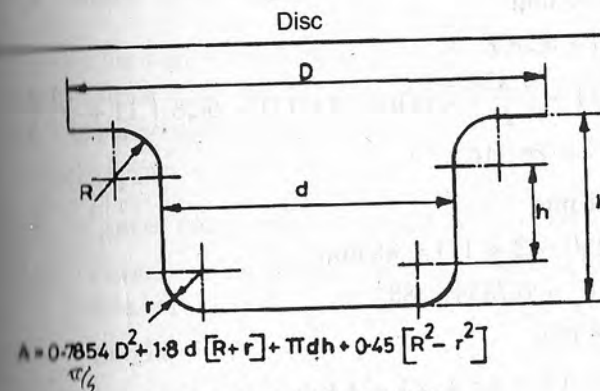
For A1, rim width = $\frac{140 - 110}{2} = 15$ mm

Referring to Fig. E4a

Mean dia = $2r = 15 - 1.42 = 13.58$ mm

$d = 140 - 15 = 125$ mm

A1 = $9.87rd$ (From Fig. E4a)



$$= \frac{9.87 \times 125 \times 13.58}{2} \text{ mm}$$

$$A1 = 8377.16 \text{ mm}^2$$

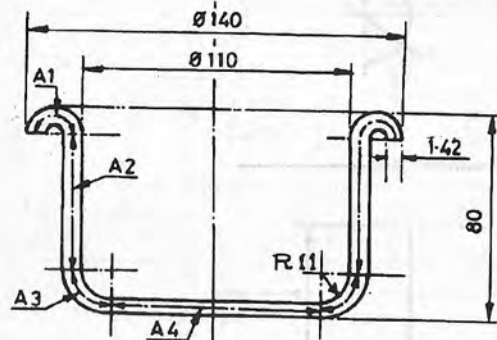


Fig. E5 Computation of blank ϕ for a composite cup

For A2

$$\text{Mean dia } d = 110 + 1.42 = 111.42 \text{ mm}$$

$$\begin{aligned} \text{Height } h &= 80 - 15 - (11 + 1.42) \\ &= 52.58 \text{ mm} \end{aligned}$$

$$A2 = \pi dh$$

$$= \pi \times 111.42 \times 52.58 \text{ mm}$$

$$A2 = 18404.91 \text{ mm}^2$$

$$A3 = 4.94 rd + 6.28 r^2$$

$$\begin{aligned} &= 4.94 \left(11 + \frac{1.42}{2} \right) \times (110 - 2 \times 11) + 6.28 \left(11 + \frac{1.42}{2} \right)^2 \\ &= 5090.57 + 861.14 \end{aligned}$$

$$A3 = 5951.71 \text{ mm}$$

$$\text{In A4, } d = (110 - 2 \times 11) = 88 \text{ mm}$$

$$A4 = 0.7854 d^2 = 0.7854 \times 88^2$$

$$A4 = 6082.14 \text{ mm}^2$$

$$\text{Total cup area} = A = A1 + A2 + A3 + A4$$

$$A = 8377.16 + 18404.91 + 5951.71 + 6082.14$$

$$A = 38815.92 \text{ mm}^2$$

$$\text{Blank dia} = D = \sqrt{1.273A}$$

$$= \sqrt{1.273 \times 38815.92} = 222.29 \text{ mm}$$

In precision work it is convenient to take a blank bigger than the calculated size, and trim the cup to precise size.

8.90 DRAWING RECTANGULAR BOXES

Drawing is also used for making rectangular boxes. Fig. E6 shows the method for finding the blank size and shape for rectangular boxes.

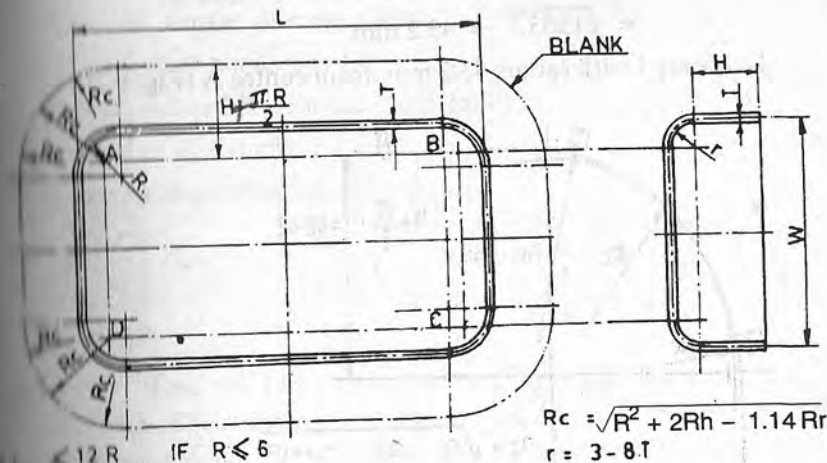


Fig. E6 Limitations in drawing rectangular cups

8.10 Blank Development

Centres of the corner radii R_c of blank lie on intersections of the centre lines of radius 'r' on the bottom of the box. Corner radius R_c can be found from the following equation

$$R_c = \sqrt{R^2 + 2Rh} - 1.141Rr \quad [\text{Eqn E9}]$$

Corner radius joining vertical sides of the box

Corner radius joining horizontal bottom to vertical sides of the box

Height of the box

For finding the shape of the corners, draw an arc with radius R_c from centres A, B, C, D, (Fig. E6). Then draw lines representing top edges of the box at distance $(h + \frac{\pi r}{2})$ from the lines passing through A, B, C, D. Draw blending radius in such a way that it is tangential to the lines representing the top edges and the corner radius as drawn earlier. The corner radius and the blending radius together constitute the corner profile of the blank.

Example E8 Draw corner profile of a box having corner radii between sides R , and side and bottom r equal to 20 mm and 6 mm respectively and height h equal to 40 mm.

Solution $R_c = \sqrt{R^2 + 2Rh - 1.141 Rr}$
 $= \sqrt{20^2 + 2 \times 20 \times 40 - 1.141 \times 20 \times 6}$
 $= \sqrt{1863.1} = 43.2 \text{ mm}$

Draw arc I with radius 43.2 mm from centre A (Fig. E7)

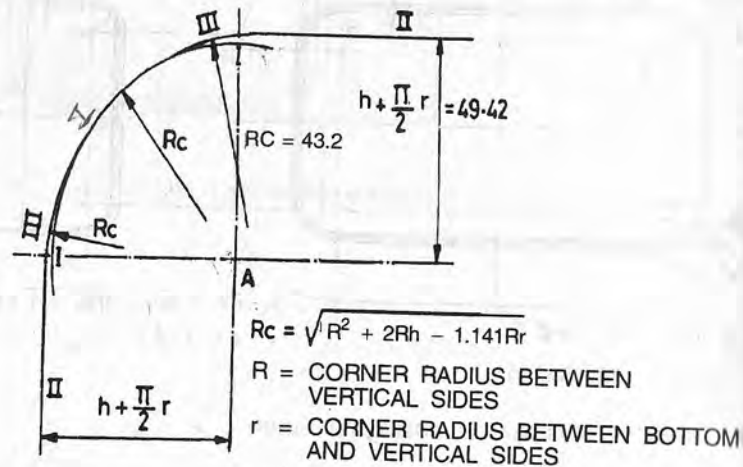


Fig. E7 Corner of blank for rectangular box

$$h + \frac{\pi r}{2} = 40 + \frac{\pi \times 6}{2} = 49.42 \text{ mm}$$

Draw line II at 49.42 mm from base ABCD. Draw blending radii III tangential to lines I and II. Fig. E7 shows the corner profile of the blank

E6.20 Corner Radius and Box Height

Fig. E6 also shows the recommended radii between the sides, and bottom and sides. Corner radius R between sides should preferably be more than one-tenth the length L of the box. The radius joining the bottom to the sides r generally ranges from three to eight times the blank thickness T . The height of the box h depends upon the corner radius R between the sides.

$$\begin{aligned} h &\leq 12 R & \text{if } R &\leq 6 \\ h &\leq 6 R & \text{if } R &= 12 - 25 \end{aligned}$$

E6.30 Drawing Force

The force required for rectangular drawing can be found from the following equation

$$V_{dr} = f_t T (2 \pi R C_1 + 0.25 L) \quad [\text{Eqn E10}]$$

- f_t = Ultimate tensile strength (N/mm^2) (Fig. B4)
- T = Thickness of blank (mm)
- R = Corner radius between the sides (mm)
- L = Length of box (mm)
- C_1 = Constant depending on ratio $\frac{h}{R}$

$\frac{h}{R}$	C_1
2	0.5
6	2.0

Example E9 Find the force required for drawing a box made from 2 mm thick M.S. Sheet having 250 mm length and 150 mm width. The radius between the sides R is 25 mm whereas the radius joining sides to bottom r is 8 mm. The box is 50 mm deep. The tensile strength of blank, $f_t = 420 \text{ N/mm}^2$.

Solution $\frac{h}{R} = \frac{50}{25} = 2 \quad C_1 = 0.5$

$$\begin{aligned} V_{dr} &= f_t T (2 \pi R C_1 + 0.25 L) \\ &= 420 \times 2 (2 \pi \times 25 \times 0.5 + 0.25 \times 250) \\ &= 118473.4 \text{ N} \approx 12 \text{ tonnes} \end{aligned}$$

E6.40 Stages in Drawing

Elongation constraints of worksheet material limit the maximum reduction possible in a single draw. (As each draw workhardens the worksheet material to some extent, the resultant loss of ductility reduces reduction in subsequent draws.) Table M12 in the Appendix states the reduction possible in the first and the following draws. It can be noted that there is a substantial decrease in reduction possible in each following draw. Thus 45% reduction is possible in mild steel in the first draw, whereas the reduction possible in the fourth draw is only 12%. Furthermore 25–50% higher reduction can be accomplished if a double action press is used.

When number of draws are used the final shape is formed gradually. The corner radii and bottom radii of earlier stages are much more liberal

than the final sizes. The blank is first drawn to a circular cup with a chamfered corner. In the second stage, the cup has got sides with large radii. The third and final draw finishes workpiece to required size. Now the big chamfer at corner joining vertical side with base in the first stage. Even in the prefinishing draw vertical sides are connected with a large radius.

Number of draws necessary for producing a rectangular box depends upon ratio h/R between the box height (h) and the finish radius (R) joining the vertical walls of the cup. The following table E2 states the number of draws for various ratios.

Table E2 Number of Draws Required for Rectangular Cups

Sr. No.	h/R	No. of Draws
1	Upto 6	1
2	7-12	2
3	13-18	3
4	19-24	4

E7.00 DRAW EDGE DESIGN

The edge of the die effects gradual change in size and shape of the blank. The edge is usually made circular to facilitate easy manufacture. However, sometimes it is necessary to make the die edge elliptical or conical to increase blank holder contact area and to enhance reduction in drawing.

E7.10 Circular Die Radius (Fig. E8)

For smooth material flow the die edge should have generous radius preferably four to six times the blank thickness but never less than three times the sheet thickness because lesser radius hinders material flow while an excessive radius reduces the pressure area between the blank

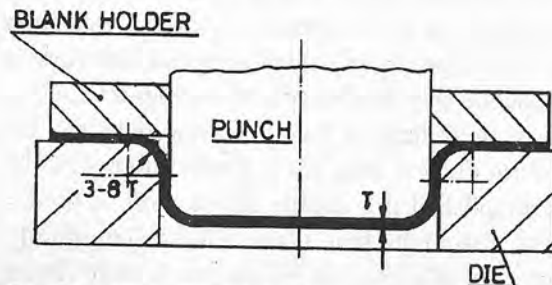


Fig. E8 Draw radius on die

and the blank holder (Fig. E9). During drawing, the material near the blank holder periphery gradually moves towards the die bore. As soon as it

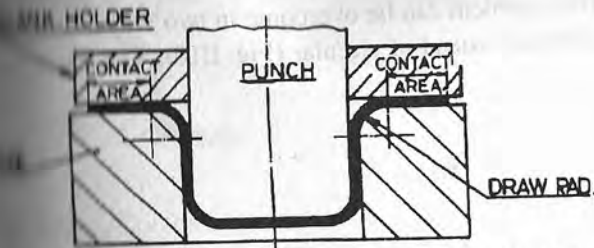


Fig. E9a Reduction in contact area due to draw radius on die

reaches the draw radius the material loses contact with the blank holder, and ceases to be under blank holder pressure. Larger the draw radius, larger the top part of the cup drawn without blank holder pressure. Thus excessive draw radius wrinkles the top part of the drawn cup. Die edge

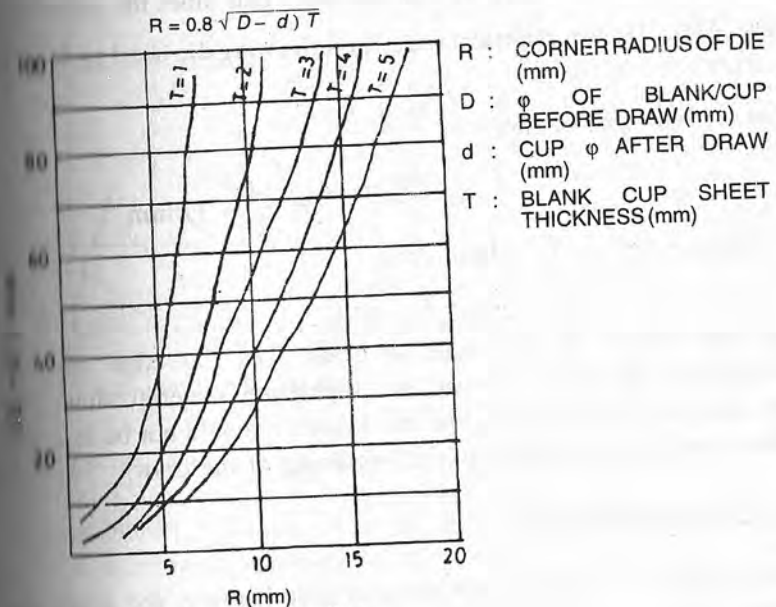


Fig. E9b Graph for die radius

radius should be less than twenty times the sheet thickness T . The graph in Fig. E9b can be used to find the circular die edge radius from difference in blank D and cup d diameters ($D - d$) and sheet thickness T . The radius can also be found from the following equation

$$R = 0.8 \sqrt{(D - d) T} \quad \text{[Eqn E11]}$$

E7.20 Elliptical Die Edge

Bigger die edge radius promotes material flow but causes wrinkles in the portion of the cup. This problem can be overcome in two ways. The die edge can be made elliptical instead of circular (Fig. E10). The minor axis

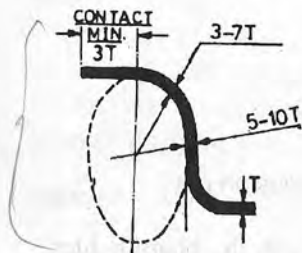


Fig. E10 Elliptical die edge

of the ellipse is usually kept half of the difference between the blank and cup diameters. The major axis is kept one and a half times the minor axis.

Example E10 Design elliptical edge for a drawing die used to draw a ϕ cup from a 100 ϕ blank.

$$\begin{aligned} \text{Solution Minor axis of ellipse} &= \frac{D - d}{2} \\ &= \frac{100 - 66}{2} = \frac{34}{2} = 17 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Major Axis} &= 1.5 \times \text{Minor Axis} \\ &= 1.5 \times 17 = 25.5 \text{ mm} \end{aligned}$$

Fig. E10 shows the die edge to scale. The die edge must be polished/ground to smooth finish for troublefree material flow. The pressure area between the blank and blank holder should not be less than three times the blank thickness at the beginning of the draw.

E7.30 Conical Die Edge

Another method of increasing the pressure area between the blank and the blank holder is to use a conical draw edge (Fig. E11a). The blank holder, too, must be made conical; and have the same angle as the draw edge. The conical part is blended with the die top and sides with $3T$ radius. The conical draw edge facilitates gradual material flow and permits more reduction than the circular edge. The cone angle ranges from 90° to 120° . Thicker blanks require lesser cone angle than thinner blanks.



Fig. E11a Conical draw edge

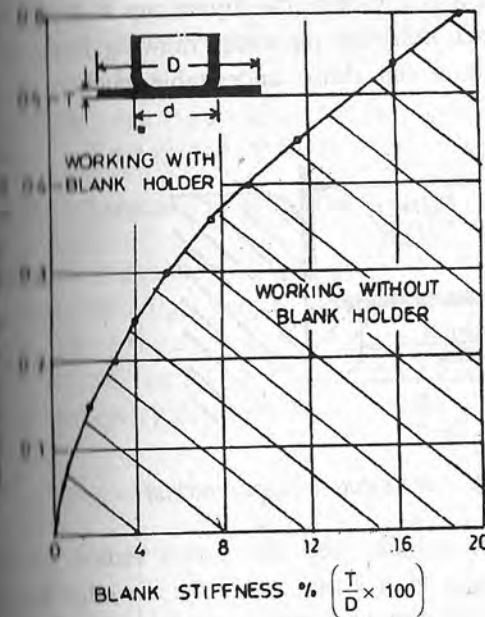


Fig. E11b Working without blank holder

Thick blanks require lesser blank holder pressure because this extra thickness increases the strength of the blank and makes it less vulnerable to buckling which causes wrinkles. No blank holder is necessary if blank thickness to diameter ratio $\left[\frac{T}{D} \times 100\right]$ is high or reduction required $\left[\frac{D - d}{D}\right]$ is low [Fig. E11b]. Shallow cups in which the width of annular blank holder contact is less than three times blank thickness can be drawn wrinklefree without any blank holder.

✓ E8.00 PUNCH EDGE DESIGN

E8.10 Circular Punch Edge

Drawing punches, too, must have corner radius exceeding three times the blank thickness T . However, the punch radius should not exceed one-fourth the cup diameter d .

$$3T < \text{Punch Rad} < \frac{d}{4}$$

Excessive punch radius too, reduces the contact area between the blank, cushion, and punch (Fig. E12a). Large corner radius reduces the flat portion of the punch. This can fracture the drawn cup at the bottom. For the flat face of the punch transmits the entire drawing force to the blank. Excessive punch radius can cause undesirable puckers in the drawn workpiece.

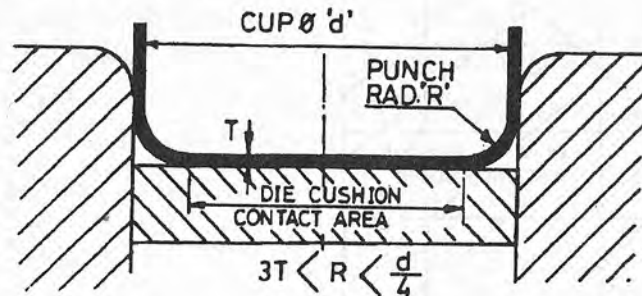


Fig. E12a Reduction in contact area due to punch radius

When more than one draws are used the punch radius for the preceding draw should extend at least 3 mm inside the die edge for the following operation. Thus we have to work backwards from finish radius of the cup to preceding draw to keep the centre line of the radius about 3 mm inside the following draw.

Example E11 Design punch radius for drawing 104 ϕ outside and 2 mm thick cup if it is to be redrawn to a 66 ϕ outside and 8 mm inside corner radius (Fig. E12b).

Solution Inside ϕ of following die = 66

$$\text{Pitch circle } \phi \text{ of punch radius} = 66 - 2 \times 3 = 60 \phi$$

$$\text{Outside } \phi \text{ of punch for first draw} = 104 - 2 \times 2 = 100$$

$$\text{Radius of 100 } \phi \text{ punch} = \frac{100 - 60}{2} = 20$$

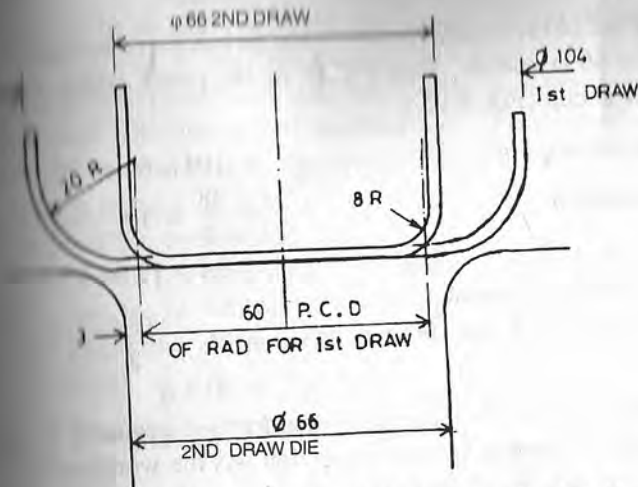


Fig. E12b Finding punch radius for cups subjected to redrawing workpiece for Example E11

E8.20 Conical Punch Edge Angle

The cone angles for following draws are lesser and lesser. The final draw converts the corner cone to the finish radius. The corner radius r for the entry side of the conical punch is usually kept 60% of the radial reduction (Fig. E12c). The P.C.D. of centre of radius is kept $r/2$ less than inside ϕ of the following die. >

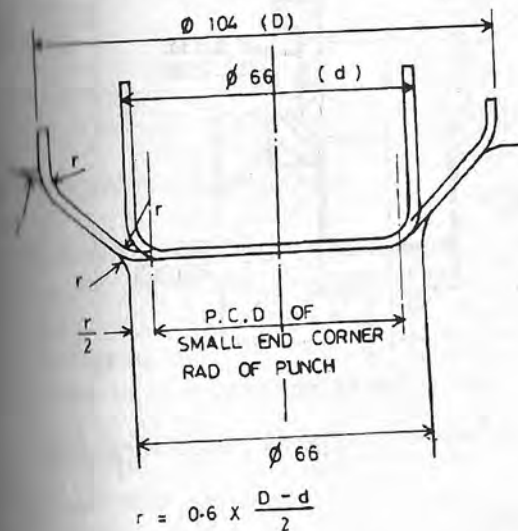


Fig. E12c Finding corner radius p.c.d. for cups with conical bottoms

✓ **Example E12** Find corner radius for a conical punch for reducing a 104 ϕ outside dia cup to 66 ϕ outside. Find P.C.D. of the punch corner radius for punch for 104 ϕ cup (Fig. E12c).

Solution Reduction on dia $= 104 - 66 = 38$

Radial reduction $= \frac{38}{2} = 19$

$\therefore$ Punch corner radius $= 0.6 \times 19 = 11.4$

Inside ϕ of die for 66 ϕ cup $= 66$

Corner radius P.C.D. for 100 ϕ punch $= 66 - \frac{11.4}{2}$

$= 60.3 \phi$

(When a component calls for more than one draws it is advisable to use a conical draw edge. This permits more reduction. As the workpiece gets workhardened in the first draw, the reduction in second draw is generally limited to about 20% if a circular draw edge is used. A conical edge, however, increases possible reduction in the second draw to 30%. This reduces the number of draws necessary for manufacture of a deep drawn component.) Furthermore, the cup drawn in the first operation can be located more precisely for the second operation if bottom of the cup has got a conical shape. Naturally, the cone angle of the draw edge for the second operation should be equal to the cone angle of the punch edge for the first operation (Fig. E13).

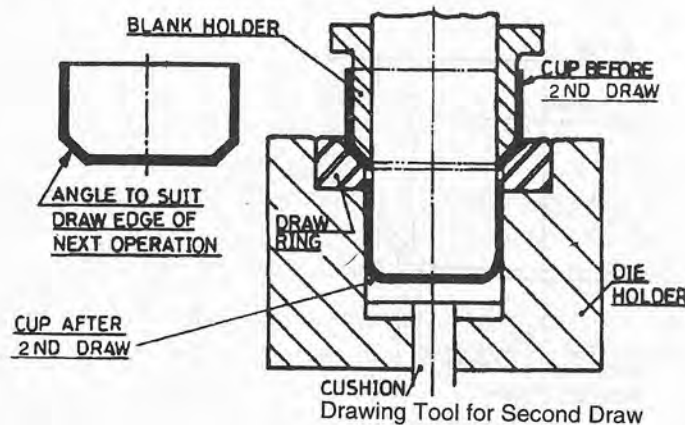


Fig. E13 Matching cup bottom with draw edge for the following draw

✓ E9.00 AIR ESCAPE HOLES

(Both punch as well as ejector should be provided with holes for escape of the air entrapped between the blank, punch, and ejector.) Failure to

provide air holes can lead to damage to the workpiece under pressure of entrapped air. If only the punch is provided with an air hole, the air trapped between the blank and the ejector gets compressed during the downstroke. The pressurised air drives the unsupported part of the cup into the air hole in the punch. This can lead to an upward dimple in the cup bottom. In a severe case, the bottom can get pierced under the force of the compressed air.

An air hole provided in the ejector only, can lead to a hollow in the cup bottom due to suction effect during the upstroke. In a severe case, the cup might turn partly inside out.

E10.00 THROUGH FEED DRAWING

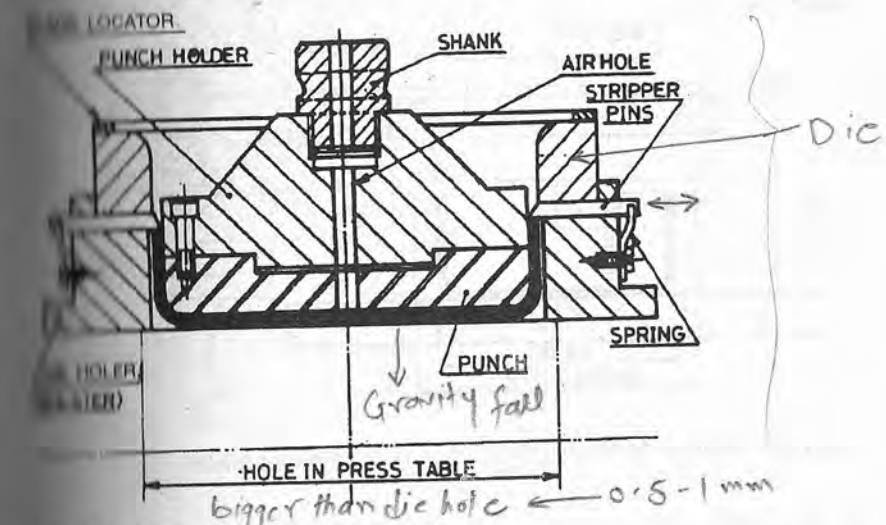


Fig. E14 Through feed drawing tool

Fig. E14 shows a through feed drawing tool. After completion of drawing, the cup is pushed down further till the top edge of the cup is slightly below the stripper pins housed in the bottom bolster. The stripper pins are spring loaded, and have a chamfer at the top. During the downstroke of the press, the stripper pins are pushed outwards against the spring by the cup bearing against the chamfer at the top. This allows the cup to cross-over the stripper pins. As soon as the cup top crosses the stripper pins, the pins are pushed back inwards radially by the light springs backing them. During upstroke of the press the drawn cup is ejected by the straight part underneath of the stripper pins; while the

punch continues the upstroke travel. Thus the stripper pins remove the cup jammed on the punch.

The bottom bolster is provided with a hole 0.5–1 mm higher than the cup outside diameter. This permits free gravity fall of the drawn cup through the bottom bolster and press table, into the receptacle below.

E10.10 Disposal of Cups Bigger than Press Table Hole

Through feed drawing tools are particularly convenient for drawing cups smaller than the hole in the press table. If the cup diameter is bigger than the hole in the press table, it is necessary to use a sturdy bridge with a span exceeding the outside diameter of the cup (Fig. E15). The height

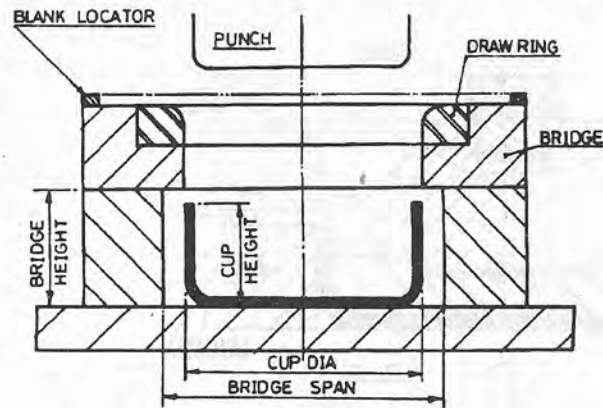


Fig. E15 Bridge for cups bigger than hole in press table

of the bridge, too, must be more than the cup height to permit the cup slide out easily. It is advisable to use an inclinable press so that the fallen cup slides down automatically on the inclined table to the rear of the press.

Through feed is used widely in industry as the automatic disposal of the drawn cup saves the time required for manual unloading of cup ejected upwards above die level by an ejector [Fig. B5b]. This increases the rate of production considerably. Cups with high T/D ratio can be drawn without any blank holder. These advantages make through feed drawing convenient and economical for shallow thick cups of smaller sizes on a cranked mechanical presses.

E11.00 DRAWING ON CRANKED MECHANICAL PRESSES

Single action cranked mechanical presses are designed for cutting and forming work. Nonetheless designers have been using these machines for drawing work by adding some ingenious devices.

E11.10 Holding Blank by a Rubber Pad

Equipping a rubber pad can equip the tool/press with blank holding action. Fig. E16 shows an inverted drawing tool fitted with a rubber pad. The bottom bolster is screwed with a stout stud on the lower face. The stud carries two plates in between which a heavy rubber pad is

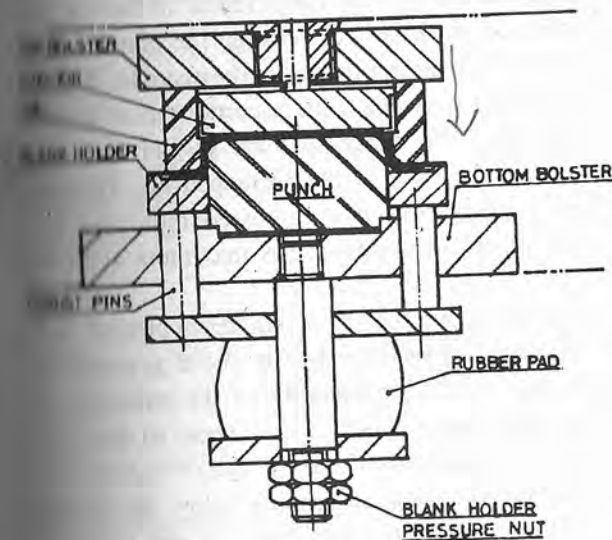


Fig. E16 Inverted drawing tool

sandwiched. (The blank holder pressure can be varied by compressing the pad as required by moving the retainer plate up or down with aid of two hexagonal check nuts below.) The nuts should be locked in position after setting the blank holder pressure.

E11.20 Inverted Drawing (Fig. E16)

The bottom bolster carries an inverted drawing punch on top surface. The punch is located by a spigot and fixed by allen screws. The blank holder has got a counterbore for locating the blank on its outside diameter. The blank holder slides up and down around the punch during

the operation. Four thrust pins transmit the rubber pad force from the pressure plate to the blank holder.

E11.30 Ejection by Press Knockout

The top tool is provided with an ejector operated by the press knockout. A thrust pin passing through the hollow shank transmits the press knockout impact to the ejector.

When the press ram is up, the blank holder should be a few millimeters above the punch top face. This ensures that the blank is sandwiched between the die and the blank holder with a certain pressure before drawing commences. As the top tool descends further, the inverted punch draws the blank up into the die screwed to the top tool. The central undrawn portion of blank is held between the punch and the ejector which moves up in the die during the press downstroke. Both the punch as well as the punch have been provided with a corner radius equal to five times the blank thickness. The punch and the ejector have been provided with suitable holes for escape of the entrapped air. The blank holder pressure increases as the rubber is compressed more and more during the advance of downstroke. The pressure is maximum at the end of the downstroke.

During the upstroke of the press, the blank holder is pushed up by the force provided by the rubber pad. The drawn piece generally gets jammed in the die in the top tool. During upstroke of the press ram, the knockout hits the top thrust pin which transmits the impact to the ejector plate. This pushes down the jammed cup out of the die. When the press ram is up, the ejector should project a few millimeters below the die level. This ensures positive ejection of the drawn cup from the die.

Sometimes, it is convenient to fit the rubber pad permanently to the press table itself (Fig. E17). The same rubber pad can be used for various cups by varying the (Fig. E17) rubber force suitably with aid of the retainer plate and the two check nuts. The arrangement shown in Fig. E17 has got an integral cushion plate. Various drawing tools used with this common arrangement are only provided with suitable thrust pins and a blank holder to suit the workpiece.

E12.00 DRAWING CUSHIONS

The rubber pad arrangement can also be used for ejection and cushioning. Fig. E18 shows rubber pad cushion/ejection arrangement. The rubber pad force transmitted through the pressure plate and thrust pins

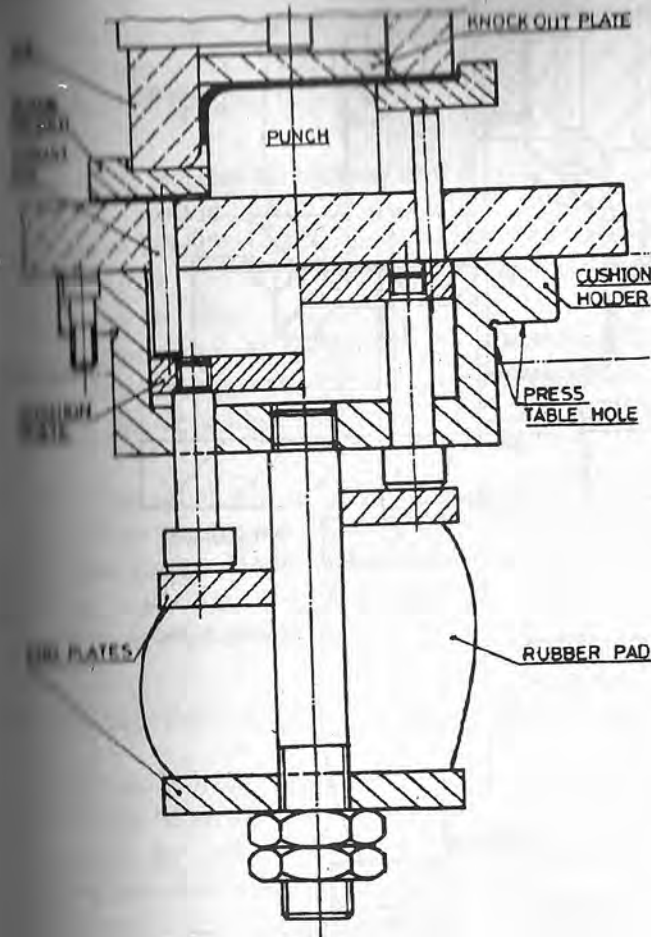


Fig. E17 Permanent cushion for single action press

pushes the ejector up during unloading of the drawn component and loading a new blank. During downstroke, the central part of the blank is held sandwiched between the ejector and the drawing punch under the force of the rubber pad. The press ram pushes the ejector downwards against the rubber force during the downstroke.

E12.10 Using Ejector for Forming Cup Bottom

The ejector can also be used as a die for forming the bottom of the cup. Generally, the ejector profile at top should conform with the finished profile of the cup bottom. Reaching the end of the downstroke the ejector rests on the bottom bolster to act as a die. The drawing punch profile conforms to the required inside profile of the cup bottom.

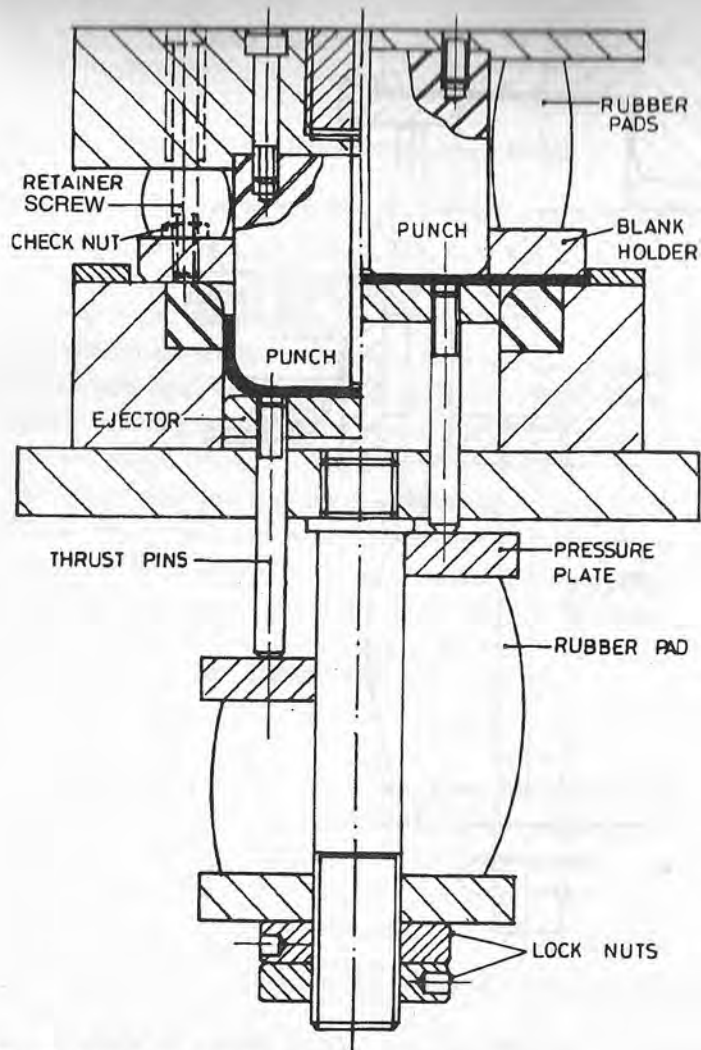


Fig. E18 Use of rubber pad for ejection

During the last part of the downstroke the drawing punch pushes the cup bottom into the ejector top to form the bottom of the cup.

E12.20 Blank Holder in Top Tool *h lubricant* (2)

The top tool is provided with a blank holder [Fig. E18]. The blank holding force can be obtained from compression springs or rubber pads. Rubber can develop 70 kilogram force per square centimeter of the cross sectional area of the rubber pad, and is more suitable for high blank holding pressures. Springs can be used for lighter pressures suitable for

drawing thicker cups. The blank holder force can be adjusted with the set of retaining screws, which can be locked in the set position by tightening the check nuts.

E12.30 Top Bolster Thickness and Cup Height

The thickness of the top bolster must exceed the height of the drawn cup by 10 mm in the least to provide room for the upward movement of the retaining screws during downstroke.)

During upstroke of the press, the ejector moves up under the force of the rubber pad to eject the cup from the die. Simultaneously, the blank holder slides down around the punch to strip off the drawn cup.

This triple action tool provides all the three motions of blank holder, punch, and ejector necessary for drawing a deep cup. However the blank holder pressure varies during the downstroke, and is maximum at the end of the stroke. Similarly, the ejection force, too, varies with maximum value at the end of the downstroke.

E12.40 Ejection by Hydraulic and Pneumatic Cushions

Pneumatic or hydraulic cushions provide uniform force throughout the stroke length. Moreover, the force can be varied suitably by adjusting the pressure of the air/oil. Fig. E19 shows an arrangement for fitting hydraulic/pneumatic cushions to press table.

The press table underneath is screwed with two studs which holds the cylinder mounting plate at the other end. The air/oil pressure acting underneath the cylinder piston provides the upward cushioning force. The pressure plate screwed to the piston rod transmits the force to the ejector plate through the thrust pins. The ejection/cushioning force can be varied by changing the pressure of the air/oil through a pressure regulator/pressure relief valve. The upward force of the cylinder holds the ejector 0.5 mm below the die top when the press ram is in up position. During downstroke, the press ram pushes the ejector and the cylinder piston down against the air/oil pressure. It is necessary to provide a pressure relief valve for passage of the oil coming out of the hydraulic cylinder during the downstroke (Fig. E20). Similarly, an air cylinder needs a check valve for discharging the air coming out of the air cylinder to the atmosphere. The check valve can be set for the opening pressure. On reaching this pressure the valve discharges the compressed air to the

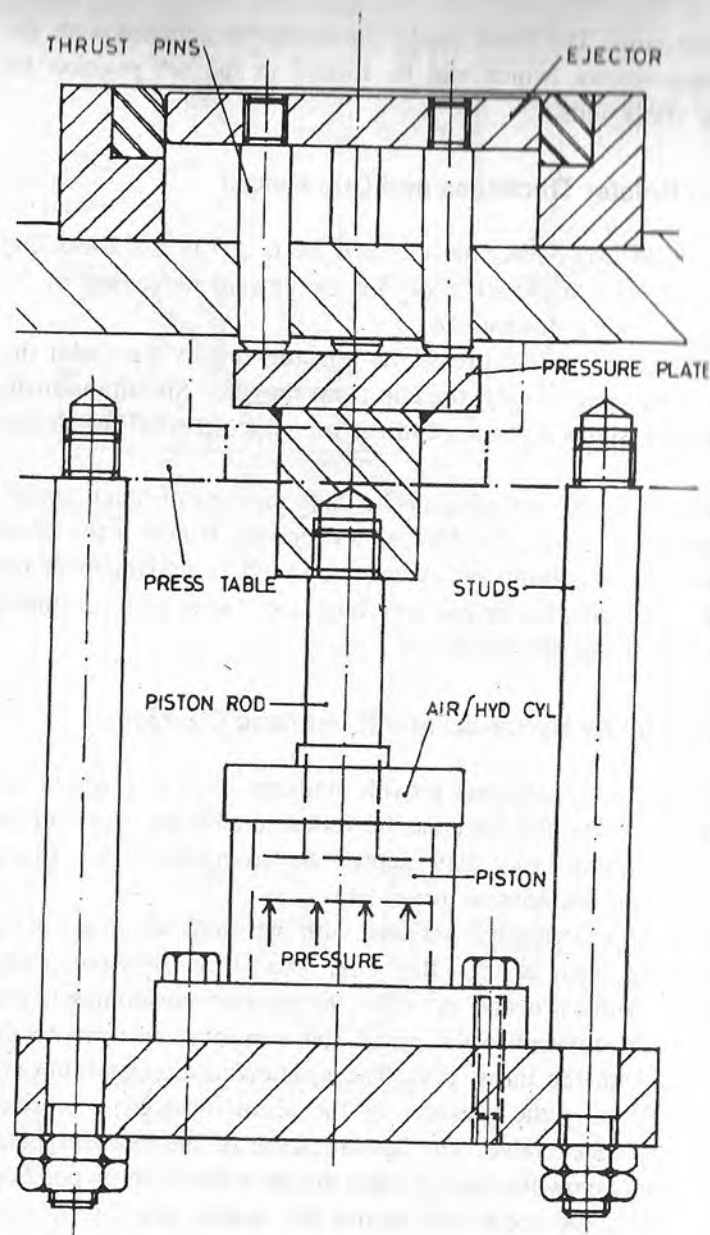


Fig. E19 Hydraulic/pneumatic cushions

atmosphere. The valve closes as soon as the pressure drops below the set value.

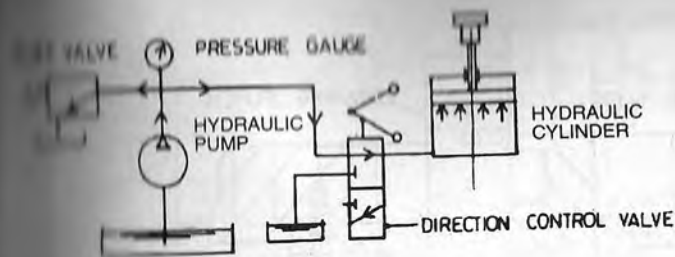


Fig. E20a Circuit for hydraulic cushion

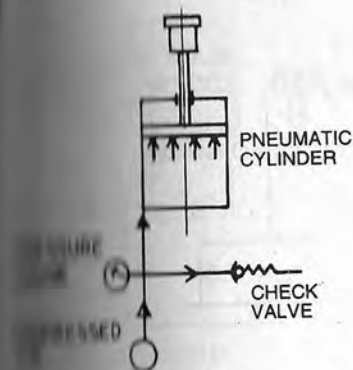


Fig. E20b Circuit for pneumatic cushion

E12.00 Using Die Cushion as Blank Holder

Pneumatic/hydraulic cushions can be used to provide the blank holding force in inverted drawing tools. The arrangement is similar to one shown in Figs E16 and E17. Only the rubber pad is replaced by the air/oil cylinder. Once set, the blank holder pressure remains steady throughout the stroke length.

The devices described in sections E11.00 and E12.00 enable drawing on cranked presses which are unsuitable for deep drawing work. These devices increase the tooling cost substantially. The tooling cost can be reduced very much by using a drawing press which is an ideal machine for the manufacturing of deep cups.

E13.00 TOOLING FOR DRAWING PRESSES

Drawing presses are provided with a separate blank holder slide which can be fitted with an insert ring to suit the blank (Fig. E21). The drawing punch can be screwed into the inner drawing ram, and is guided by the precision running ($H7/f6$) bore in the blank holder. The die is generally made of two parts; the bigger cast steel or

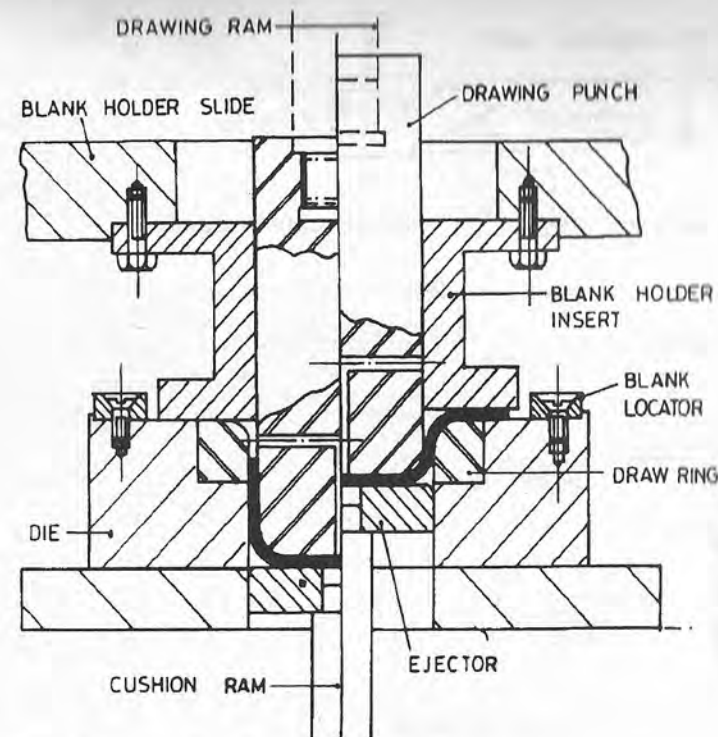


Fig. E21 Tool with pneumatic cushion

meehanite cast iron housing and a smaller, hardened replaceable drawing ring. Thus a drawing press is like a large drawing tool with interchangeable inserts of punch, die ring, and blank holder ring for different sizes of cups. There is a substantial reduction in material, and machine time required for making a drawing tool. This reduces the tooling cost considerably.

✓E13.10 Combining Blanking and Drawing

Fig E22 shows a combination tool which blanks and draws a cup in a single operation. (The blank holder ring also acts as a blanking die, whereas the draw ring also acts as a blanking punch.) The die cushion force is used for ejecting the finished cup. A spring stripper is necessary to strip the blanking punch off the scrap hole in the strip.

When the press ram is up, the blank holder underneath should be 3–4 mm below the drawing punch face. The spring stripper should be about 0.5 mm above the top face of the die whereas the ejector top should be 0.5 mm above the draw ring top.

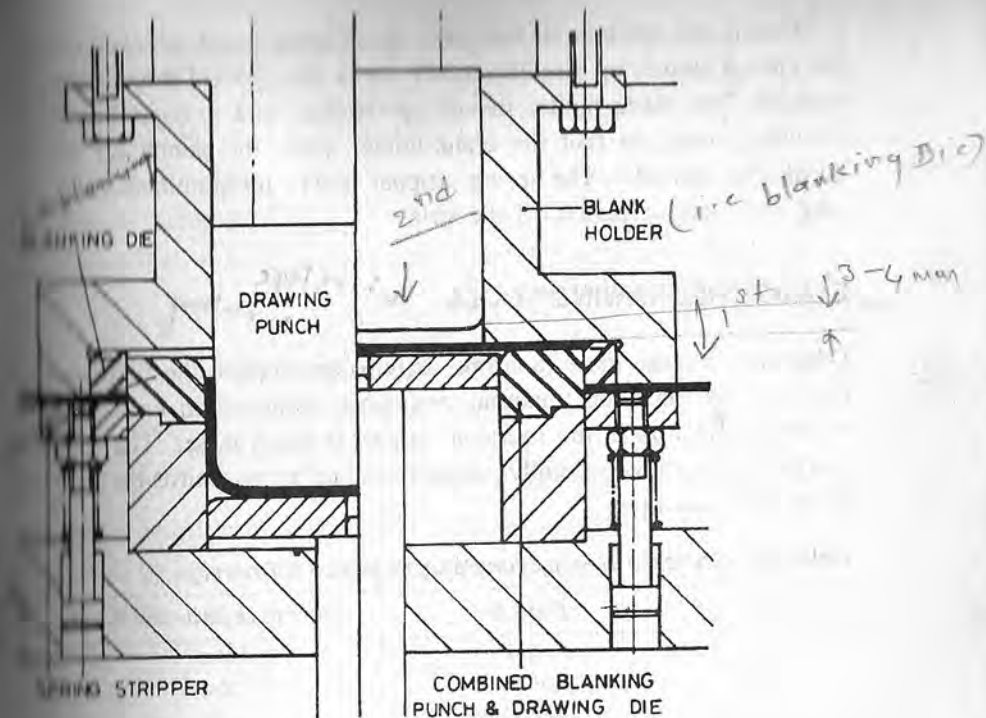


Fig. E22 Combination die for blanking and drawing

The inside diameter of the blanking die should be equal to the required outside diameter of the blank, whereas the outside diameter of the draw ring should be less than the blanking die bore by an amount equal to the die clearance required for blanking. During the downstroke of the press the blank holder ring-cum-blanking die descends first around the draw ring to shear the blank against the draw ring-cum-blanking punch outside diameter. The blanking die face pushes the spring stripper downwards against the spring.

The blank holder descends further to the set position. It maintains a gap about 10% more than the blank thickness, between the draw ring top and blanking die face. The blank holder remains stationary in this position for a considerable part of the operation cycle. The down position of the blank holder can be set with the adjusting screws provided on the blank holder slide.

The inner slide carrying the drawing punch descends and overtakes the stationary blank holder; and draws the blank into the draw ring. The central undrawn part of the blank is sandwiched between the punch face and the ejector which is pushed down against the die cushion.

During the upstroke of the press the drawing punch ascends first and the ejector moves up simultaneously under the upward thrust of the die cushion. The blank holder moves up the last, and is overtaken by the drawing punch; so that the blank-holder strips the punch off the cup during the upstroke. The spring stripper moves up simultaneously stripping the blanking punch off the strip.

✓ E14.00 REDRAWING TOOLS

Interstage annealing

Deep cups require more than one draw to accomplish the final shape of the cup. As the blank material gets work hardened in each draw the possible reduction in the following draws is much lesser. The reduction in a following draw generally ranges from half to two-thirds the reduction in the previous draw.

Table E3 Decrease in Reduction Percentage Due to Drawing

Sr. No.	Draw No.	Percentage Reduction Possible
1	Ist Draw	45%
2	IInd Draw	20%
3	IIIRD Draw	15%
4	IVth Draw	12%
5	Vth Draw	8%

The reduction in the following draws can be increased by annealing the cup to remove the brittleness caused by workhardening. This restores the ductility and a cup can be reduced by 45% after annealing. Annealing is, however, a costly operation to be used only as a last resort. Use of double action press enhances the above reduction by 25–33%.

✓ **Example E13** Find the number of draws and cup diameters and heights for various stages of a mild steel cup shown in Fig. E23a.

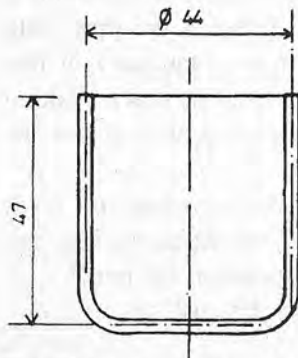


Fig. E23a Workpiece for Example E13

Solution Let us first find blank ϕ

$$\begin{aligned} D &= \sqrt{d^2 + 4dh} \\ &= \sqrt{44^2 + 4 \times 44 \times 47} \\ &= 101.03 \phi \end{aligned}$$

Referring to Table E3

(I) First draw $\phi = d_1 = 101.03 \times 0.55 = 55.57 \approx 56 \phi$

Cup height = $h_1 = \frac{D^2 - d^2}{4d} = \frac{101.03^2 - 56^2}{4 \times 56} = 31.567$

(II) Second draw reduction = 20%

$d_2 = 56 \times 0.8 = 44.8 \approx 45 \phi$

$h_2 = \frac{101.03^2 - 45^2}{4 \times 45} = 45.45$

(III) Third draw reduction = 15% [possible]

$d_3 = 45 \times 0.85 = 38.25 \phi < 44 \phi$ required

For required 44 ϕ cup,

$h_3 = \frac{101.03^2 - 44^2}{4 \times 44} = 47$

Third draw reduction [actual] can be found as follows.

Required reduction = $\frac{45 - 44}{45} \times 100$
 $= 2.2\% < 12\%$ possible

✓ The third draw should draw the cup to finished size $d = 44 \phi$ and $h = 47$.

E14.10 Increasing Reduction

E14.11 Conical Draw Edge

The possible reduction can be increased by using a conical draw edge. Cups subjected to more than one draw use conical draw edge from the first draw itself till the final draw which shapes the cup bottom to the required form.

E14.12 Reverse Drawing

Another method of increasing the reduction is to use reverse drawing. (Fig. E23b). The sleeve die is mounted on the bottom tool and the cup from the previous draw is placed inverted on the die. The external diameter of the die locates the cup precisely. It is advisable to make the top of the cylindrical die half round for good material flow during the operation. Naturally, the preceding operation should draw the cup to the

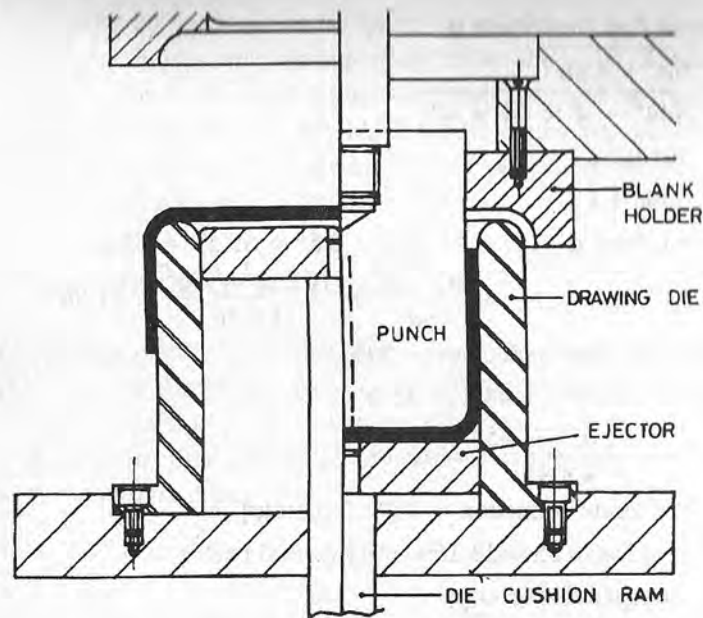


Fig. E23b Reverse drawing

corner radius equal to the draw radius on top of the reverse drawing die. The blank holder ring should have a holding radius equal to the external corner radius of the cup.

During downstroke the blankholder descends first, and dwells in the set position while the punch on the inner slide draws the cup into the bore of the die.

Reverse draw reverses the disposition of the stresses caused in the preceding operation (Fig. E24). In any drawing, the inside surface of a

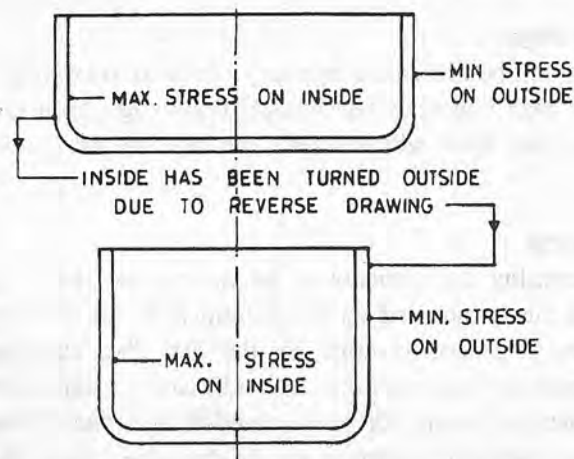


Fig. E24 Reversal of stress disposition in reverse drawing

drawn cup is stressed the most, whereas the external surface is stressed the least. As the reverse drawing turns (draws) the cup from the previous draw inside out, the surface subjected to maximum stress in the preceding operation is stressed the least; whereas the surface stressed least in the previous operation is subjected to maximum stress in reverse drawing. This reversal of stress disposition along the thickness of the cup allows higher reduction in reverse drawing.

E14.20 Common Tool for Two Draws

It is sometimes possible to use a common tool for two drawing operations (Fig. E25). The blank holder ring of the multi-drawing tool is extended to serve as an inverted die for the first draw. The blank holder and die cushion provide the blank holding force during the first operation. The top (inner) drawing slide carries no punch in the first draw. The external diameter of the reverse drawing die itself serves as an inverted drawing punch for the first draw.

It is only necessary to fit the drawing punch to the inner slide, and remove the stripper plate from the bottom tool to ready the tool for the second, reverse draw. The die cushion is used for ejection of the finished cup. Use of a single tool with detachable punch, stripper (1st draw), the ejector (2nd draw) effects considerable saving in the tooling cost.

E14.30 Double Draw Tool

Fig. E26 shows a double drawing tool for the workpiece shown beside. The top inner slide of the press is fitted with a hollow punch-cum-die. The external diameter of the top punch serves as a drawing punch whereas the internal bore is used as a die. The bottom tool is fitted with the outer die, and the inner punch. The die cushion provides the blank holder force for the inner drawing. The top blank holder strips the finished cup from the top punch-cum-die, whereas the die cushion ejects it from the bottom outer die and the bottom inner punch. This tool combines two reverse drawing tools into one to reduce the number of draws and enhance the productivity.

E15.00 DRAWING BEADS

E15.10 Containing Material Flow by Beads

Excessive material flow, also causes wrinkles. Increase in blank holder pressure reduces wrinkles. Excessive blank holder pressure can however

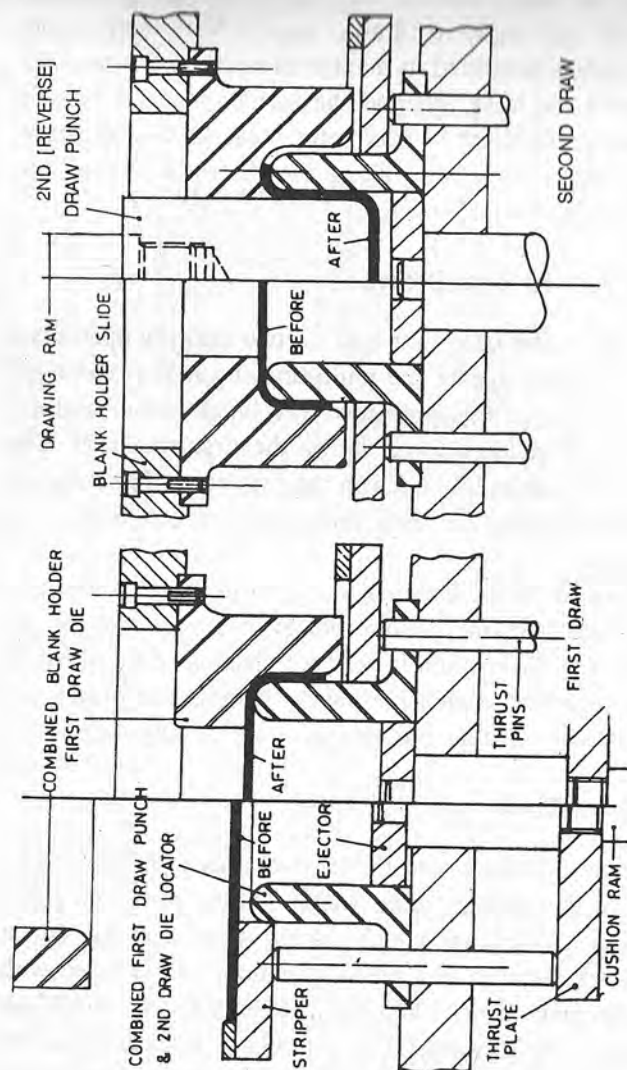


Fig. E25 Combining 2 draws in 1 operation

obstruct the material flow to such an extent that the cup might crack before the wrinkles are completely eliminated. Under such circumstances the material flow should be contained by placing beads in the path of the material flow. Fig. E27 depicts a shallow bead. Like a speed breaker on a road the bead obstructs the path of the material flow. As the blank material must climb and unclimb the bead before reaching the draw bore, the material bends and unbends. This causes excessive stretching beyond the bead thus increasing the elongation percentage

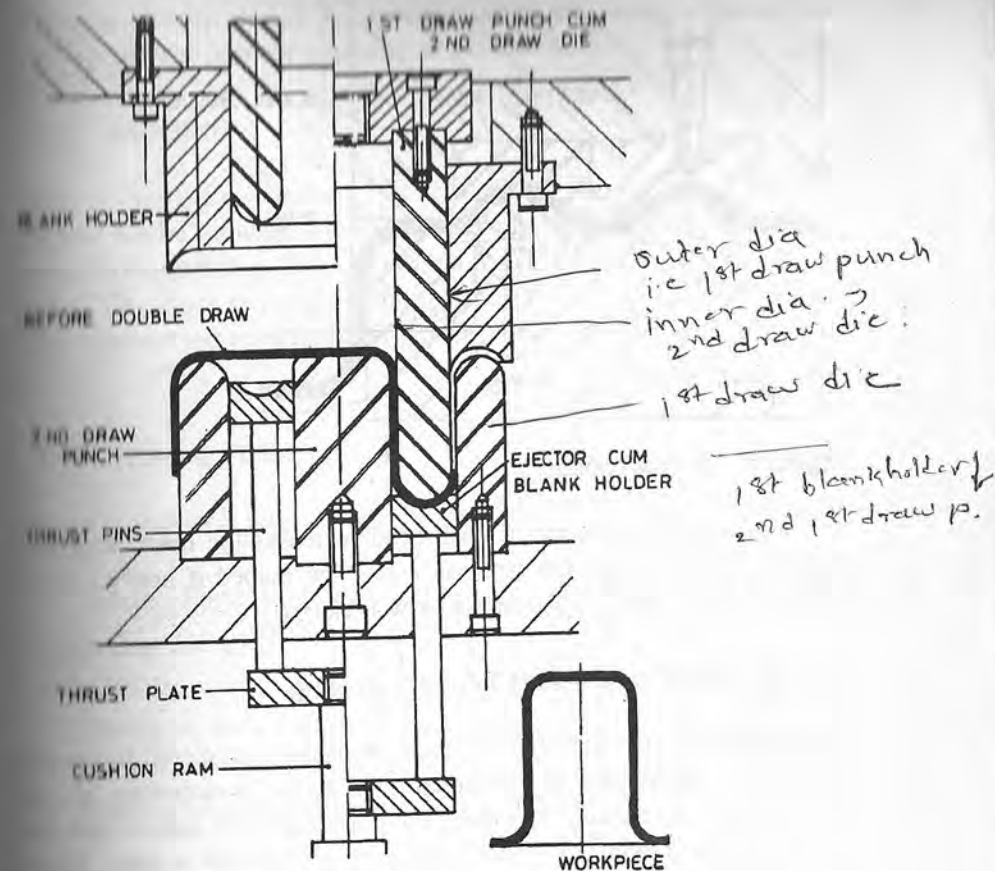


Fig. E26 Double draw tool

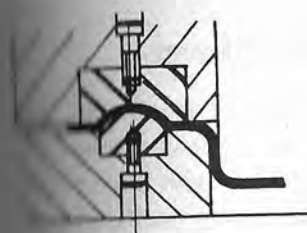


Fig. E27 Shallow bead

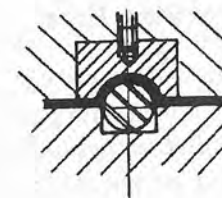


Fig. E28 Deep bead

Deep beads contain material flow. Excessive material flow from the sides of a rectangular cup can cause side wrinkles. Deeper bead is required for deeper cups [Fig. E28]. Very deep cups require two or three tandem beads [Fig. E29].

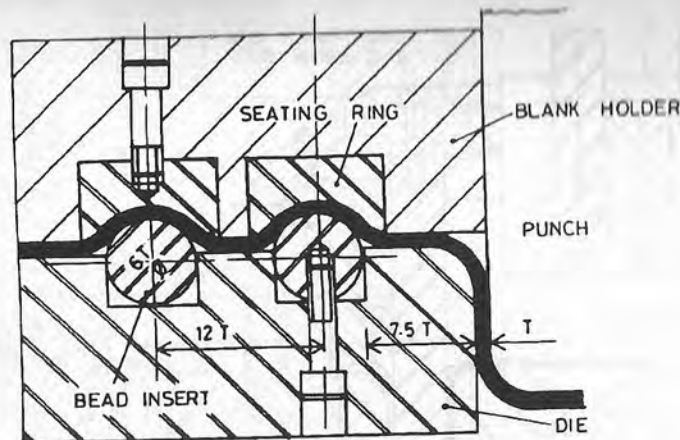


Fig. E29 Tandem beads

Naturally, the addition of each bead increases the force required for drawing. Nonetheless, the increase cannot be helped if heavy reduction is desired and drawn cups are to be wrinklefree.

E15.20 Hardened Insert Type Bead Ring

Drawing beads are subjected to severe abrasion, and should be hardened and polished preferably in the direction of draw. Consequently, an insert type design is preferable to a solid integral bead. It is easy to add beads in cylindrical drawing dies. The die can be grooved on a lathe. There is no problem in turning the bead ring for the die or the corresponding female insert for the blank holder.

E15.30 Silver Steel Beads for Rectangular Drawing

Rectangular drawing beads can be made conveniently from silver steel bars. The die is milled with grooves into which the silver steel inserts can be brazed. Fig. E30 shows a die for a rectangular box with three tandem beads. It should be noted that no beads are necessary in the corners. Furthermore in tandem beads, the beads further from the die edge can be made progressively shorter in length than the preceding beads. The size and the shape of the bead depends upon the physical properties of the material being drawn. For mild steel the width of bead should be approximately six times the thickness T . The bead radius should be three times the material thickness. Tandem beads should be about $12T$ apart. The innermost bead should be $7.5T$ from the draw bore. It is not necessary to provide beads all around the periphery on odd-shaped

workpieces. Beads should be provided only on places vulnerable to wrinkling and the corners need not be beaded at all.

E16.00 IRONING

Ironing is used for thinning the walls of drawn cups. The wall thickness can be reduced by 30 to 35% of the unironed thickness in a single operation (Fig. E31). The bottom thickness does not change in ironing. For more reduction two dies can be arranged in tandem, one above another, to accomplish more reduction in a single stroke (Fig. E32).

E16.10 Ironing Force

The force required for ironing can be calculated from the following formula

$$\text{Ironing Force} = V = \pi d T_2 f_t \times 2.3 \log \frac{T_1}{T_2} \quad [\text{Eqn E12}]$$

V = Ironing force

d = Mean dia of cup (mm)

T_2 = Thickness after ironing (mm)

T_1 = Thickness before ironing (mm)

f_t = Material ultimate tensile strength (N/mm^2)

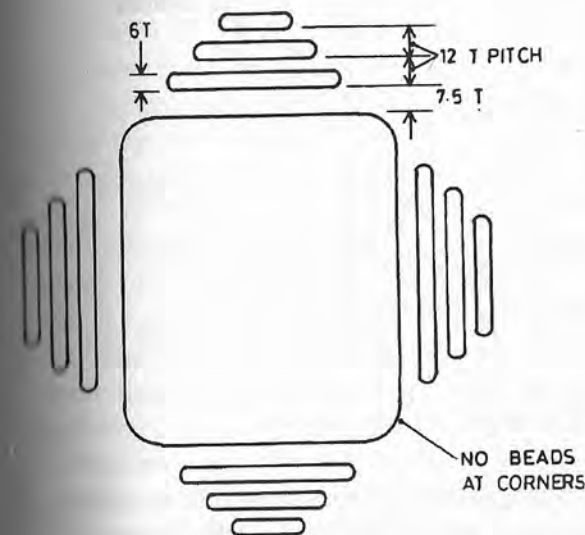


Fig. E30 Beading die for rectangular box

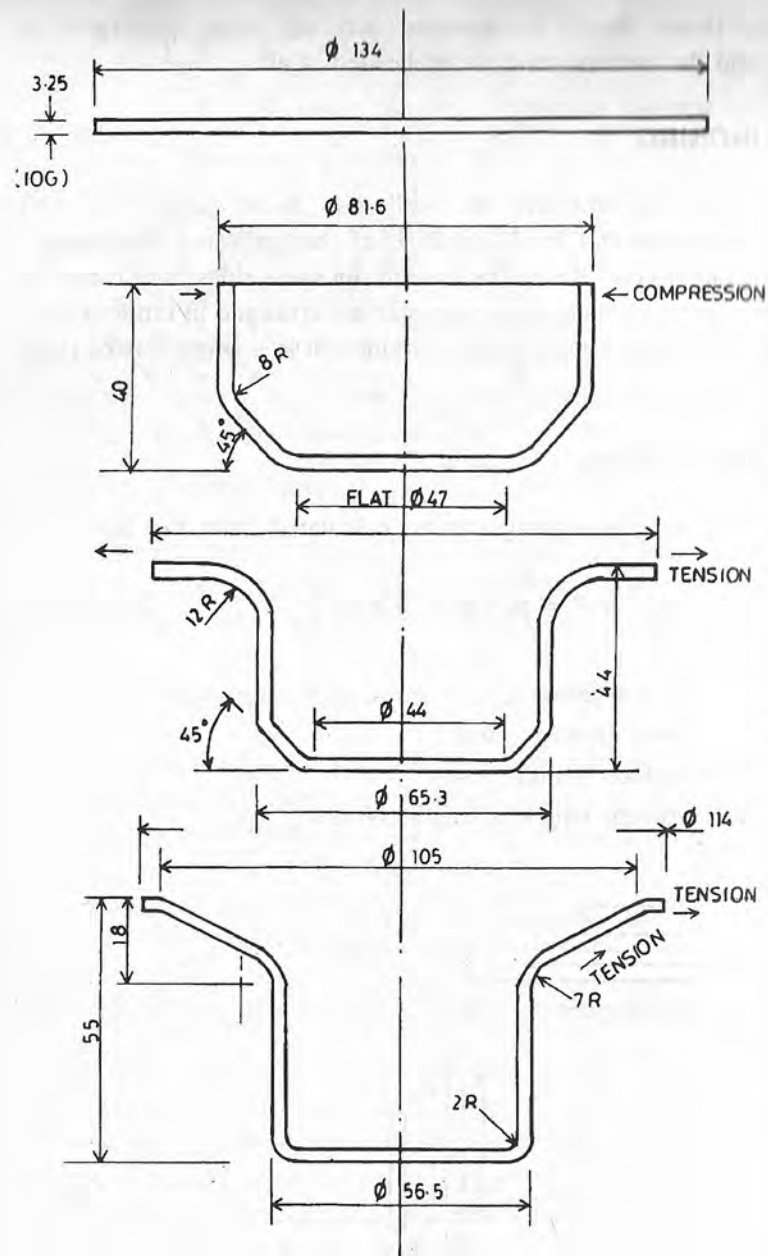


Fig. E30b Drawing flanged cups

✓ **Example E14** Find the force required for reducing 100 outside dia of 1.5 mm thick cup to 99.4 dia, by ironing. U.T.S. $f_t = 290 \text{ N/mm}^2$.

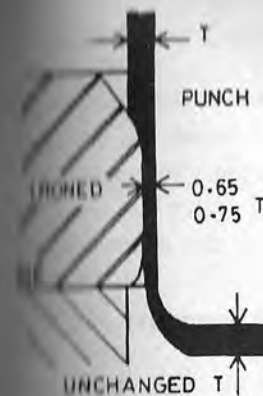


Fig. E31 Ironing

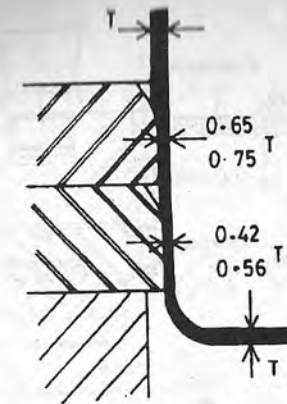


Fig. E32 Tandem ironing dies

Solution $d = 100 - 1.5 = 98.5 \text{ mm}$

$$\begin{aligned}
 V_1 &= \pi d T_2 \times 290 \times 2.3 \log \frac{T_1}{T_2} \\
 &= \pi \times 98.5 \times \frac{(99.4 - 97)}{2} \times 290 \times 2.3 \log \frac{1.5}{1.2} \\
 &= 247681.3 \log \frac{1.5}{1.2} = 24002.70 \\
 &\approx 2.4 \text{ t}
 \end{aligned}$$

E17.00 TRIMMING TOOLS

Cup or flange edges often get damaged and distorted in drawing. For in the first draw the peripheral material of the blank is drawn without any blank holder pressure. As soon as the outer edge reaches the draw radius it loses contact with the blank holder, and is no more under its pressure. Thus the last drawn portion is likely to be wrinkled. This part is trimmed off to finish the drawn workpiece to size. Fig. E33 shows a trimming tool for flange of a drawn cup. The punch is fitted with a close-running fit pilot which engages with the cup bore to centralize it precisely with the trimming tool. The design uses sturdy die housing with a hardened die insert. The plate type punch insert is screwed to a much larger punch holder. The punch holder is guided in the stripper assembled on two columns fitted in the die housing. The trimmed cup is pushed down through the die. It falls through the clear hole in the die housing, pressable hole, into the receptacle below. The scrap ring around the punch is stripped off during the upstroke. The scrap ring is removed manually when the punch is in up position.

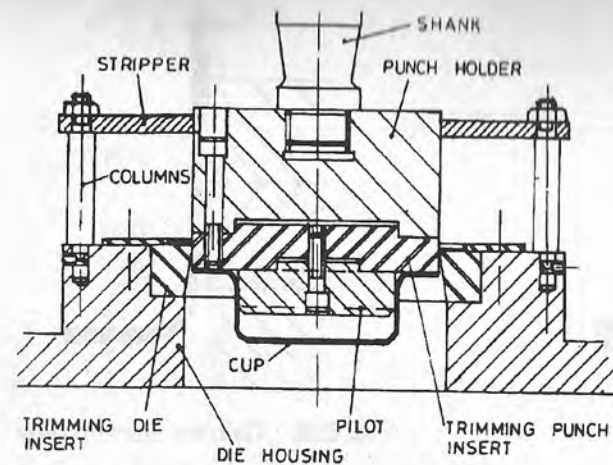


Fig. E33 Trimming tool for flanged cup

E17.10 Inverted Trimming

For workpieces bigger than the hole in the press table, it is necessary to use an inverted trimming tool (Fig. E34). In this design, the punch is mounted on the bottom bolster. The punch is fitted with a pilot for precise location of the workpiece. The top tool carries the die and a knockout operated ejector. The shank is threaded to die holder, and has got a hole for knockout pin. The ejector has got a step to prevent gravitational fall.

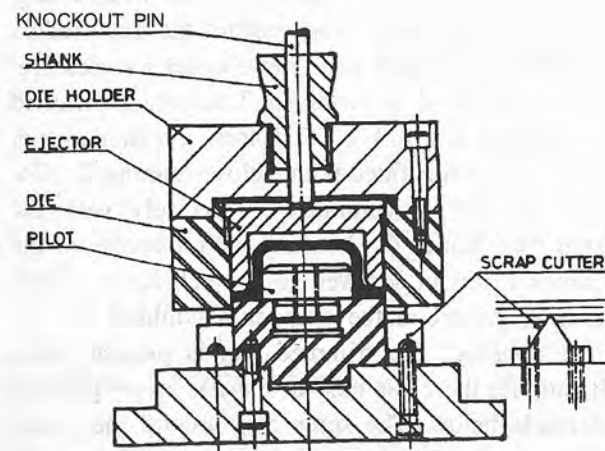


Fig. E34 Inverted trimming tool

E17.20 Scrap Cutters

The bottom tool is fitted with two 'V' shaped scrap cutters. After trimming, the die descends further to push down the scrap ring against the two diametrically opposite the scrap cutters. The cutters break down the rings into two halves which can be removed periodically without stopping the production run.

E17.30 Trimming Machines

Collared cups are trimmed to the required length in trimming machines (Fig. E35). The cup is clamped on a rotating spindle, and

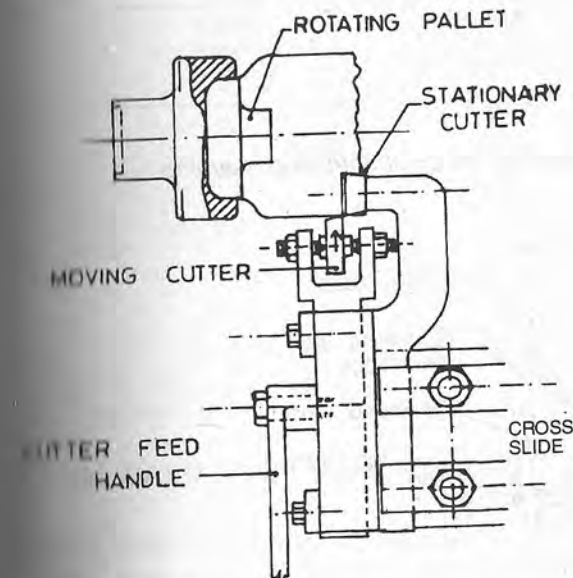


Fig. E35 Trimming machine

trimmed by a pair of cutters. The fixed cutter supports the cup from within the bore. The other cutter can be fed radially inwards to trim the cup to the required length. Only the spindle carrying the cup is power driven. Nonetheless, the cutters revolve due to friction with the cup. Fig. E36 shows trimming arrangement for cup flanges. The lower portion shows a roller for beading (curling) the trimmed flange. Rotary forming (spinning) can also be used for flanging (Fig. E37) and internal beading (Fig. E38).

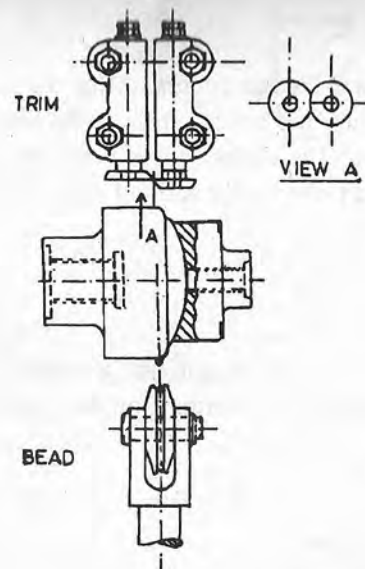


Fig. E36 Cutting and beading flange on trimming machine

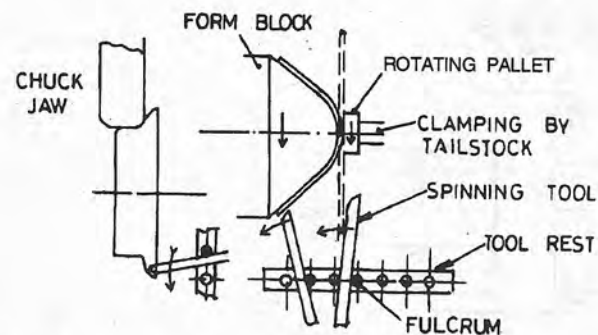


Fig. E37 Spinning (rotary forming)

As most of the drawn components are trimmed to size there is no need for calculating the blank size very precisely. The approximate size of a cup can be found from ready tables (Fig. E39). The trimming allowance must be added to the calculated blank size to obtain the required blank size. The trimming allowance depends upon the cup/blank thickness and the hardness 'RB' of the material. It ranges from 0.63 to 3.6 mm/side. The harder and thicker components require more trimming allowance. Table E4 gives the recommended allowances for various sheet thicknesses and hardnesses.

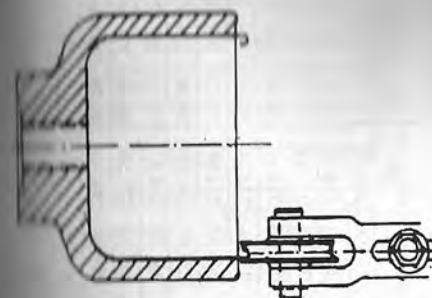


Fig. E38 Shrink beading on trimming machine

Table E4 Trimming Allowances for Cups

No.	Cup Thickness (mm)	Trimming Allowance/side (mm) Cup Hardness Rockwell 'B'		
		50-65	75-90	90-106
1	1.2	0.63	0.75	1.06
2	1.6	0.75	1.06	1.25
3	2.0	0.90	1.25	1.5-1.8
4	2.36	1.06	1.50	1.8-2.24
5	2.80	1.25	1.80	2.24-3.30
6	3.17	1.8	2.24	3.0-3.6

E10.00 CARBIDE DIES AND PUNCHES

Drawing subjects the punches and dies to severe abrasion. As sintered carbides have excellent wear resistance, carbide inserts can be used conveniently to enhance tool life immensely.

E10.10 Carbide Draw Rings (Fig. E40)

As carbides are costly, it is economical to fit a small cross-sectional ring in a solid housing hardened to RC40. The draw rings are made shrink fit in the housing. The outside diameter of the housing should be two to two and a half times the outside diameter of the die ring insert.

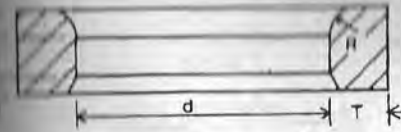
The die ring insert should have at least 5 mm flat surface beyond the draw edge radius/cone.

Example E15 Find outside diameters of carbide draw ring and housing if the cup is 100 ϕ and the draw edge radius is 11 mm.

Cup ϕ (mm)	Height of Cup (mm)																
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	90	100
5	14.14	18.03	20.62	22.91	25.00	26.93	28.72										
10	22.36	26.46	30.00	33.17	36.06	38.73	41.23	43.59	45.82	47.96	50.00	51.96	53.85	55.68	57.44		
15	28.72	33.54	37.75	41.53	45.00	48.22	51.23	54.08	56.79	59.37	61.85	64.23	66.52	68.74	70.89	75.00	78.90
20	34.64	40.00	44.72	48.99	52.91	56.57	60.00	63.25	66.33	69.28	72.11	74.83	77.46	80.00	82.46	87.18	91.65
25	40.31	46.10	51.23	55.90	60.21	64.23	68.01	71.59	75.00	78.26	81.39	84.41	87.32	90.14	92.87	98.11	103.08
30	45.83	51.96	57.45	62.45	67.08	71.41	75.50	79.37	83.07	86.60	90.00	93.27	96.44	99.50	102.47	108.17	113.52
35	51.23	57.66	63.44	68.74	73.65	78.26	82.61	86.75	90.69	94.47	98.11	101.61	105.00	108.28	111.47	117.58	123.39
40	56.57	63.25	69.28	74.83	80.00	84.35	89.44	93.81	97.90	101.98	105.83	109.54	113.14	116.62	120.00	126.49	132.66
45	61.85	68.74	75.00	80.78	86.17	91.24	96.05	100.62	105.00	109.20	113.25	117.15	120.93	124.60	128.16	135.00	141.51
50	67.08	74.16	80.62	86.6	92.20	97.47	102.47	107.24	111.80	116.19	120.42	124.50	128.45	132.29	136.01	143.18	150.00

Cup ϕ (mm)	Height of Cup (mm)																	
	20	30	40	50	60	70	80	100	110	120	130	140	150	160	170	180	190	200
55	86.17	98.11	108.74	114.43	127.38	135.74	143.61	158.19	165.00	171.54	177.83	183.91	189.80	195.51	201.06	206.46	211.72	216.85
60	91.65	103.92	114.89	124.90	134.16	142.83	151.00	166.13	173.20	180.00	186.55	192.87	199.00	204.94	210.71	216.33	222.81	227.16
65	97.08	109.66	120.93	131.24	140.80	149.75	158.19	173.85	181.18	188.21	195.00	201.56	207.91	214.07	220.06	225.89	231.57	237.12
70	102.47	115.33	126.88	137.48	147.31	156.52	165.23	181.38	188.94	196.21	203.22	210.00	216.56	222.93	229.13	235.16	241.04	246.78
75	107.82	120.93	132.76	143.61	153.70	163.17	172.12	188.74	196.53	204.02	211.25	218.23	225.00	231.57	237.96	244.18	250.25	256.17
80	113.14	126.49	138.56	149.67	160.00	169.71	178.88	195.96	203.96	211.66	219.09	226.27	233.24	240.00	246.58	252.98	259.23	265.33
85	118.43	132.00	144.31	155.64	166.21	176.14	185.54	203.04	211.25	219.15	226.77	234.15	241.30	248.24	255.00	261.58	268.00	274.27
90	120.10	134.26	147.05	158.82	169.78	180.07	189.80	207.90	216.39	224.55	232.43	240.05	247.44	254.61	261.58	268.37	275.00	281.47
95	128.94	142.92	155.64	167.41	178.40	188.75	198.56	216.85	225.44	233.72	241.71	249.45	256.95	264.24	271.34	278.25	285.00	291.59
100	134.16	148.32	161.24	173.21	184.39	194.94	204.94	223.61	232.38	240.83	249.00	256.90	264.58	272.03	279.28	286.36	293.24	300.00

Fig. E29 Blank sizes for cylindrical cups



d	Thickness T	Straight Land S	Back Relief B	Corner Radius R
T_o				
12	5	3	1.5	1-3
25	10	5	2.5	2-8
38	12	6	3	3-10
62	14	8	3	4-12
125	16	10	4	5-14
250	20	12	5	6-16
380	22	13	6	7-18

Fig. E40 Carbide draw rings

Example Outside ϕ of draw edge bell mouth = $100 + 2 \times 11 = 122$
 Adding 5 mm wide annular flat land beyond bell mouth all around,
 Outside ϕ of draw ring = $122 + 2 \times 5 = 132$
 Outside ϕ of housing = $2 \times 132 = 264$

E18.20 Carbide Inserts for Drawing Punches

Carbide inserts can be screwed or brazed to holders hardened to RC40 to enhance tool life (Fig. E41). Large diameter carbide rings can be provided with a counterbore for a steel clamping ring which can be screwed to punch holder (Fig. E41a). Smaller sizes of punches should be provided with hole and counterbore for an allen screw (Fig. E41b), a tapped hole and location spigot (Fig. E41c) for assembly. Usually punches are provided with holes in moulding. The threaded holes are tapped by electric discharge machining (E.D.M.) later. Fine punches which are too small to provide weakening (assembly) holes are provided with a locating cone for alignment and are brazed to a holder provided with a female location cone (Fig. E41d).

E18.30 Machining Carbide Inserts

Carbides being very hard are moulded to required shape and size. Even the minimal essential finishing must be carried out at a very slow pace with costly diamond wheels. So the insert shapes should permit finishing with a diamond impregnated grinding wheel.

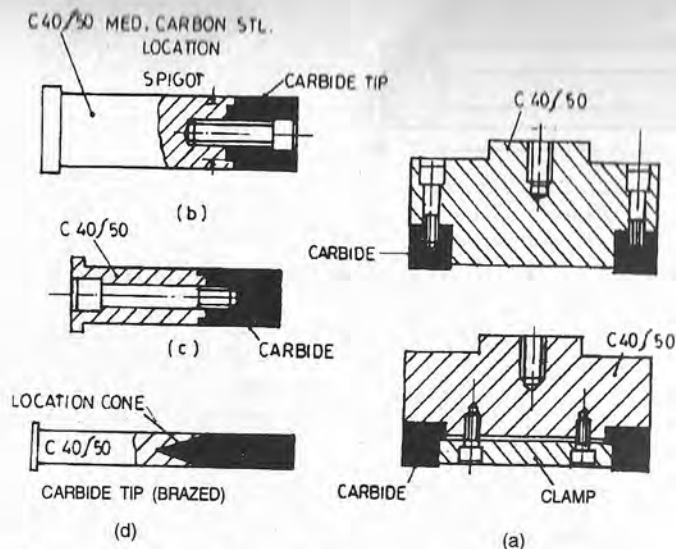


Fig. E41 Punches with carbide inserts

E19.00 DRAWING MATERIALS

Inputs to press comprise of rolled sheets, strips, flats and bars. Rolled steel sheets above 6 mm thickness are usually referred to as plates.

E19.10 Rolled Sheets

✓ E19.11 Hot Rolled Sheets

Oxide scales on the surface impede material flow, and cause excessive die and punch wear. It is better to pickle the sheets and oil them before drawing.

✓ E19.12 Cold Rolled Sheets

Excellent surface finish of cold rolled sheets justify their use when the drawn product must have good surface finish. Cold Rolled Close Annealed (CRCA) sheets are stress relieved by annealing after rolling. They provide core softness so valuable in bending, forming, and drawing operations.

E19.20 Thickness Variation

Materials used for deep drawing should not vary by more than 0.05 mm in thickness. If the blank thickness is undersize the excessive die clearance leads to ugly wrinkles on the side walls of the cup. Excessive

thickness of the blank, on the other hand, can cause fracture at the bottom corner of the cup due to insufficient die clearance.

E19.30 Ductility

Drawability

Ductility or Formability of material can be found by cupping tests.

E19.31 Swift Cupping Test

This test uses circular blanks of increasing diameters to determine Limiting Drawing Ratio (LDR). Using any cup drawing tool suitable for the thickness of the material to be tested the smallest blank is drawn to full depth cup under blank holder pressure. If the cup does not crack, the next bigger size of blank is drawn to deeper cup. One after another, larger and bigger blanks are drawn to cups till the cup bottom fractures. The biggest blank which can be drawn to full depth cup without fracture gives us the value of the Limiting Drawing Ratio (LDR)

$$LDR = \frac{\text{Diameter of the (biggest) blank}}{\text{Diameter of cup (punch)}}$$

E19.32 Erichson Test

This test gives better measure for formability or stretchability of the workpiece material. Instead of circular blank a strip is used. The punch is spherical (Fig. E42). The die is much bigger than the punch diameter. Therefore any thickness of workpiece sheet can be tested with one tool. Under heavy blank holder force (10000 N for ϕ 20 mm punch) the punch is plunged into the sheet. The stroke is stopped as soon as the bulge formed in strip fractures. The depth of the bulge (in mm) gives the Erichson Number: measure of ductility.

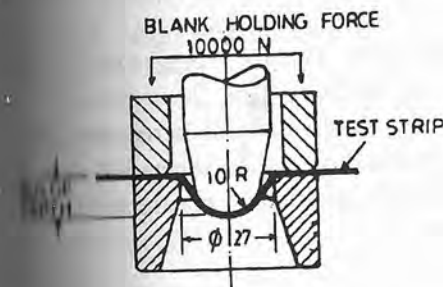


Fig. E42a Erichson test

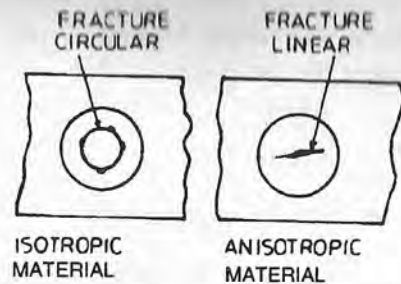


Fig. E42b Inspection of fracture (Erichson test)

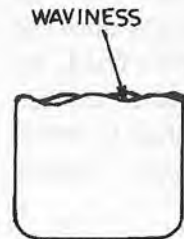


Fig. E42c Waviness in cup edge in anisotropic material

Inspection of the fracture indicates drawability of the test material in two directions: along and across the grain (or rolling direction).

If the drawability of the test material is equal in both the directions the fracture will be circular. Such material is called 'Isotropic'.

If the drawability along and across grains are different the material is called anisotropic. Such materials give a linear fracture.

Thus Erichson Test indicates biaxial ductility of the workpiece material. It also gives an indication of grain size. The spacing between the fruit peel-like point depressions on the spherical surface of the bulge indicates grain size. Depending upon the grain size, the spacing ranges from 0.015 to 0.20 mm : wider spacing for bigger grains.

In the U.S.A., Olson Test is used widely. But for a bigger punch and die, Olson Test is almost similar to the Erichson Test.

Rolled sheets are usually anisotropic. As the ductility across the grain size is much lesser, unflanged cups drawn from rolled sheets have wavy edges which need trimming. Anisotropy is specified by plastic strain ratio r between width and thickness strains.

$$r = \frac{\text{width strain}}{\text{thickness strain}}$$

Higher the value of r lesser the thinning of sheets during drawing and easier the compression of flange under blank holder; as a result better

drawability. The value of r should be more than one. It ranges from 1.2 to 1.6 for stainless steels and is as high as 2 to 6 for titanium sheets.

E10.40 Work Hardening

Every cold working operation leads to work hardening of workpiece material. Workpieces subjected to multiple draws become harder and harder with successive draws till they cannot be drawn further without annealing.

Coefficient of work hardening n is the slope of true stress : true strain curve, or true strain at which necking commences in a tensile test. Higher the value of n more the work-hardening and lesser the suitability for multiple draws. Lesser value of n permits more draws without fracture, although there will be more thinning of walls. Value of n ranges from 0.10 to 0.26 for stainless steels.

Cold working increases tensile strength and reduces ductility (drawability). Fig. E43 shows possible elongation (without fracture) in relation with tensile strength for low carbon steels and medium carbon steels.

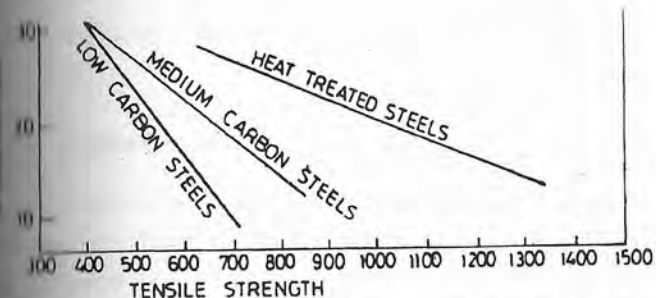


Fig. E43 Relation between tensile strength & ductility of steels

E10.50 Age Hardening

In drawing work, the cups should not be stored long between two draws. The storage of work-hardened material increases hardness further due to age hardening. Cups stored long might become unworkable for the following operations due to age hardening. It might become necessary to resort to costly annealing to soften cups for the further drawing.

E10.60 Materials Tables

Appendix (Sect. M01.11) states the physical properties of the materials used in press work. It can be noted that deep drawing steels contain less than 0.15% carbon, and have tensile strength less than 340 N/mm². They

have as high as 27% elongation. This steel is often referred to as *Rimming Steel* in the automobile industry.

E19.70 Non-Ferrous Drawing Materials

Aluminium (IS 19000, 19500 grades) having 70 N/mm^2 tensile strength and 18–23% elongation is eminently suitable for deep drawing. Cooking utensils, pressure cookers and many other deep articles are made from aluminium sheets. Brasses and bronzes too have high elongation and can be drawn well.

F

Miscellaneous Tools

This section covers less often used press tools such as bulging tools, reducing tools, embossing tools, coining tools, rivetting tools, shaving and sizing tools, and extrusion tools.

F1.00 BULGING TOOLS

Bulging involves local deformation to increase the size of a part of a drawn cup.

F1.10 Open Bulging

Fig F1 shows a punch and die for open bulging of a cup to expand its top diameter. The shape of the cup before bulging is shown by a chain-dotted line. The conical connecting plane facilitates gradual bulging of the cup

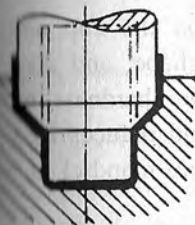


Fig. F1 Open bulging tool

diameter to a bigger size. The cup is stretched during the operation. As such, the amount of deformation possible is more than that possible in shrink forming. Naturally the increase possible in bulging will depend upon the state (work hardening) of the cup being bulged.

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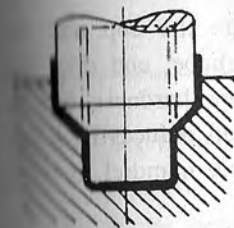


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F1.20 Rubber Bulging

Bulging is used widely to form rims on cups. Rims at bottom or centre of cups are formed by using rubber pads to facilitate unloading of the bulged cup from punch/die. Fig. F2 shows a press tool for bulging a rim at the bottom of the cup. The cup is located on a close running fit locator

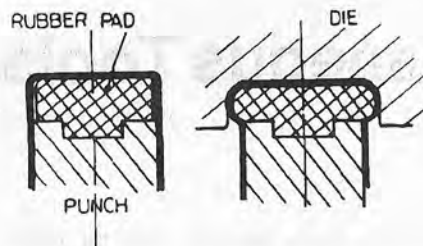


Fig. F2 Rubber bulging

screwed to the bottom bolster. The size of the rubber pad punch on top of the locator should be about 1 mm less than the cup. The pad is spigotted in the locator to prevent any displacement during operation. The inverted die in the top tool should have an open profile as shown to permit withdrawal of the die after bulging. The profile should correspond with the exterior dimensional requirements of the bulged cup.

During the downstroke of the press, the die presses the cup and the rubber underneath it. The rubber expands to bulge the cup. The die profile matches the bulge in shape and size. During bulging, the rubber pad assumes the shape of the interior of the bulge, and serves as a collapsible punch during unloading.

Upstroke of the press removes the pressure on the cup and the rubber. The rubber resumes its earlier cylindrical shape, and does not obstruct unloading of the cup. Thus flexible [shore hardness 60-70] rubber punch facilitates unloading of bulged cup, and reduces tool cost considerably. Imagine the cost of the split collapsible mandrel in place of the rubber punch.

Sometimes, it is necessary to make segmental die of two or more parts which can be separated for unloading the bulged component. Fig. F3 shows a tool with a four piece die. Four movable segments are held open by compression springs to facilitate unloading of the bulged component and loading a fresh workpiece. During the downstroke of press, the angular cams attached to the top bolster bear with the angular seat on the rear of movable segments. As a result, descent of cams pushes the

movable die segments inwards to bulge the cup against the rubber part of the composite punch. The rubber part is dovetailed into the steel part of the bulging punch.

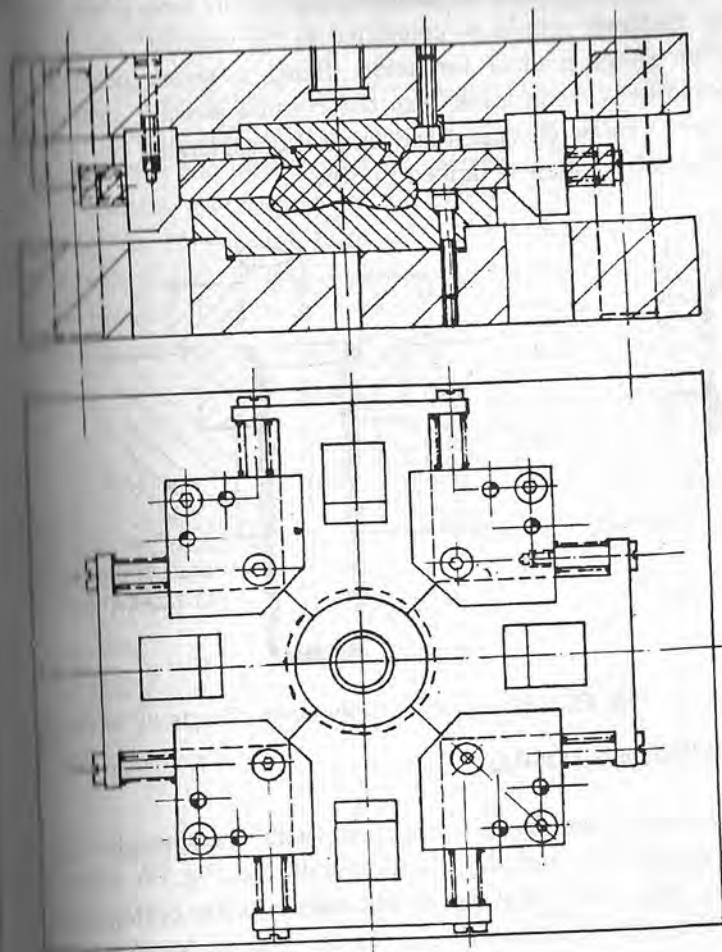


Fig. F3 Segmental bulging die for unloading deep cups

When the ram goes up, the spring opens the movable die segment wide to enable unloading the bulged piece. Removal of the pressure on the rubber punch restores it to smaller size cylinder. This facilitates unloading the bulged component.

The bottom bolster is anchored with the fixed die segment. The form of the fixed segment should not obstruct unloading of the bulged cup. The working faces of the movable die segments should blend well at the joints in closed position to avoid unseemly marks on the bulged cup.

F2.00 REDUCING TOOLS

Reducing involves local deformation to decrease the size of a drawn cup. Fig. F4 shows die and punch for reducing cup top to form a bottleneck. The reduced diameter should be connected to the original cup diameter by a cone to effect gradual formation. Being a shrink process, the reduction possible is much lesser than deformation possible in bulging.

Drawn cups can be elongated and thinned considerably by reducing (Fig. F5). The deformation is limited to 30%.

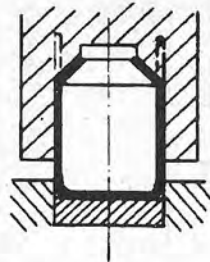


Fig. F4 Reducing tool

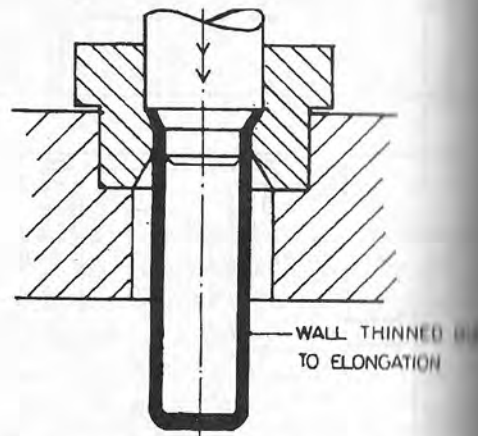


Fig. F5 Elongation and thinning of cups by reducing

F3.00 EMBOSSING TOOLS

Embossing involves marking a component with the manufacturer's emblem, the product size and identification code, etc. Fig. F6 shows an embossing tool. The punch and die should have profiles corresponding to top and bottom of the embossed part. In the case of drawn cups the cup bottom can be embossed conveniently by placing the embossing die on the base of the drawing punch while the ejector top can make a convenient punch. Usually pneumatic and hydraulic cushions can provide adequate force for embossing. If the cushion force is insufficient

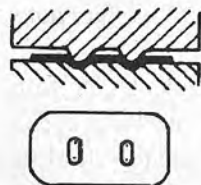


Fig. F6 Embossing tool

embossing can be effected by bottoming the punch against the die at the end of the downstroke.

F4.00 COINING TOOLS

Coining involves considerable metal redistribution. A flat blank is cold-chambered to form some depressions and raise some protrusions to effect desired patterns and impressions. Coining is used widely in the manufacture of medals, badges and coins. Coining punch and die are mirror images of the coined part. Generally the punch and die impressions are copied from master models of plaster of Paris, wood, or lead. Impressions can be copied on die-sinking machine; or on Spark-erosion machine which requires a brass or copper electrode; a replica of the coined part (Fig. F7).

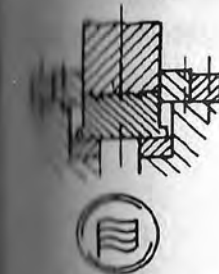


Fig. F7 Coining tool

F5.00 RIVETTING TOOLS

Rivetting involves cold forging. Nonetheless a press tool designer is often told to design a rivetting tool for assembly of two or more components. Fig. F8 shows a simple rivetting tool for rivetting two flats

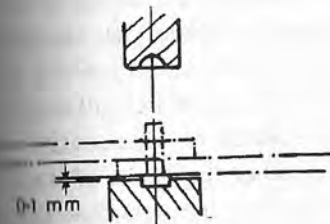


Fig. F8 Tool for rivetting two flats together

together. The rivet is placed upside down with the head locating in a close fit counterbore in the die mounted on the bottom bolster. After placing the inverted rivet in the die, the two flats are inserted onto the rivet. The punch face resembles the desired rivet head. During downstroke of the press, the top punch squeezes the rivet to the required shape. The chain-dotted line shows the rivet before the operation.

In gang rivetting, it is more convenient to keep the collars of the rivets at top during insertion of rivets into the constituents. When the sub-assembly is inverted upside down for loading in the tool, some of the rivets might fall off due to gravity. This can be avoided by using a holding plate. The holding plate is provided with holes for the rivets. These have grooves which house a holding ring of hardened and tempered spring steel. The holding ring is split to permit its expansion. The inside diameter of the holding ring is 0.5 mm less than the outside diameter of the rivet. As a result, the holding ring expands slightly when a rivet is pushed through. The holding ring clamps lightly on the rivet outside

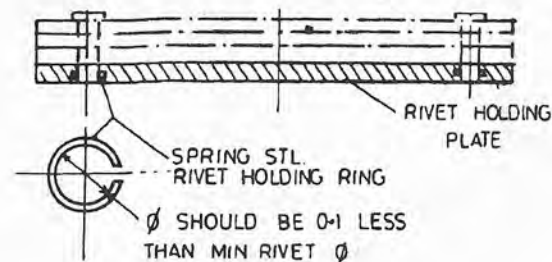


Fig. F9 Holding plate for preventing fall of rivets after turning upside

diameter by spring action [Fig. F9]. The clamping force is sufficient to hold the rivet against the gravitational fall, when the sub-assembly is inverted for loading in the rivetting tool.

The sub-assembly with the holding plate can be safely conveyed to the press tool and positioned for gang rivetting. After the sub-assembly is loaded on the gang rivetting tool, the holding plate can be removed from top to bare the rivets for heading. The light holding force of the spring holding ring poses no problem in removal of the holding plate. Fig. F10 shows a tool for forming two rivet heads simultaneously.

For positive rivetting of constituents together the depth of the locating counter-bore in the rivetting die should be 0.1 mm less than the rivet head (collar) thickness. This ensures positive resting of the component faces against the rivet heads during the operation.

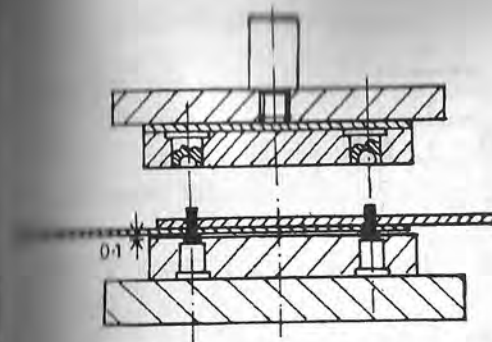


Fig. F10 Press tool for rivetting two heads simultaneously

10.00 SHAVING AND SIZING TOOLS

Shaving is used to finish the blank/hole edges to high surface finish and accurate size. The blank periphery can be sheared off by passing it through an accurate die under the push of a slightly smaller punch. The outer face of the blank should rest on the die to ensure that the direction of shaving is same as direction of blanking.

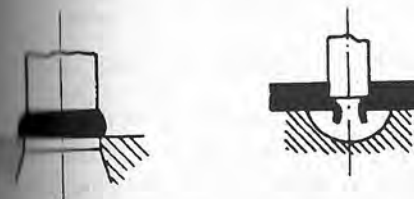


Fig. F11 Shaving blank and hole

Holes can be shaved by passing an accurate punch through a slightly undersized hole. The direction of shaving should be the same as the direction of piercing. Simple plate with a depression can serve as a die.

Shaving should remove the angular fracture of sheared edges to make them square with blank faces. Consequently, the allowance left for shaving should exceed the die clearance by approximately 0.15 mm.

The edges of holes and blanks periphery can also be finished by sizing (Fig. F12). Sizing tools squeeze the material gradually from the angular edges. The blanks are passed through tapered dies which squeeze material off its edges. Sizing punches for holes have rounded edges which squeeze the material off the hole edges. Thus sizing squeezes off the material whereas shaving removes the material by a sharp edge cutting.

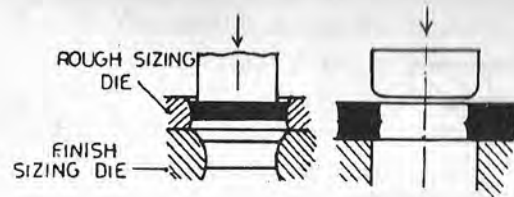


Fig. F12 Sizing blank and hole

F7.00 EXTRUSION TOOLS

Extrusion involves pushing the metal through a die opening to impart required form. (Fig. F13). In forward extrusion, the die remains stationary

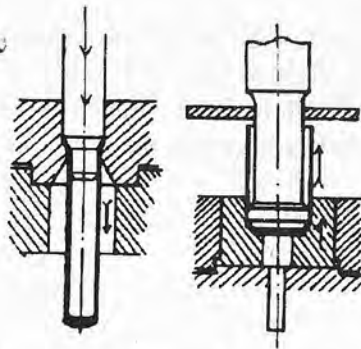


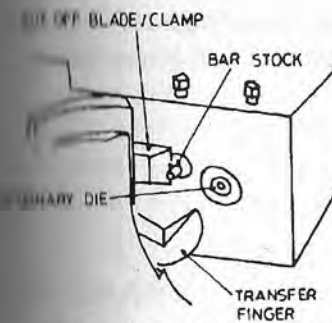
Fig. F13 Forward and backward extrusion

while the punch forces the workpiece through it, i.e. the die is placed on the press table while the punch is fitted to the top tool. In backward extrusion, the punch is stationary and the die moves against the punch to extrude the workpiece.

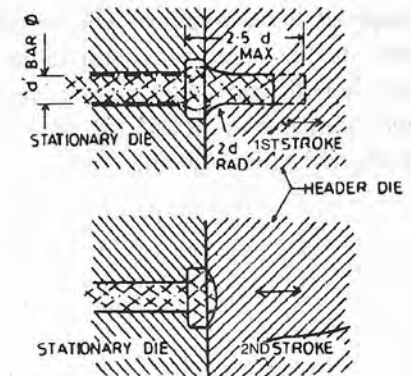
Extrusion is used mainly to form long lengths of uniform sections such as channels, angles, and many sophisticated shapes. As such, normally extrusion is executed on special purpose hydraulic presses with long strokes, adjustable force, and speed. Nonetheless an ordinary hydraulic press can perform extrusion work within the limits imposed by its stroke, tonnage, and table height as loading and unloading of long workpieces requires considerable space between press table and ram (daylight). The clear space underneath table determines the maximum finished workpiece length which can be unloaded after extrusion.

F8.00 COLD FORGING TOOLS

Bar stock can also be used for cold working (forging) of bars and rolled sections. The process is used mainly for increasing cross-section of bars to form rivet and screw heads. Special purpose presses for cold forging are called headers. Fully automated mass production headers have arrangements for automatic feeding, cutting, and loading bar-stock into the header. The ram, called header, holds the die for cold forging the head (Fig. F14).



(a) Bar cut off and transfer arrangement in cold header



(b) Cold forging rivet head in 2 operations

Fig. F14 Cold forging bars on heading machine

Cold working causes strain (work) hardening and reduces ductility. Smaller grain size promotes better cold working. With proper tools and lubrication, good surface finish and IT 13 grade precision is feasible.

F8.10 Deformation Limits

The diameter of bar can be increased to two and a half times the bar size in a single stroke. The increase possible in the following operations is lower due to strain (work) hardening. Second operation can expand the head diameter only to 1.8 times the head diameter formed in the first operation. The possible increase is even lesser only 1.33 times in the third operation. The following table summarizes the process limitations.

Table F1 Percentage Increase Possible in Cold Heading

Op. no.	% Increase	Head dia
0	0	16 (Bar ϕ)
1	150	40
2	80	72
3	33	96

The bar remains stationary while the first, second and third operating heading dies are brought in operating position by linear indexing mechanism in cold heading machines. These machines are also provided with arrangement for ejection of the cold-forged workpiece.

The bar overhangs beyond the stationary die, and is subjected to buckling. So for the bar overhang should be limited to two and a half times its diameter.

Being feminine in shape both header tool as well as the stationary tool are called dies. The dies correspond with the finish/intermediate shape of the workpiece. The mounting dimensions as well as the thickness of dies should be compatible with the heading machine stroke and shut height (gap). Dies can be made of high carbon high chromium steel and hardened to RC52 to 58 for forming. Cut off blades should be hardened to RC 58 – 62.

G

Press Tool Components

This section describes the various designs of press tool components used in the industry. Most of the components have already been used in various press tools illustrated in earlier sections. As such, the figures in this section have been simplified to highlight the functioning principles. At the same time the text cites the applications in the press tools illustrated in this volume.

31.00 SHANKS

The major function of the shank is to locate the press tool on the machine. The ram has got a seventh grade (*H 7*) location hole with a transverse clamping screw (Fig. G1). The shank location diameter should be easy running fit (*f8*) in the ram hole. The stripping load on top tool tends to pull the shank out of the ram hole. So the shank is clamped by the transverse clamping screw housed in the ram. Shanks are often filed or milled a flat in front to provide a clamping face for the transverse screw

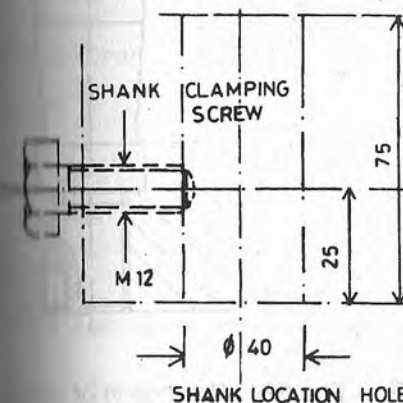


Fig G1 Shank location and clamping arrangement

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This section describes the various designs of press tool components used in the industry. Most of the components have already been used in various press tools illustrated in earlier sections. As such, the figures in this section have been simplified to highlight the functioning principles. At the same time the text cites the applications in the press tools illustrated in this volume.

31.00 SHANKS

The major function of the shank is to locate the press tool on the machine ram. The ram has got a seventh grade (*H 7*) location hole with a transverse clamping screw (Fig. G1). The shank location diameter should be easy running fit (*f8*) in the ram hole. The stripping load on top tool tends to pull the shank out of the ram hole. So the shank is clamped by the transverse clamping screw housed in the ram. Shanks are often filed or rolled a flat in front to provide a clamping face for the transverse screw

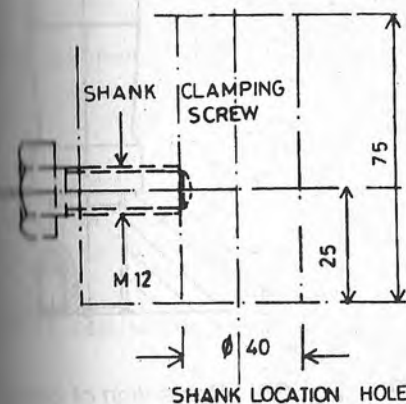


Fig. G1 Shank location and clamping arrangement

[Fig. G2]. It is convenient to make the flat inclined [Fig. G3]. The angle of the inclination should be such that shank is pulled up into the ram hole when the transverse clamping screw is tightened. This ensures that the top bolster face positively touches the ram face, and transmits the press energy to the tool. Shanks can be conveniently tapered up in the clamping length (Fig. G4) for positive contact between top bolster and ram. Tapered position and length are determined by the size and position of the clamping screw. There should be adequate clearance below and above the transverse clamping screw as shown in Fig. G4.

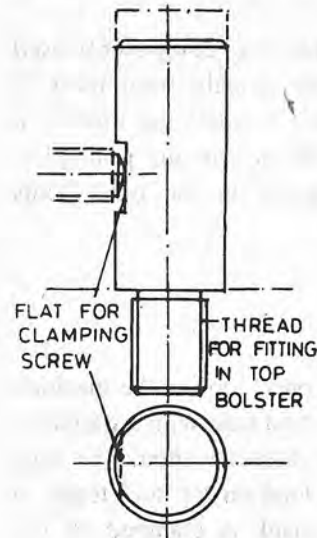


Fig. G2 Shank with a clamping flat

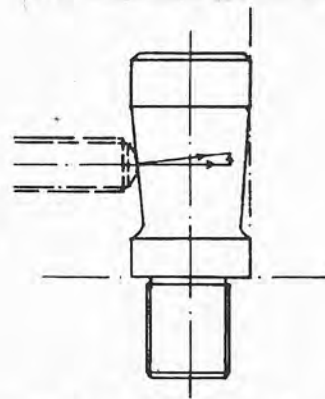


Fig. G4 Tapered shank for positive contact between ram and top bolster faces

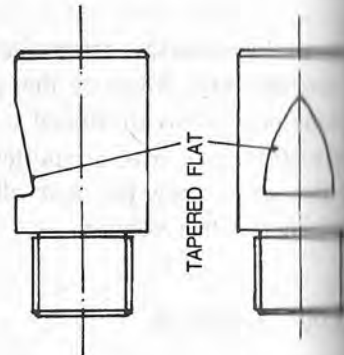


Fig. G3 Shank with tapered flat for clamping screw

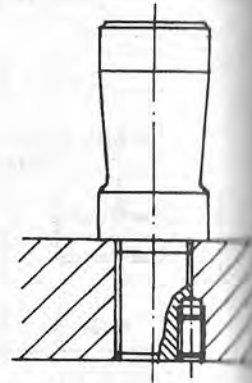


Fig. G5 Prevention of loosening of shank on threads

Shanks are generally threaded at the lower end of assembly in the top bolster. One shank can be used for a number of press tools by keeping the mating threads in the top bolsters of same size.

It should be remembered that the threads on the shanks cannot withstand the full cutting force necessary for the operation. The thread should, however, be capable of withstanding the stripping and ejection loads, i.e. ten per cent of operation tonnage. Thus a shank for a 50 tonne press should have threads strong enough to withstand 5 tonne force safely. Sect. M20.01 states the strengths of standard metric threads.

When a shank is used on a tool aligned by pillars and guide bushes, loosening of shank on threads does not affect the operation of the tool. Tools relying on press ram accuracy for alignment of top and bottom tools should have keyed shanks. A grub screw fitted half-half in the shank and the top bolster prevents loosening of the shank [Fig. G5]. This is necessary as loosening of shank and ensuing rotation of the top tool out of alignment with the bottom tool can damage the press tool in operation.

Compound tools for circular rings generally house a piercing punch at the centre of the top tool. Consequently you can not have a weakening threaded hole for shank above the piercing punch. As a matter of fact the central space is not available even for ejection knock-out pin. Such press tools generally use flanged shanks (Fig. G6). The triangular or square flanges are housed in matching slots milled in the top bolster.

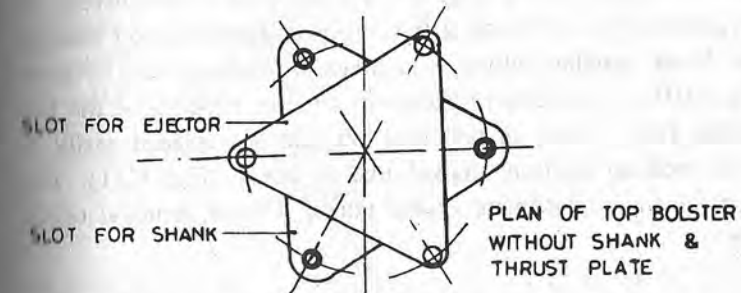
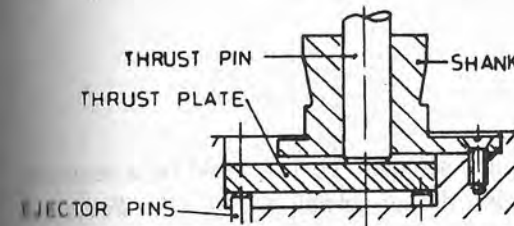


Fig. G6a Triangular flanged shank Assy

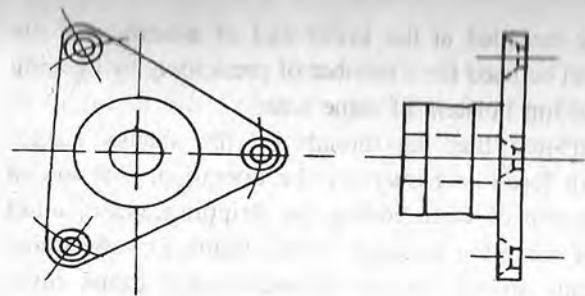


Fig. G6b Triangular flanged shank

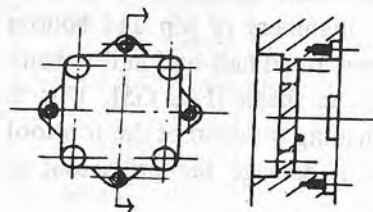


Fig. G6c Bolster for square flanged shank

There is another offset slot for the thrust plate underneath the shank slot.

Fig. M9 shows commonly used flanged shanks. The stripping strength of the shank is equal to the total tensile strength of all the shank fixing screws.

G2.00 PUNCHES

G2.10 Piercing Punches

These are often made parallel and straight. There should be a retaining collar at top to prevent extraction during stripping (Fig. G7). For small size punches a stepped design (Fig. G8) can be used. Alternatively, an insert type punch (Fig. G9) with a thrust pin and unhardened housing can be used. Small punches subjected to frequent breakages can be made flanged (Fig. G10) to facilitate replacement without removal of the tool from the press. Bigger sizes of punches, too, can be replaced easily by making their locating portion shaped like a shank (Fig. G11). This permits removal and replacement of the punch without removal of the tool from press.

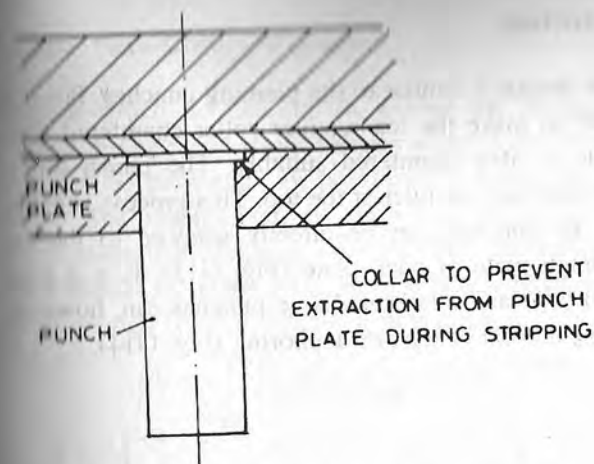


Fig. G7 Straight piercing punch with retaining collar

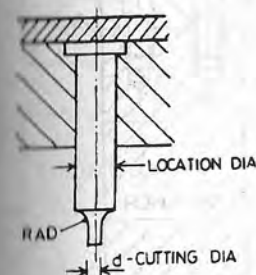


Fig. G8 Stepped punch

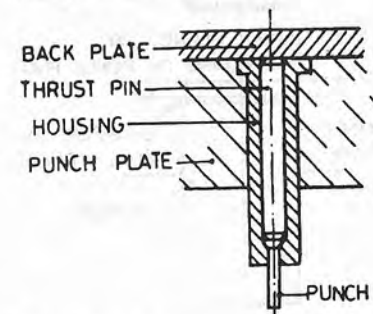


Fig. G9 Insert punch with thrust pin

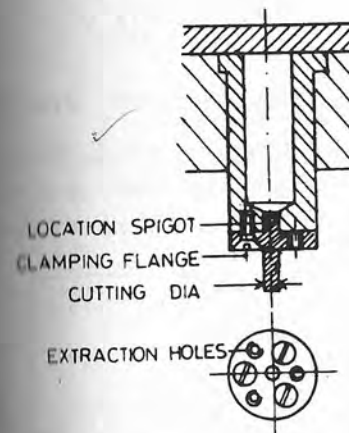


Fig. G10 Flanged quick change punch

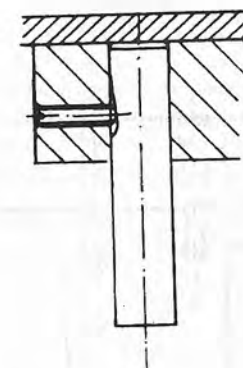


Fig. G11 Bigger quick change punch

G2.20 Blanking Punches

For round punches, the design is similar to the piercing punches. For odd shapes, it is convenient to make the top retainer collar chamfered (Fig. G12). The punch plate is also chamfered suitably. The punch top is hammered to form the retaining chamfer at the top. This process is called peening. Bigger sizes of punches can be directly screwed to the top bolster without any punch plate or back plate (Fig. G13). It is a good practice to anchor such punches in bolster. Large punches can, however, be secured with two big dowels instead of anchoring (Fig. G14).

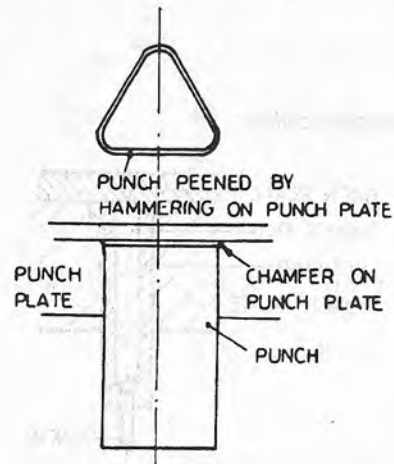


Fig. G12 Chamfered blanking punches

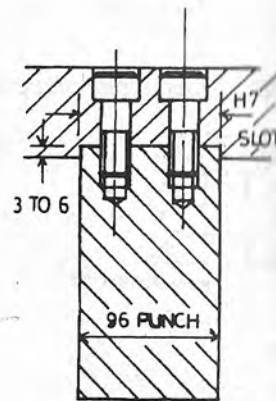


Fig. G13 Anchoring blanking punch

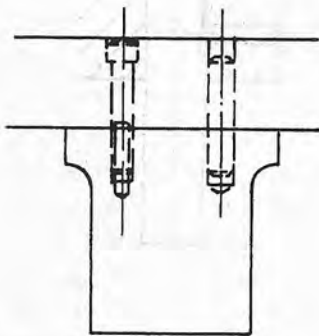


Fig. G14 Fixing large blanking punches by screws and dowels

G2.30 Side-Cutting Punches

Punches which do not cut all around the periphery are subjected to bending in directions at right angles to the direction of cutting (Fig. G15). This can be prevented by providing a supporting heel on the bottom bolster. The punch should be shaped in such a way that the non-cutting part engages with the heel before cutting starts. The heel as well as the punch should be anchored in the respective bolsters. The heel should be sturdy enough to contain punch deflection to 0.0025 mm (Ref. Section 416.30).

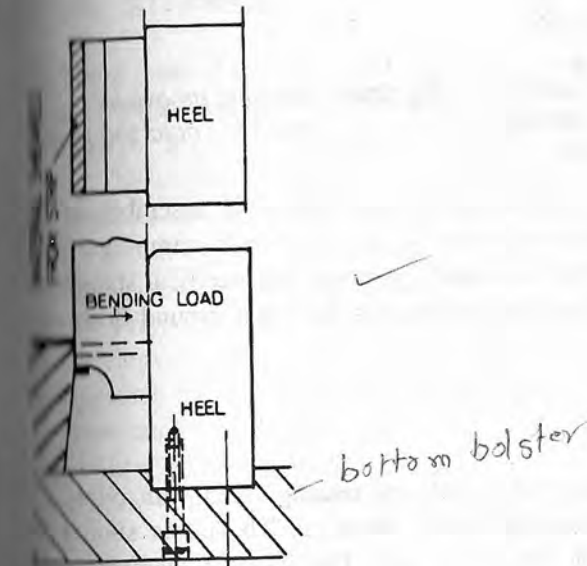


Fig. G15 Providing heel to reduce bending of side-cutting punches

Instead of providing heel the punch can be housed in a sturdy holder which can contain bending within 0.0025 mm (Fig. G16). The small punch insert can be screwed suitably to the strong punch holder.

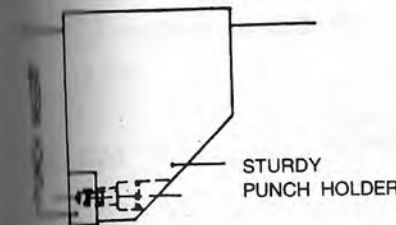


Fig. G16 Minimizing punch deflection by using sturdy punch holder

G2.40 Tiny Punches

Small, slender, odd-shaped punches can be dovetailed in punch holder. Retention is accomplished by making the rear seating face tapered to 2° – 5° (Fig. G17). This prevents extraction of the punch from the punch

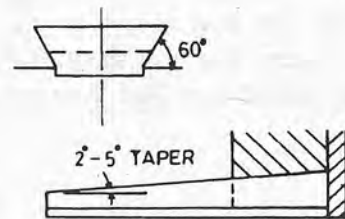


Fig. G17 Mounting tiny piercing punches in electrical stamping tools

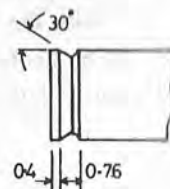


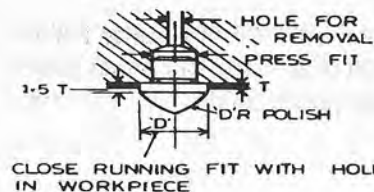
Fig. G18 Caulking groove in stamping notching punch

plate during stripping. This design is used widely in assembly of the piercing punches in compound tools for electric motor stampings.

Fig. G18 shows the end of a notching punch for electrical stampings. The end is caulked into the punch plate, and the top is ground flush with the punch plate.

G2.50 Pilots

Blanking punches in progressive tools are usually fitted with pilots for precise positioning of the strip before blanking. The pilots should be chamfered or rounded at the entry point. The locating diameter need



(a) Press fit pilot



(b) Screwed pilot



(c) Pilot for blind holes

Fig. G19 Press pilots

not be longer than one and a half times sheet thickness. This diameter should be close running fit (ϕ) with the pierced hole it centralizes. The strip should fall off the pilot by gravity. Pilots can be made press fit or assembled by screws (Fig. G19). Pilots wear fast and need replacement. As such there should be a provision for easy removal, and replacement of the pilots. This can be accomplished by providing a through hole above the pilot so that it can be hammered out from above. Alternatively, the pilot can be provided with a tapped hole which can be used for extraction from the punch.

G3.00 STRIPPERS

Strippers remove the strip from the jammed punch. Strippers arrest the strip upwards during upstroke of press. Fig. G20 shows a simple fixed stripper for a piercing punch with the strip arrested during upstroke of press. The stripper is also used to support and guide the piercing punch. A common stripper can be used in gang punching. Strips/sheets thinner than 1.5 mm can be worked better with spring strippers (Fig. G21). The spring stripper is fitted to the top tool. When the press ram is up, the spring stripper is held a few millimetres below the punch level by compression springs and retainer screws. During downstroke the stripper touches, and presses the thin strip/sheet flat against die before piercing/blanking, commences. During upstroke the springs push the strip off the punches. The top bolster thickness should be sufficient to provide room for vertical movement of the retaining screws during the downstroke.

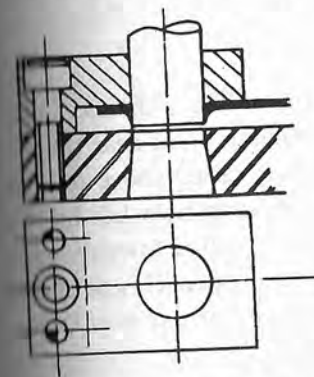


Fig. G20 Fixed stripper for piercing

It is convenient to use rubber pads instead of springs. Care should be taken to see that excessive force is not wasted in pressing the rubber which can provide thrust up to 700 N/cm^2 area of its cross-section. Fig.

B9b in Sect. B3.03 gives proportions of urethane rubber stripping bushes for piercing punches.

Drawing tools used in single action cranked presses use rubber pads for holding the blank under pressure during drawing. The blank holding pressure ranges from 25% to 40% of the drawing pressure. Sect. M14.00 gives blankholder pressures used for various materials. Strippers used in drawing tools are usually called blankholders.

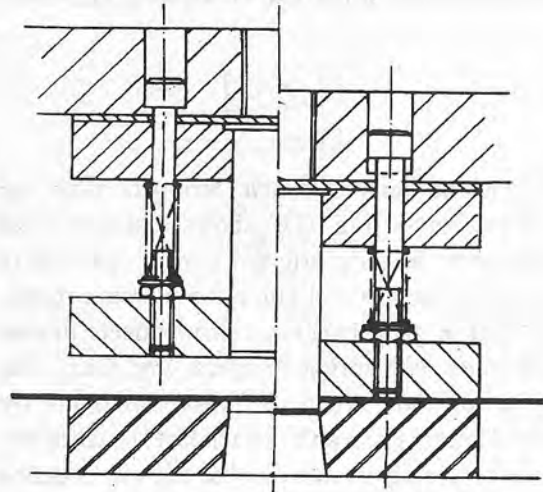


Fig. G21 Spring stripper

G4.00 STOPPERS

G4.10 Forward Stop (Fig. G22)

This stop consists of a flanged pin screwed and dowelled to the die. Long odd-shaped flanges are necessary to avoid weakening holes near the die cutting edge. After blanking one piece, the strip is raised above the top face of the stopper to feed it towards right. The scrap hole left by the blank is dropped onto the stopper, and the strip is pulled towards right till the left hand edge of the scrap hole touches the stopper. This positions the strip for blanking the next piece. The productivity of this stop is less as the strip must be lifted and lowered for feeding.

G4.20 Backward Stop (Fig. G23)

This consists of a collared pin. The top of the collar is ground chamfered in direction of the feed. The inclination facilitates raising the strip above

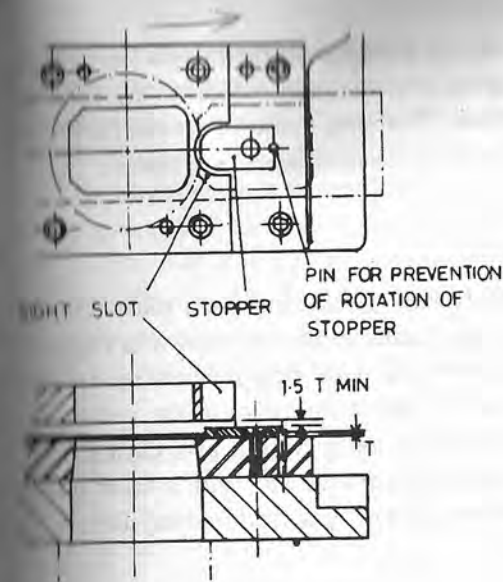


Fig. G22 Simple forward stop

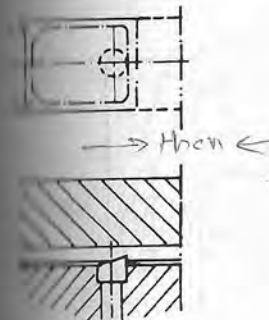


Fig. G23 Back stop

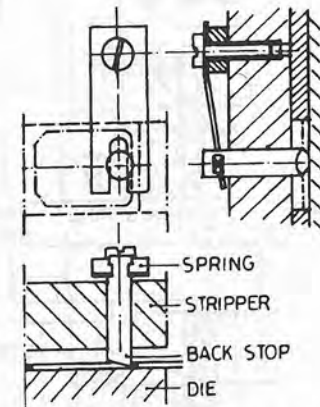


Fig. G24 Spring loaded back stop

stopper top for feeding. After blanking, the strip is pulled towards right. It climbs the incline and the scrap hole left by the previous blank falls around the stop. For positioning the strip for the next blank, the strip is pulled back towards left till the right hand edge of the scrap hole touches the stopper. Thus feeding involves forward and backward movement of the strip in addition to raising it to cross over the stop top face.

Lifting of the strip can be avoided by using an inverted spring loaded back stop in stripper (Fig. G24). The light strap spring yields when the scrap hole edge is pushed against the incline of the stop pin. The stop pin lifts against the spring, and the strip can be fed forward. The stop will rub

lightly the strip top under the spring pressure till the margin between the two blanks is crossed. After cross-over the stop automatically falls into the scrap hole under spring force. The strip must be pulled backwards towards left to touch the stop before the next piece is blanked.

G4.30 Trigger Stops

These are automatic stops used in high production press tools. Conventional press tools use a trigger stop similar to the one shown in Fig. G25. The trigger is pivoted in the stripper. The pivot hole is chamfered at both ends to leave just 0.5 mm straight land at the pivot at the centre. The chamfer allows the trigger to tilt about the pivot pin axis during operation. The stripper, too, is provided with a wide slot with a taper on one side to allow the trigger to tilt as shown by a chain-dotted line in the enlarged plan.

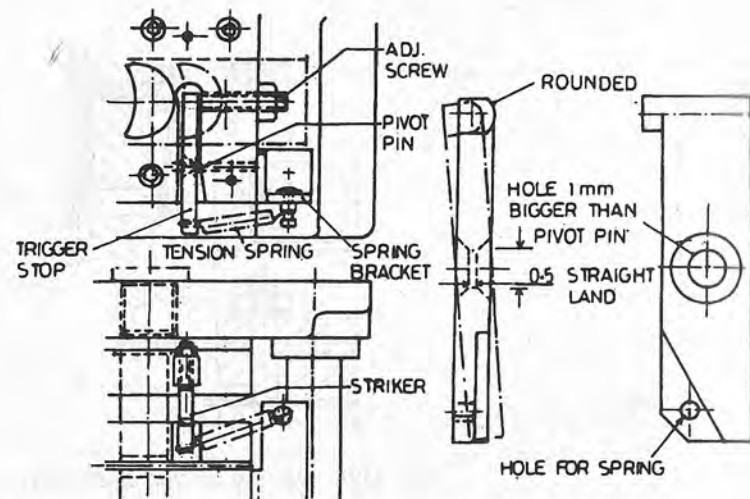


Fig. G25 Trigger stop

One end of the trigger is attached to a light tension spring which pulls it upwards as well as towards right. As a result, the stop end of the trigger is pushed downwards and towards left under the spring pull. The top tool carries a striker screw which hits the spring end of the trigger during downstroke of the press. When the spring end is pushed down, the stop end of the trigger rises well above the strip top face. The tension spring pulls the spring end of the trigger towards the right causing the stop end of trigger to move towards left; above the top face of the strip.

As the striker rises in upstroke, the downward pressure on the spring end of trigger is removed; and the stop end descends on the strip top face and remains there under force of the tension spring. When the strip is fed towards right and the bridge between the two blanks is crossed, the stop end of the trigger descends in the scrap hole under the spring force. The strip is pulled towards right till the left hand edge of the scrap hole reaches the stop. The pull of the strip pushes the stop end towards right, against a light spring force, till the trigger touches the adjusting screw. The adjusting screw can be used to vary the pitch between the two blanks originally. Fig. B22a shows a blanking tool with a trigger stop.

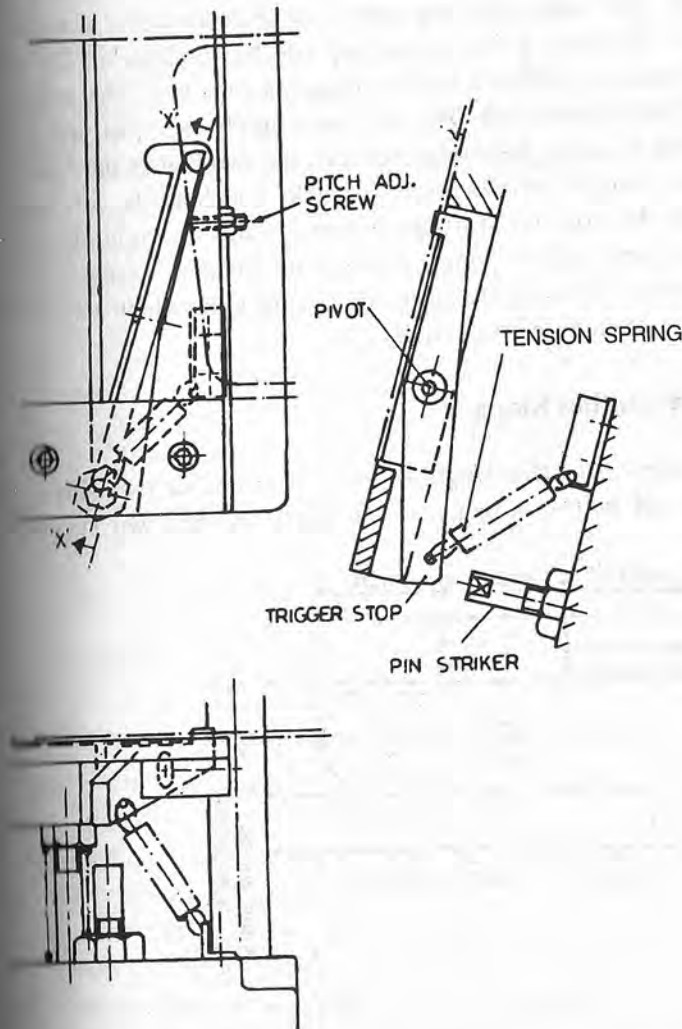


Fig. G26 Inverted trigger stop

Large inverted blanking tools use inverted trigger stop (Fig. G26). The inverted trigger is pivoted in a bracket fitted underneath the spring stripper. A pin serves as a striker. It is necessary to provide a slot in the stripper to allow for tilting of the trigger. The tension spring pulls the spring end of the trigger towards right and downwards. This causes the stop pin to move upwards and towards left in the stripper slot. The stripper houses the pitch adjusting screw.

The bottom bolster also carries the striker screw. During downstroke of press the stripper alongwith the inverted trigger is pushed down against stripper compression springs. The spring end of the trigger hits the stationary striker on the bottom bolster. The spring end of the trigger is pivoted up. This causes the stop end to move downwards. The tension spring causes the stop end to move towards left underneath the strip. During upstroke, the pressure on the trigger is removed. The stop rises to touch the strip underneath. The stop rubs lightly the strip underneath during feeding. Crossing the bridge between the two blanks the stop rises into the scrap hole left by the previous blank. Touching the left edge of the scrap hole the stop end of trigger moves towards the right against the tension spring force till the trigger touches the adjusting screw.

Trigger stops eliminate the need for raising strip which can be fed fast blindly to attain high productivity.

G4.40 Side-Cutting Stops

Side-cutting stops cut off a length of strip from one or two sides. The length of the cut portion is equal to the pitch between two successive

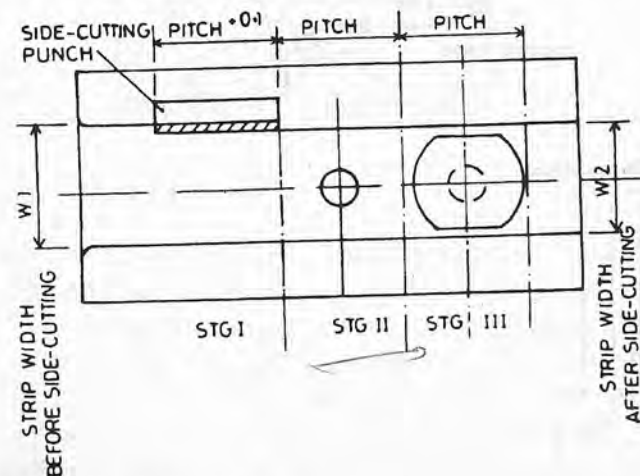


Fig. G27 Side-cutting stop

blanks (Fig. G27). The strip having width $W1$ is fed towards the right between the strip guides. The distance $W2$ between the guides beyond the side-cutting punch is less than strip width $W1$. Consequently, a fresh strip can be fed only up to the right hand end of the side-cutting punch, where it stops against the guide.

During downstroke of the press the side-cutting stop cuts off a length equal to pitch p of the strip to width $W2$.

When the ram goes up the strip is fed blindly toward right. It moves by distance p . Thus for every downstroke the strip side is cut to width $W2$ for length p .

As the strip side is cut off accurately, the guides beyond side-cutting stage guide the strip precisely. Thus side-cutting stop facilitates high speed production of precision blanks.

For even more accurate work, two side-cutting stops are used (Fig. G28). Cutting off both sides of strip precisely can provide accurate guidance of the cut-off strip beyond the side-cutting stage.

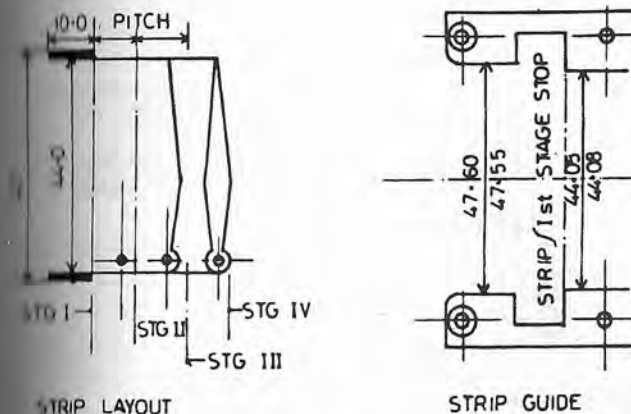


Fig. G28 Sizing strip with two side-cutting stops

When a blanking punch is fitted with a pilot the length of the side-cutting punch should be 0.1 mm more than the required pitch. The pilot in the blanking punch, however, pulls back the strip by 0.1 mm to locate it precisely with the blanking punch.

In spite of high productivity and accuracy, side-cutting stops are not used widely due to the inherent wastage of material due to cutting off the sides and resultant decrease in material utilization.

G4.50 Stage Stops

Multi-stage progressive tools require as many stops as the stages, particularly for strips cut from rectangular sheets. Fig. G29 shows stage stops for a four-stage progressive tool.

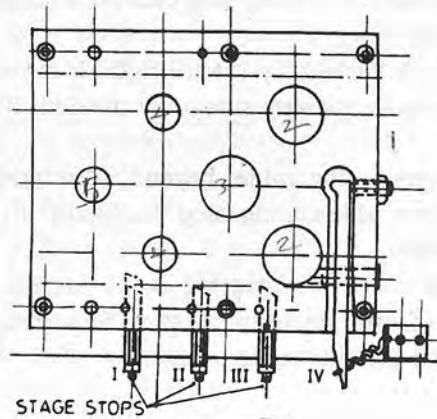


Fig. G29a Stage stops

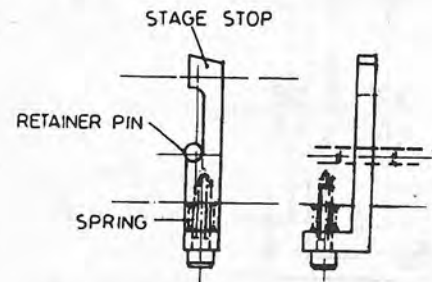


Fig. G29b Retention of stage stop

The first three stage stops should be self-retracting type. The stops are held back by compression springs and retainer screws to keep the strip passage clear in the normal run.

When a new strip is taken, the first stage stop is pushed in against the spring to protrude in the path of the strip as shown by chain-dotted line. The strip end is held against the first stage stop for piercing one hole in the stage. Then the first stage stop is released. The second stage stop is pressed inwards against the spring. The strip is fed towards right to touch the second stage stop and two more holes in the stage are pierced. The third stage stop positions strip for blanking the piece pierced in the first stage.

Then the third stage stop is released, and the strip is fed right till it touches the trigger stop for the fourth stage blanking. For the following blanks only the trigger stop is used for feeding the strip. *i.e. 5th*

G8.00 DIES

G8.10 Piercing Dies

Button inserts can be used conveniently for circular holes. The buttons should have collars on lower side to increase thrust area. The collar should be ground flush with the die holder. The top face of the button, too, should be level with the die holder (Fig. G30). There is about 3 mm

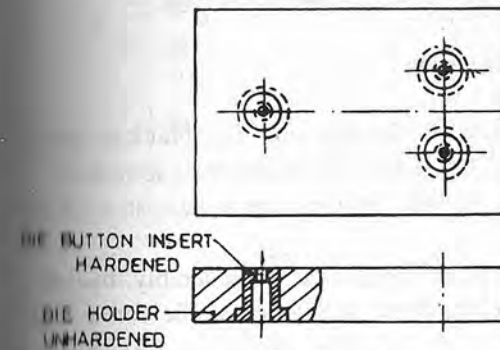


Fig. G30 Die button inserts

straight land in the die button bore. The bore below can be drilled 0.5 to 1 mm bigger. If there are numerous pierced holes it is economical to make a one piece plate die with number of die holes. The bore below 3.4 mm straight land can be C' bored 0.5 to 1 mm bigger than die bore to facilitate the gravitational fall of the scrap. Wall thickness between two holes should not be less than 3 mm. The margin should preferably be equal to die bore d . Design step [d] in Section A describes the method for calculating thickness and margins for cutting dies.

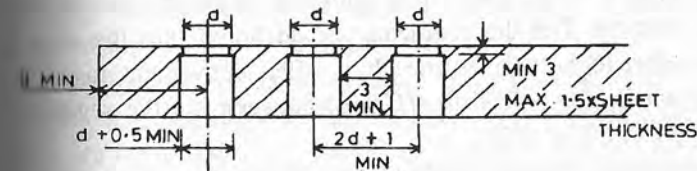


Fig. G31 Integral piercing die

G5.20 Blanking Dies

Blanking dies too, should have about 3-4 mm straight land at top. The hole below should be tapered down by $1\frac{1}{2}^\circ$ to 5° . This taper releases the compressive stresses on the jammed blank and facilitates gravitational fall through the die (Fig. G32). In stamping dies the fall through taper is kept less than a quarter degree, about $10'$ - $15'$ only.

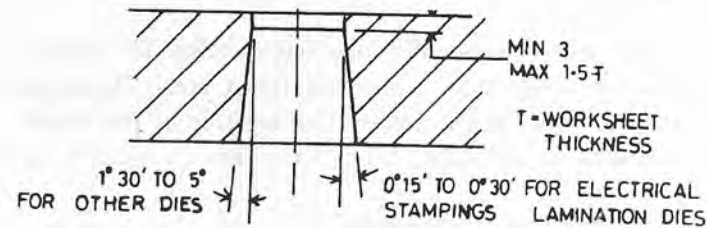


Fig. G32 Die cut-out for blanking dies

In compound tools die is fitted to the top tool. The blank is pushed up into the die during blanking, and is ejected by the press knockout. As the blank need not fall through the die, the die bore is kept straight. No fall through taper is necessary.

The manufacture of die can be simplified considerably by using segmental construction. Fig. B22a shows a segmental die for a semi-

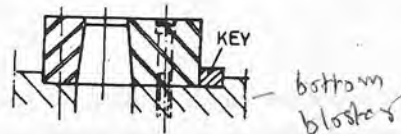


Fig. G33 Die segments with packing key

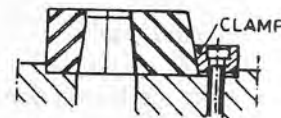


Fig. G34 Die segments with wedge clamp

circular blank. Dividing the die into two segments simplifies the manufacture. The left hand semicircular segment can be conveniently turned and ground on lathe and cylindrical grinder. The right hand segment consists of a rectangular piece with fall through taper at the central cutting portion. The die segments are anchored into the milled pocket and screwed to bottom bolster. It is often convenient to use a packing key to obtain the desired fit ($H7/m6$) between the die segments and the milled pocket [Fig. G33].

Segments needing frequent removal for sharpening regrinds are clamped with an angular clamp (Fig. G34). One of the segments as well

the clamp have got 5° - 15° angle on the side. The clamps exerts downward pressure on the segments securing them well against upward retraction.

Large dies are made from many segments which are secured in a sturdy die holder by Allen screws and dowels (Fig. G35).

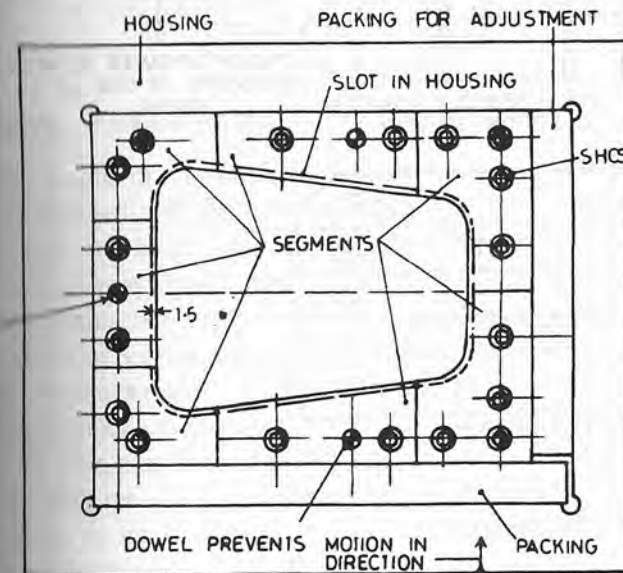


Fig. G35 Big segmental dies

The die holder takes most of the cutting load. The die segments merely serve as a lining providing hardened cutting edges.

88.00 DIE SETS

Contemporary industry uses pillar die sets extensively for alignment of top and bottom tools (Fig. G36). The pillars mounted in the bottom bolster engage into the close running fit ($H7/f6$) holes in the guide bushes carried by the top bolster to maintain the alignment. The top bolster is generally thinner than the bottom bolster which is subjected to bending in the unsupported part over the press table hole.

Although rear pillar die sets are most popular, many other designs are also available (Fig. G37). Figs N4, N5 and N6 in Standards Sect. N list standard sizes.

Die sets are specified by the clear die space available, shut height, and stroke required [Daylight].



taper of rod at end - pillars

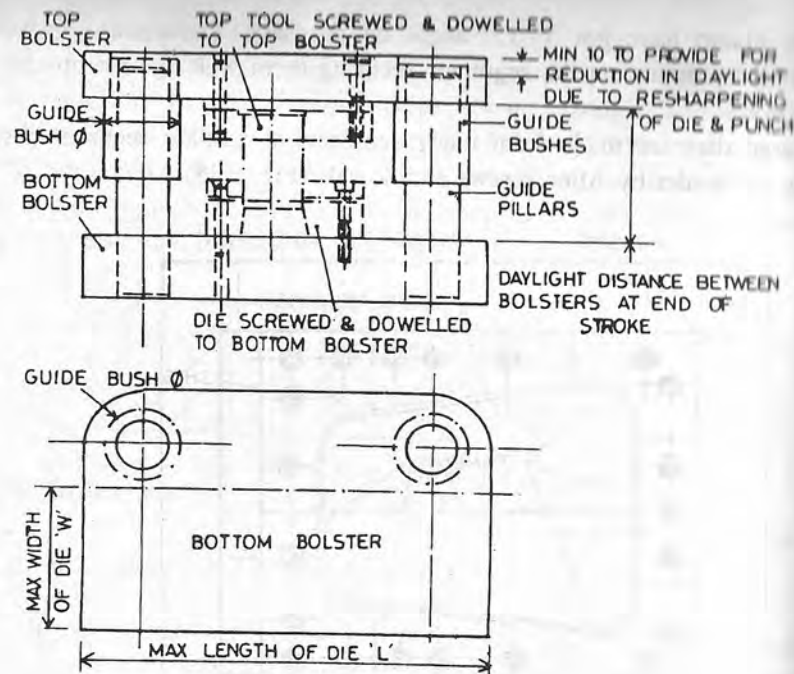


Fig. G36 Rear pillar die set

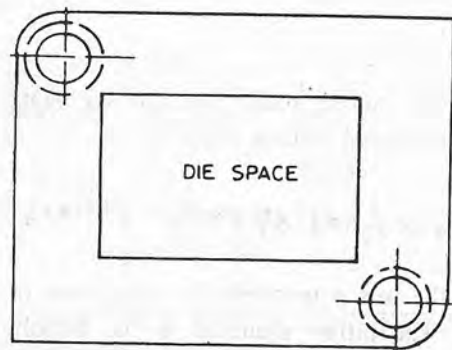


Fig. G37a Diagonal die set

The pillars should be at least 10 mm below the top face of the top bolster in the closed position of the press tool. The shut height of a press tool decreases with every resharpening grind of punch and die. The 10 mm gap allows for the decrease in height, and ensures that the pillars will not protrude out of the top bolster and damage the press ram face till the tool is consumed.

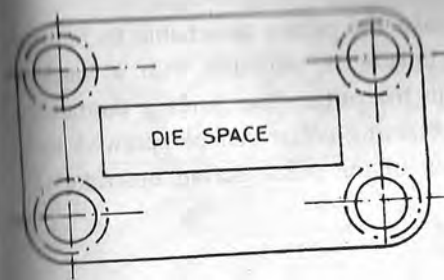


Fig. G37b 4 pillar die set

The length of the bush collar should be such that the pillars will remain engaged with the guide bushes when the press ram is up. At the same time, the bush collar should not touch the bottom bolster during operation. There should be a gap of at least 10 mm between the bush and the bottom bolster in closed position. This ensures that the bush will not touch the bottom bolster till the tool is consumed.

It is sometimes necessary to use telescopic bushes for long stroke presses without stroke adjustment (Fig. G38). When the press ram is up, the telescopic part slides down by gravity, and extends the bush length to engage with the pillars. Touching the bottom bolster face the telescopic part slides up into the outer bush as the distance between top and bottom bolsters decreases.

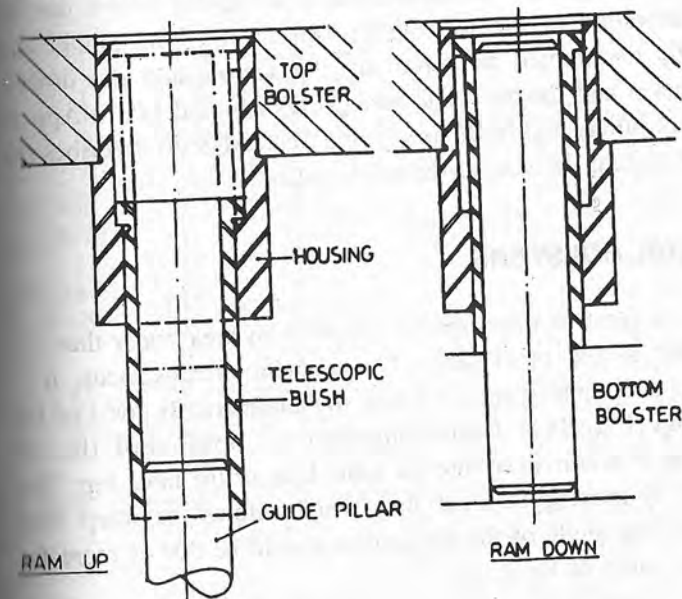


Fig. G38 Telescopic bush

It is sometimes necessary to make the pillars detachable to facilitate resharpener grinds. The bottom bolster is provided with a hardened liner which is push fit ($H7/h6$) with the pillar. The guiding diameter of the pillar is kept lesser so that a retaining collar can be screwed to the bottom bolster to prevent extraction of the pillar during upstroke (Fig G39).

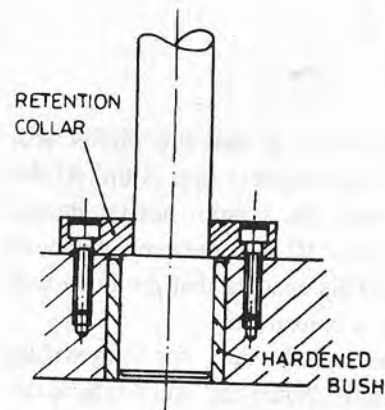


Fig. G39 Detachable pillar with retention collar

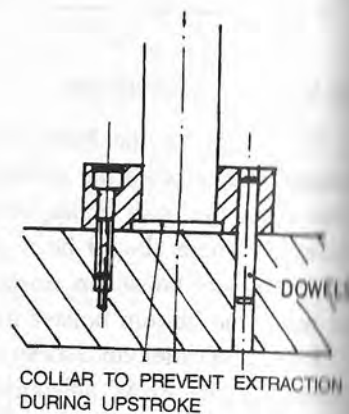


Fig. G40 Detachable pillar with dowelled housing

Alternatively the pillars can be housed in a bracket which can be screwed and dowelled to the top bolster (Fig. G40). The pillars and brackets can be disassembled by removing the screws and the dowels holding the bracket and the bolster together. Figs M4 and M5 in Appendix lists standard pillars and bush sizes while Sect. M19.20 describes the method for calculating the size of the guide pillars.

G7.00 SPECIAL BOLSTERS

In large tools, the scrap is often spread out over an area wider than the fall through hole in the press table. Under such circumstances, it is necessary to use additional special bolsters for automatic disposal of the fall through scrap (Fig. G41). Depending upon the position of the out of the range scrap it is conveyed into the table hole or the table top. This is accomplished by making inclined slots which allows the scrap slide down by gravity. The angle of the inclination should be 30° or more for easy gravitational slide of the scrap.

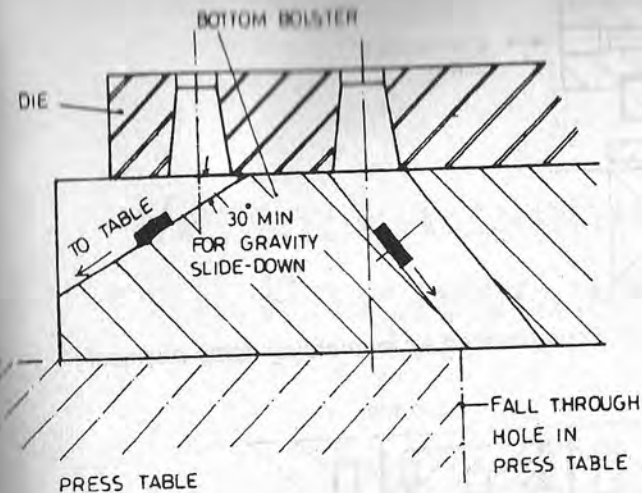


Fig. G41 Disposal of scrap outside fall through hole in press table

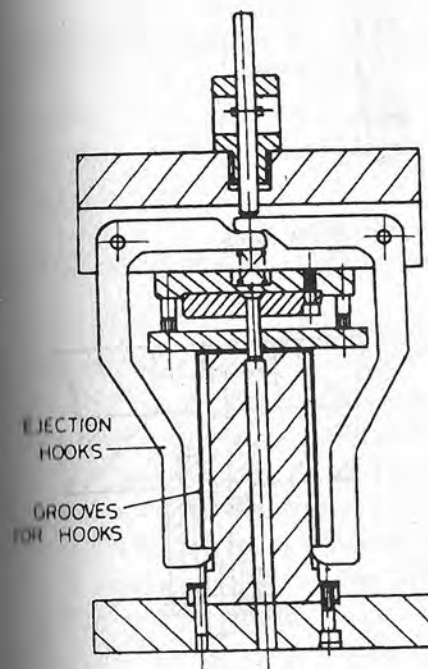


Fig. G42 Ejection by hooks in top tool

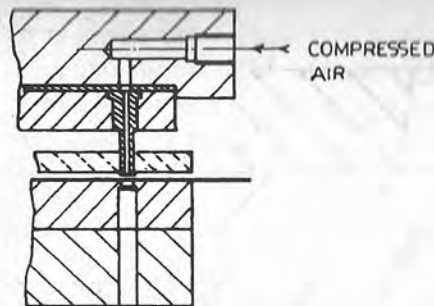


Fig. G43 Use of compressed air for piercing scrap disposal

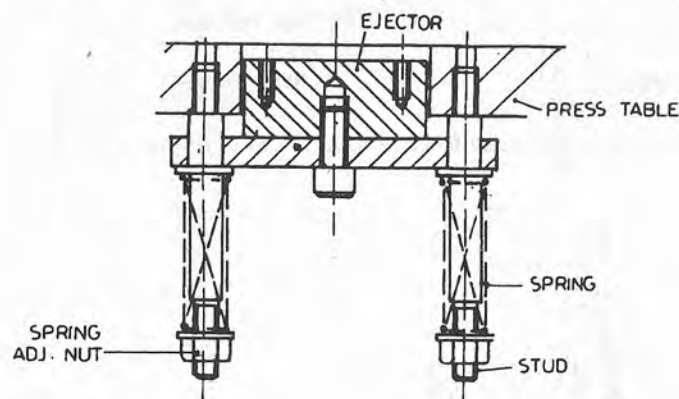


Fig. G44 Permanent common ejector for many tools

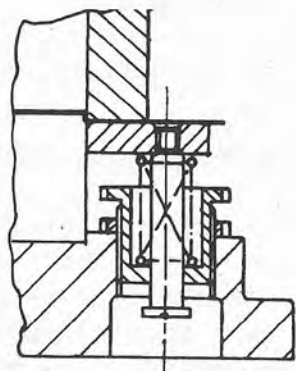


Fig. G45 Adjustment of pressure pad screws

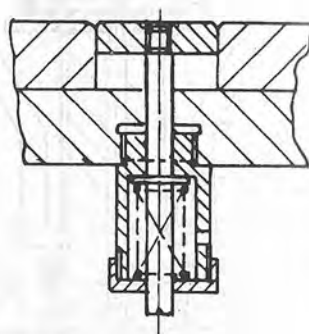


Fig. G46 Ejector plug

S. Notes

Versatile Combination Progressive Tools

Modern high speed, multi-ram, multi-station presses warrant sophisticated progressive tools which combine cutting, forming, and drawing operations in a single multistage versatile progressive tool.

H1.00 COMBINING CUTTING AND BENDING

Progressive tools also include the bending stage. Usually piercing and notching operations are carried out before bending. Obviously the cutting off and cropping, etc. should be the last stage.

H1.10 Progressive Tools for Angle

Fig. H1 shows a progressive tool for an angle with two holes in each arm. The figure also shows the strip layout. The first stage pierces all the four holes in the arms. Bending to angular shape is carried out in the second stage. The inverted 'V' die fitted to top bolster also serves as cropping punch. The feeding side of the punch cuts off the strip to required length before bending commences. The 'V' punch on the bottom tool is held level with die by springs, rubber pads or a die cushion. The 'V' angle should be adjusted suitably for spring back.

Multi-station transfer presses are equipped with forming stations with die cushions. These can be conveniently used for ejection of bent workpiece.

H1.20 Progressive Tool for Connector

Fig. H2a shows a progressive tool for an electrical connector. The right hand corner shows the workpiece with a developed blank in chain-dotted

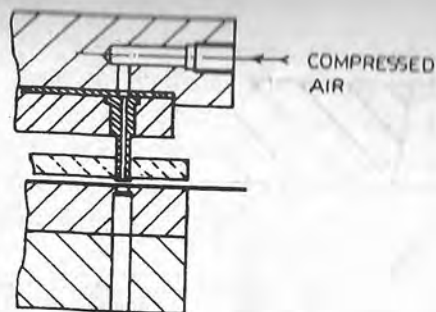


Fig. G43 Use of compressed air for piercing scrap disposal

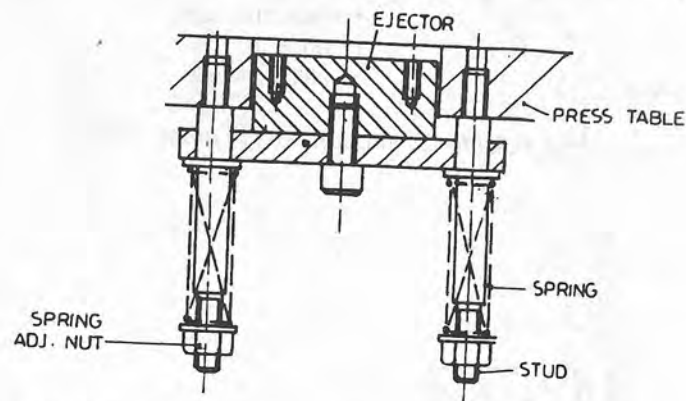


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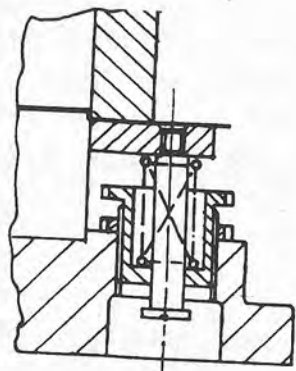


Fig. G45 Adjustment of pressure pad screws

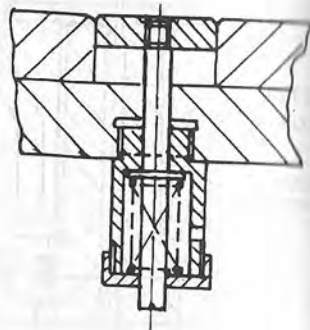


Fig. G46 Ejector plug

H

S. Notes

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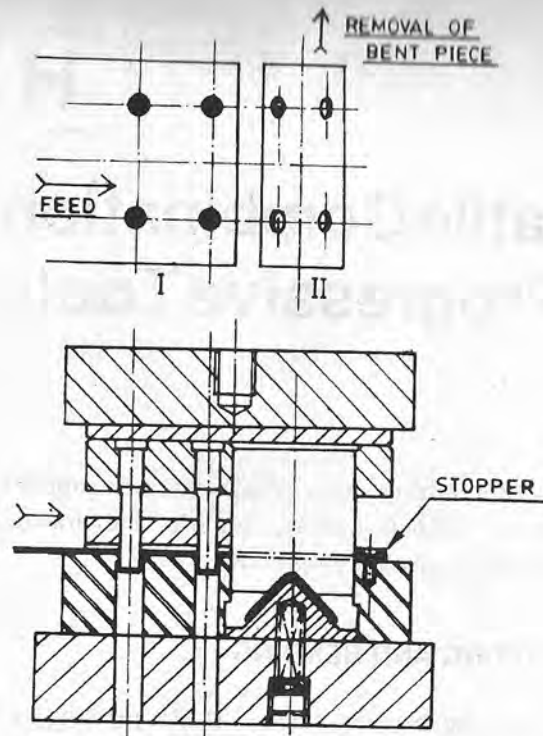


Fig. H1 Progressive tool for an angle with four holes

line. Fig. H2b shows the strip layout for the tool. The first stage trims the strip with a side-cutting stop. The second stage pierces two dia 1.3 mm holes and the central 5.75 mm hole. The third stage shears 1.5 mm radius and one side of 3 mm wide arms. The fourth stage shapes the other side of the arms. The fifth stage bends the 3 mm wide arms to 7 mm depth and 12 mm width. Note that it is an air bending operation without bottoming. Consequently the depth 7 mm of the workpiece is obtained by precise control of downstroke position of the bending punches (item 15 in Fig. H2a). The bending die (item 7) also serves as a half of the cropping die for shaping one side radius for dia 9.5 central portion. The fifth and the sixth stage shear dia 9.5 portion, and cuts off the finished workpiece from the parent strip.

It may be noted that the cropping die for the dia 9.5 comprises of just two collared pins with flats (Fig. H2c). The flats only are rounded at top edges to provide 0.5 mm corner radius for bending the 3 mm wide arms. A key (item 9) anchored in bottom bolster prevents rotation of the collared pins. The collar top can be ground level with die segments (item 5, 6) during resharpener. The edge radii of collar also need to be rounded periodically after some regrinds.

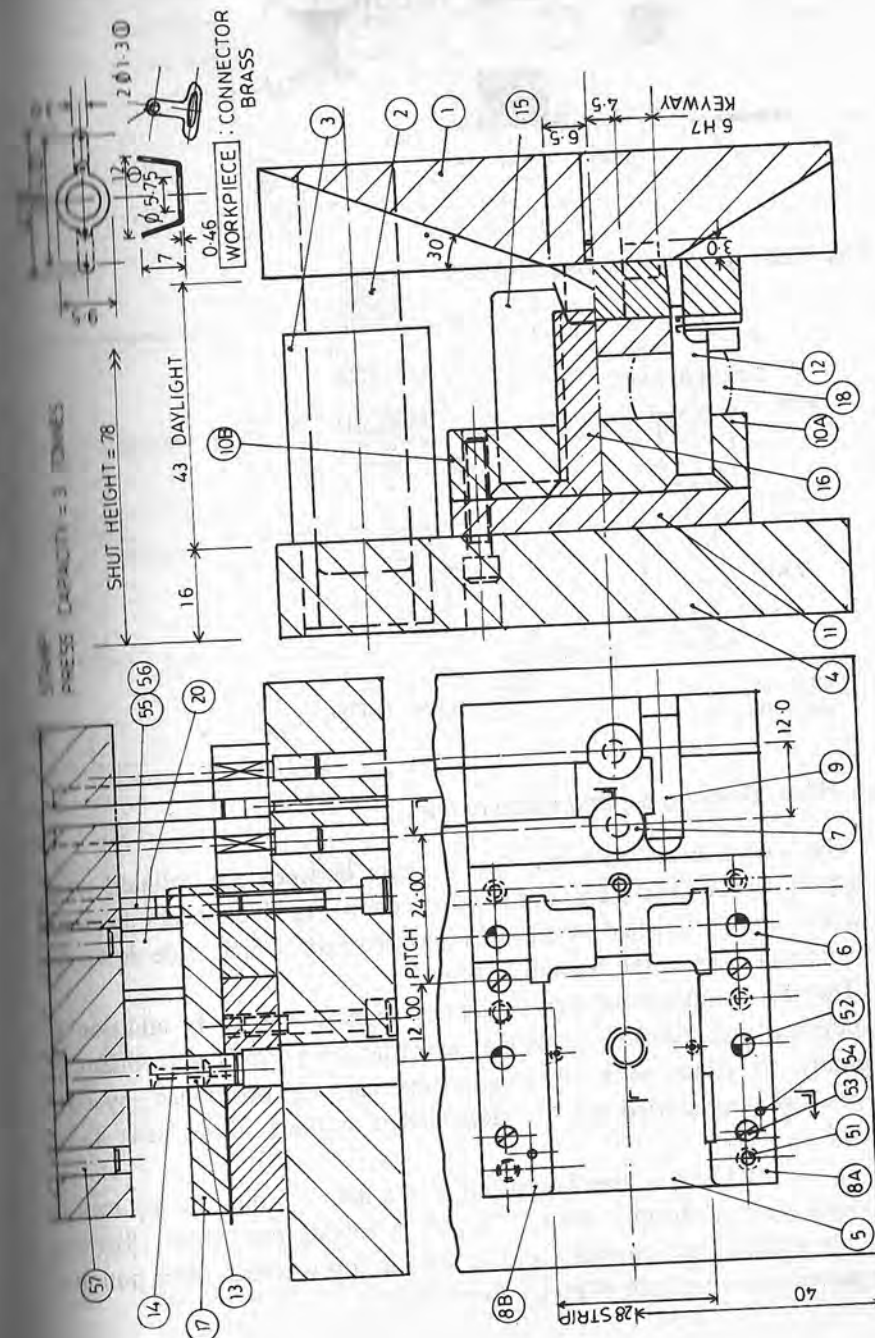


Fig. H2a Progressive tool for connector

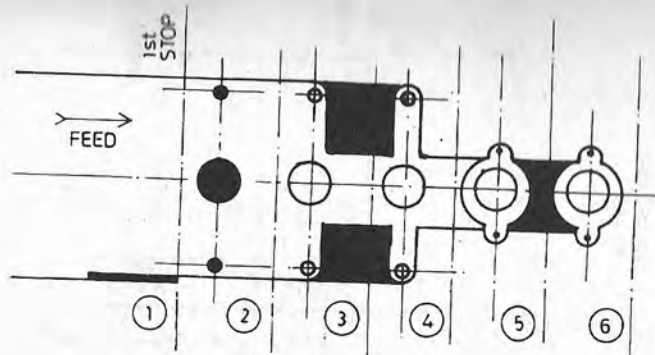


Fig. H2b Strip layout for connector

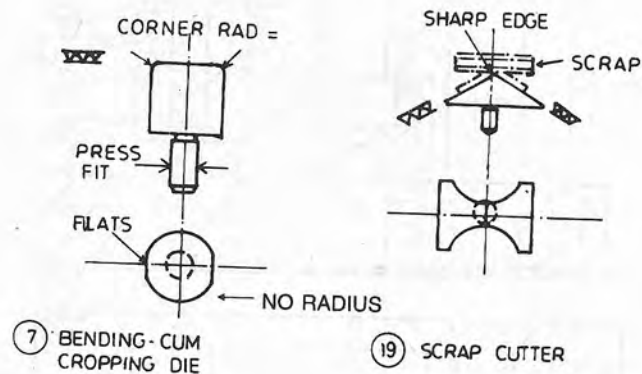


Fig. H2c Bending die and scrap cutter

The tool is provided with a scrap cutter between the collared cropping pins. Shaped like a chisel, the scrap cutter (Fig H2c) shears the scrap between the two finished workpieces into two parts which slide down the 30° inclined slots in the bottom bolster.

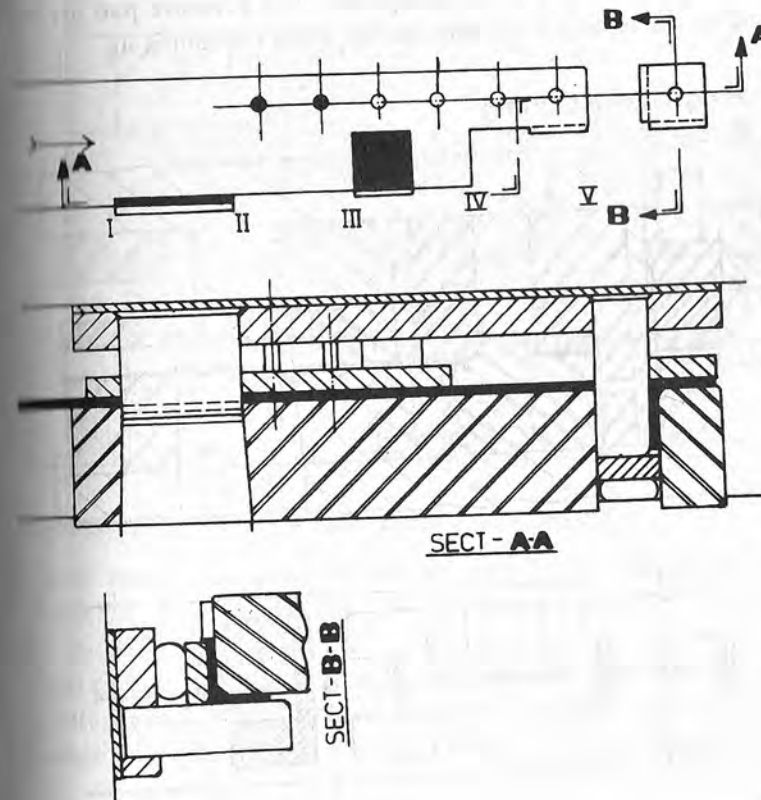
The die comprises of two segments: items 5 and 6. In addition to simplifying manufacture, segmental construction permits adjustment in assembly to exact pitch. The segments can be positioned by slip gauges/dial gauge, tried out and dowelled to bottom bolster after satisfactory try out.

As the thickness of the workpiece is less than 1.5 mm the top tool is provided with a stripper (item 17) with a rubber pad (item 18). The piercing punches are provided with collars at top whereas other punches are peened in the punch plate (item 10 B).

H3.30 Progressive Tool with Two Bends

When two bends are required, one of them must be effected first. The bent portion should not obstruct the feed path of the strip to the next stage. The workpiece is usually cut off before second bending starts.

Fig H3 shows a progressive tool for a workpiece with two bends. The first stage crops one side of the strip by a side-cutting stop.



EJECTION OF BENT PIECE

Fig. H3 Progressive tool for workpiece with two bends

The strip is pierced with two holes during the second stage. The third stage notches out the portion between two bent arms. The fourth stage bends the operator side arm to right angle. The fifth stage crops the feeding side arm to length before bending it to right angle. Note the pressure pad in bending die of the fifth stage. During upstroke of the press ram, the pressure pad ejects the bent component out of the die. The bent piece is pushed forward by the strip front during feed and slides down the slope to collect in the receptacle. The pressure pad for fifth stage bending die is held level with die top when the ram is up.

H1.40 Progressive Curling

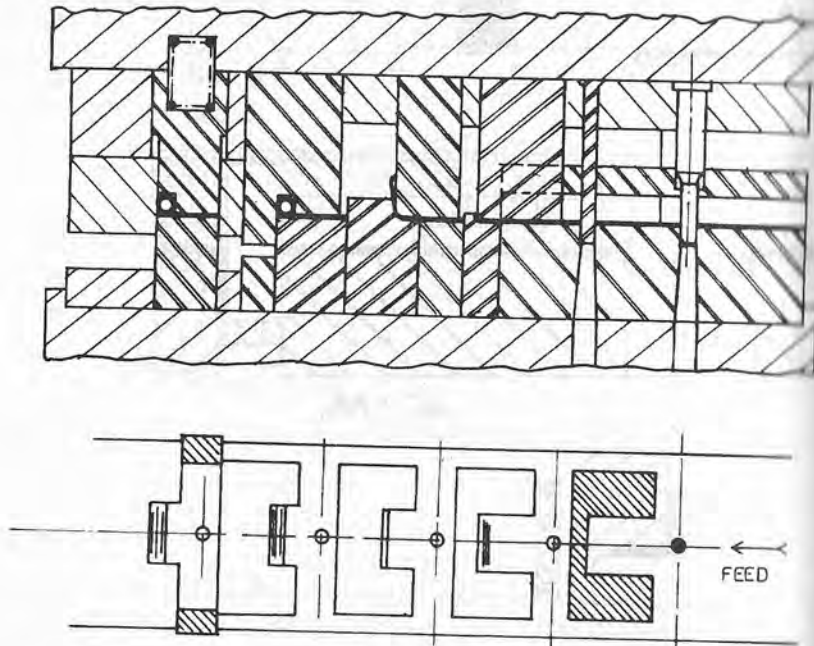


Fig. H4 Progressive tool for curled hinge

Fig. H4 shows a five-stage progressive tool for a hinge. In the first stage two holes are pierced. The 'U' shaped hole is pierced to free the bent part of the curled arm for progressive bending. The second stage lips the freed arm for curling. The third stage bends the lipped end to nearly 100° with horizontal. The fourth stage curls the arm while the fifth stage shears the completed hinge from the parent strip. It should be noted that the strip has to be lifted to clear the die projections for lipping (stage 2) and 100° bend (stage 3) dies. The width of die for lipping and 100° bend should be such that the die projections above strip level are smaller than

the cut-out created by U punch in stage 1. This cut-out increases in width due to bending and curling of central arm.

H1.50 Progressive Tool with Pivoted Bending Punch

Fig. H5 shows a progressive tool for a workpiece with two pierced holes and bends at both ends. The flat is touched against stop and cut off to

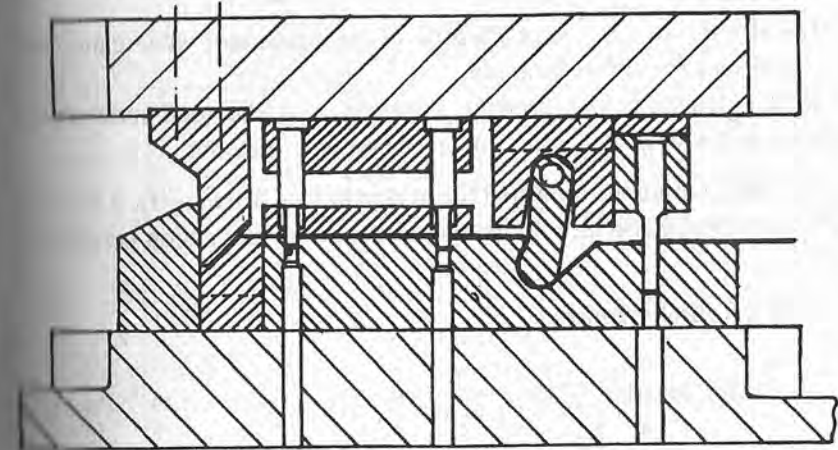


Fig. H5 Progressive tool with pivoted bending punch

length before the bending punches commence bending. The pivoted punch for 'U' bend (at right end of workpiece) slides down the inclined die to push the work-flat into the curved die. Simultaneously, the left hand end of work-flat is bent to a 45° angle by a fixed punch. A pivoted bending punch effects gradual bending. The pivot pin should be strong enough to withstand the bending force.

H2.00 CUTTING AND DRAWING PROGRESSIVE TOOLS

Combining the cutting and drawing operations is a tricky affair since during drawing the cut diameter reduces drastically while the pitch must remain unchanged for strip feed consistency. So the bridge connecting the cup must elongate permanently to compensate for increase in radial distance between the blank cut-out and the cup periphery.

H2.01 Bridge Design

The bridge cross-section should be such that the drawing force can stress the bridge beyond yield stress to permanent deformation.

Example H1 Find bridge width for a progressive drawing tool if the minimum drawing force is 20,000 N, the cup thickness is 2 mm and yield stress = 250 N/mm².

Solution Cross-section for all bridges = $\frac{20,000}{250} = 80 \text{ mm}^2$

If four bridges are used

$$\text{Bridge width} = \frac{80}{2 \times 4} = 10 \text{ mm maximum}$$

Usually the width is kept 75–80% of the maximum value calculated, i.e. 7.5–8 mm for above example.

Bridge length before drawing depends upon the total reduction in drawing and elongation limits of the workpiece material.

Example H2 Find the length of the bridge before drawing if a $\phi 30$ blank is drawn to $\phi 12$ cup with $\phi 22$ flange, if maximum elongation permitted is 30%.

Solution Radial increase = $\frac{30 - 22}{2} = 4$

$$\text{Bridge length} = \frac{4}{1 - 0.3} = 5.71 = 6$$

Fig. H6 shows a six-stage progressive tool for a flanged cup. It is an inverted drawing tool with punches fitted on the bottom bolster. The cup is drawn in five stages and the sixth stage pierces the flange with four holes. The seventh stage trims off the bridges to sever the cup from the parent strip.

Grinding cutting stages for resharpener decreases cutting die length while the drawing punch heights remain unchanged. To avoid bending of strip inordinately due to difference in level of cutting die and drawing punches it is necessary to provide shims under the cutting die to level its height. Alternatively, the drawing punches can be ground off from bottom, seating face by amount equal to reduction in cutting die length. Naturally, the length of the new drawing punches should be 3 mm more to provide the resharpener allowance.

It should be remembered that before feeding, the strip, along with partly formed cups, must be lifted to raise the cup bottom above the die to enable feeding strip forward. This can be simplified by using spring loaded strip lifting pins (Fig. H7) at various places in the long die. This will ensure that the strip is automatically raised as the ram withdraws upwards.

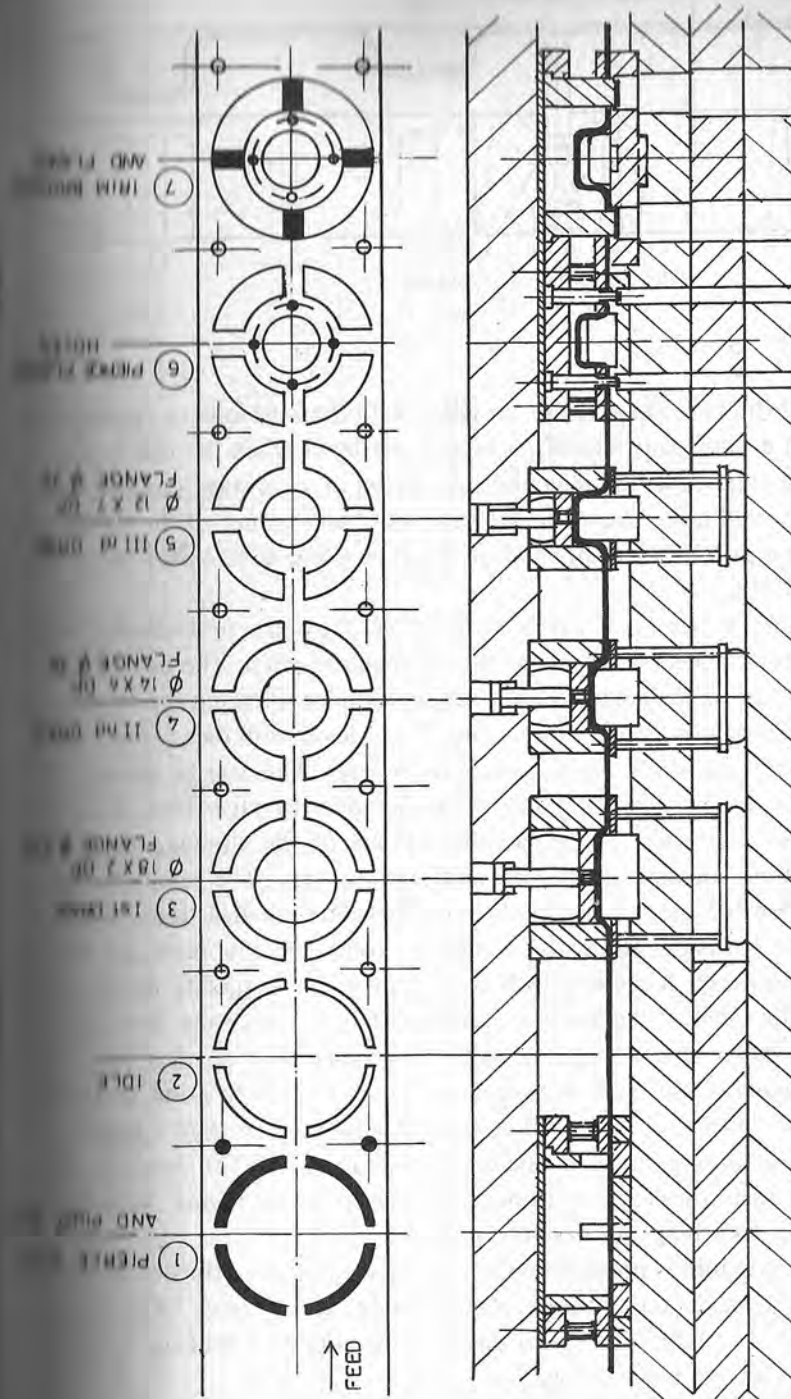


Fig. H6 Seven-stage progressive tool for a flanged cup

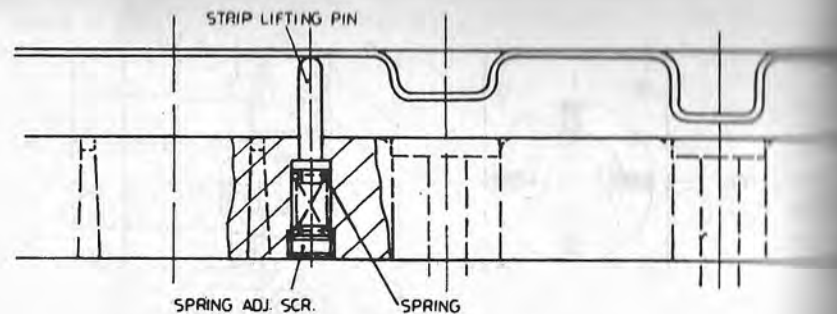


Fig. H7 Strip lifter

All drawing stations are provided with die cushions or spring/rubber loaded ejector pads which are held at die level when the ram is up.

Fig H8a shows die plan and strip layout of a six-stage progressive tool for the workpiece shown in the top right hand corner of the figure. The drawing punches are housed in a punch plate fixed to the top bolster (Fig. H8b).

The die has been divided into four segments to facilitate precise assembly of the various stages to the required pitch. The cutting dies (1 and 8) can be resharpened on a surface grinder. Piercing die '6' must be ground carefully to keep the locator '7' in level with dies (1) and (8).

Top faces of all the dies must be in level. This can be accomplished by putting shims/packing below cutting dies to raise their level after grind. Alternatively, the seating surface of the drawing die can be ground to equalize its height with cutting dies. The simplest way to resharpen the dies in Fig. H8b is to dismantle all dies from the bottom bolster. Disassemble items 6 and 7, grind the top (cutting) face of piercing die 6. Reassemble 6 and 7 and place it upside down on the magnetic table of the surface grinder. Similarly place the drawing die upside down on the magnetic table. Then place cutting dies 1 and 8 on the magnetic table with the cutting face at top. Now grind all the dies (1,3,6,8) level to resharpen dies 1 and 6 and equalize dies 3 and 8.

The cutting punches of the top tool (items 11,14,15) should be 3 mm longer than the longest drawing punch (13) to permit resharpening without disturbing the drawing punches.

The top tool is provided with a spring (or rubber) stripper which holds the strip sandwiched between strip lifters (2) ejectors (4,5); and the stripper. The strip lifters and ejectors are normally held up by spring/rubber pads or die cushion.

Resharpening progressive tools usually involves disassembly of some die elements. It is imperative to maintain level of all dies and the relative

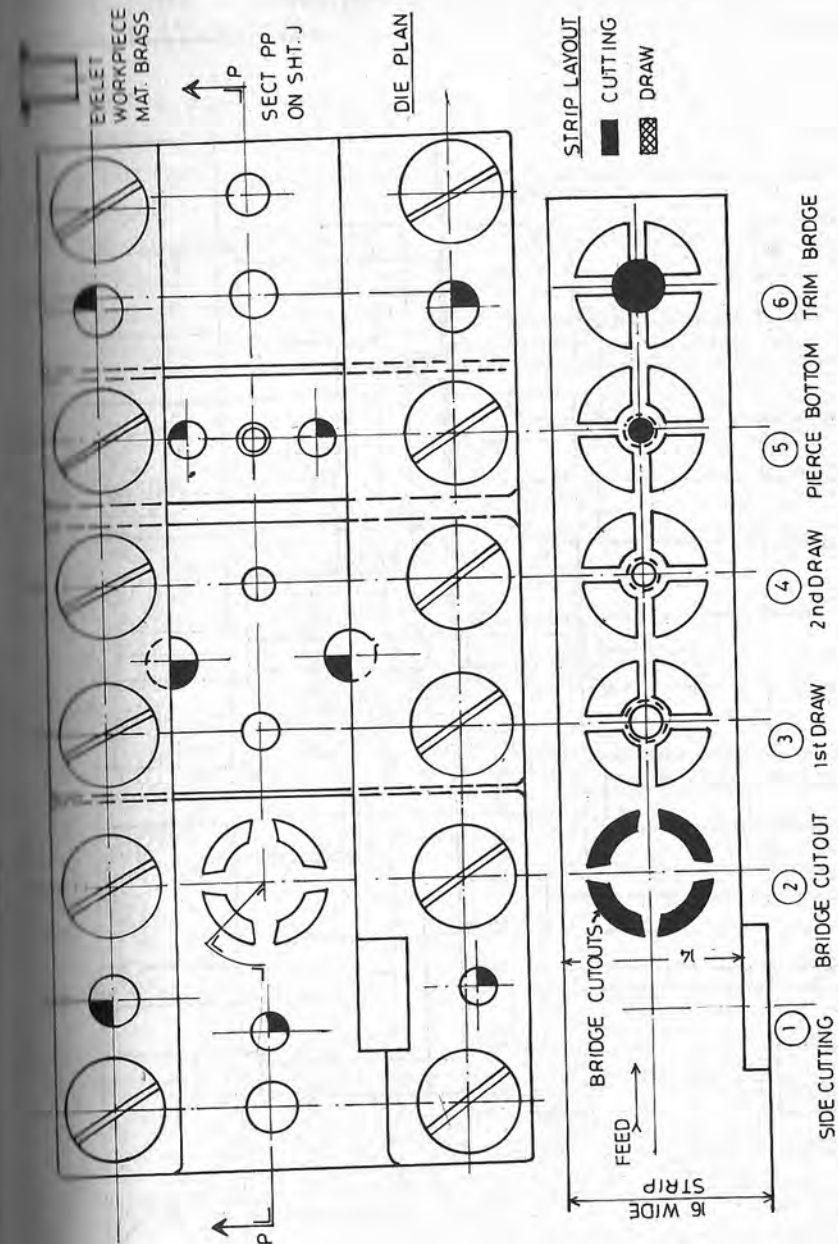
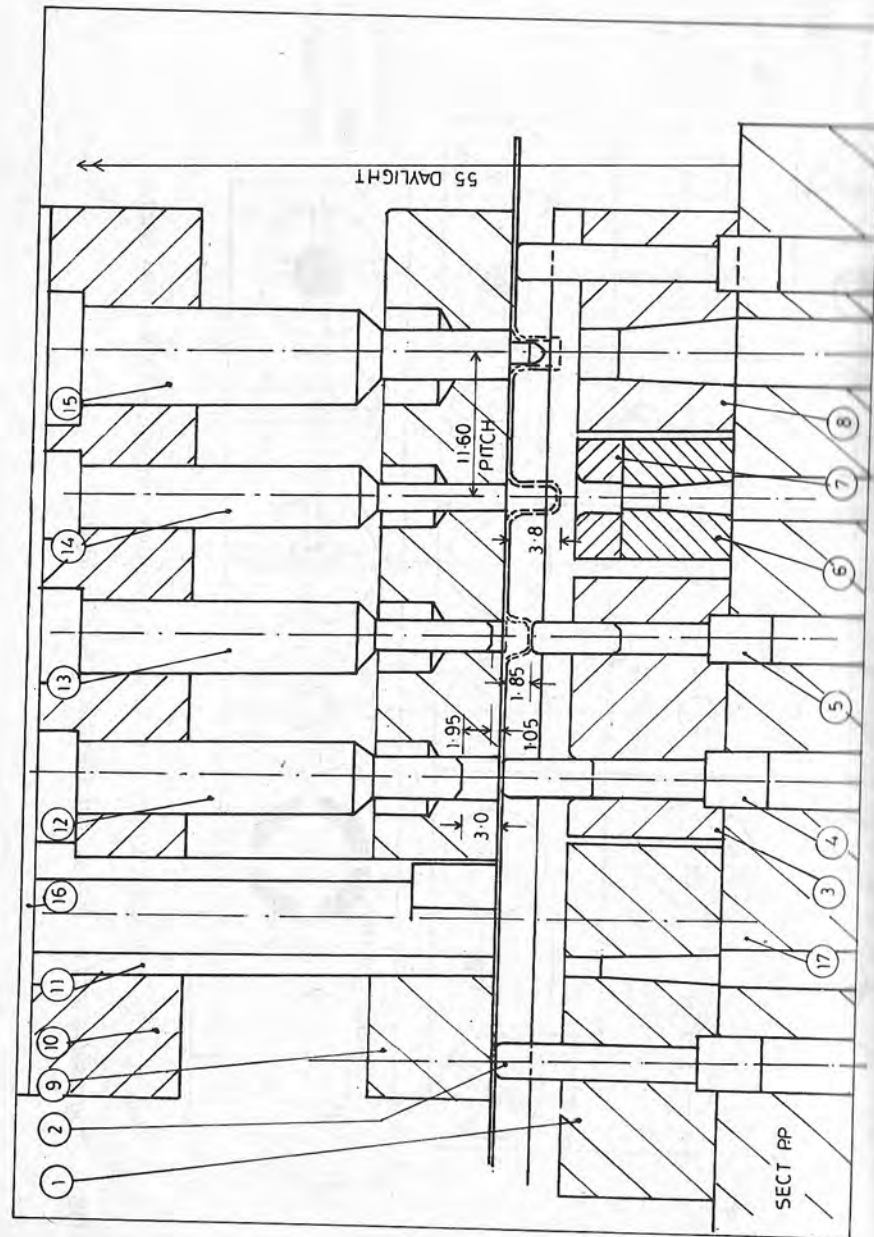


Fig. H8 Progressive tool for eyelet (a) Die plan and strip layout



difference in length of the drawing punches. Designers should endeavour to simplify resharpening by their ingenuity.

H3.00 PROGRESSIVE MANUFACTURE OF DRAWN CUPS ON MULTI-STATION PRESSES

Multi-station presses provide means for moving workpieces accurately by distances equal to pitch. But the pitch is constant for any specified press. For example Godrej 10 station transfer has got 100 mm pitch.

Naturally it will be wasteful to use 100 mm pitch and a progressive tool for much smaller (say) 30 dia cups. So multi-station transfer presses are provided with 'V' shaped grippers for transfer of partly drawn cups from station to station. All the grippers move by distance equal to pitch, release workpiece into die and return to starting position (Fig. H9).

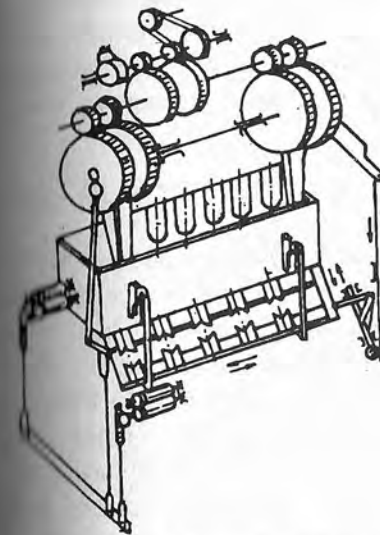


Fig. H9 Cup transfer mechanism in transfer presses

Transfer presses are provided with a blanking station and a double roll feed outside the main press frame. The blank is transferred to tandem drawing stations to draw cup progressively.

Tools for different stations are separate press tools which can be aligned accurately with different station rams.

Selection of Press

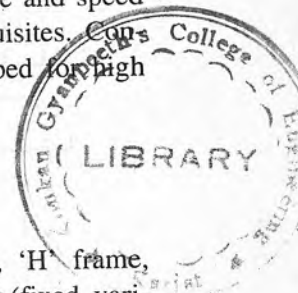
The first and foremost consideration for choosing a press is the tonnage required for the operation of the press tool. Similarly the table size, throat, stroke and shut height of the press should suit the press tool. We can mount and operate a press tool if the above requisites are met.

However, for optimum quality and productivity, the force and speed characteristics of press should also meet the operation requisites. Consequently, many special purpose designs have been developed for high volume products such as laminations and cups.

11.00 CLASSIFICATION OF PRESSES

Presses can be classified according to *shape* ('C' frame, 'H' frame, pillared), *table disposition* (inclinable, non-inclinable), *stroke* (fixed, variable), *number of slides* (single, double, triple action), *type of drive* (geared, non-geared, cranked, knuckle joint type, friction screw type), *method of actuation* (mechanical, hydraulic), *purpose for which they are used* (blanking, trimming, notching, coining, extrusion, drawing), *method of operation* (automatic feed, manual feed, transfer press), and *speed of operation* (high speed, low speed).

It is convenient to classify presses according to force and speed characteristics. The majority of the presses used in industry fall under 'varying force, varying speed' category. These include crank and eccentric-driven presses and knuckle joint presses in the mechanical category. In 'varying force and speed' presses the force is maximum just before reaching the end of the working stroke while the velocity of the ram is nearer to minimum near the end of the ram downstroke, according to laws of simple harmonic motion. As most of the cutting, bending, and shallow drawing operations require maximum operating force near the end of the stroke, harmonic motion with fast approach and slow, high force pressing provides high speed productivity with lesser investment.



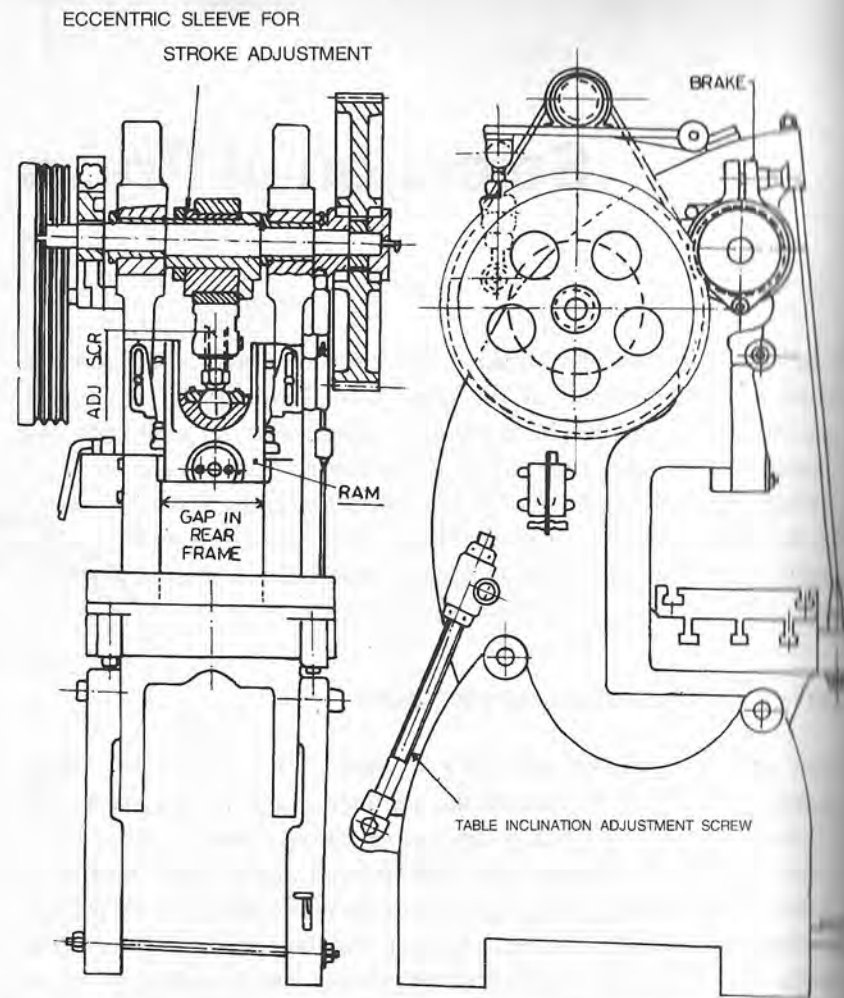


Fig. 11 Adjustable stroke (eccentric sleeve) inclinable 'C' frame press (geared)

'Uniform force and speed' presses are costlier than 'varying force and speed' presses. But some operations such as forging, extrusion and deep drawing require uniform force over a long part of the working stroke.

We will first survey the 'varying force and speed' category of presses. These have been arranged in order of popularity commencing with 'C' frame presses with cranked drive and ending with uniform speed and force, two ram hydraulic compacting presses. It should be remembered that most of the mechanical press configurations described here are also available in hydraulic version.

11.10 Conventional Mechanical Presses

These comprise of general purpose presses which can be used for a variety of operations such as blanking, bending, drawing and embossing.

11.11 'C' Frame Press

The press frame is shaped like 'C' to provide access from three sides. A sheet strip can be fed longitudinally from left to right or right to left by an operator in the front. It is convenient to provide a gap in the rear frame to allow feed from front to rear (Fig. 11). Facility for swivelling the table backwards facilitates automatic gravitational downslide of blank (bigger than bolster hole) through the gap in the rear frame.

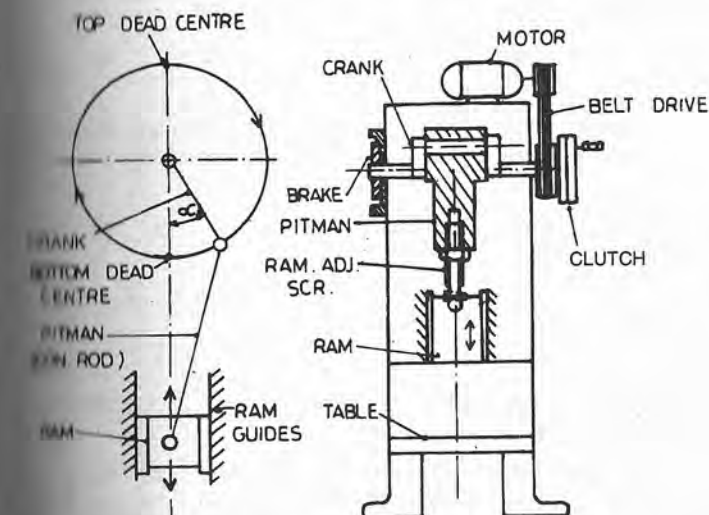


Fig. 12 Cranked 'C' frame press

Cranked drive is most common (Fig. 12) although the fixed stroke offers lesser flexibility. Variable stroke presses are provided with an eccentric drive in which eccentricity can be adjusted to vary the stroke length. Table 11 states the specifications of Heavy Built Godrej presses from 10 to 100 tonnes.

The force developed by an eccentric or a cranked press varies along the stroke length and is maximum near the end of the stroke. Press capacity is usually specified at 20° from the bottom dead centre of the crank/eccentric ram. Heavy duty presses are provided with geared drive between crankshaft/eccentric and the intermediate shaft. The latter is usually driven by belts from motor pulley (Fig. 14). Bigger presses are

Table 11 Specifications of Godrej Heavy Presses [Figs 13a, b]

Dimensions	Model no.			GE 1-10	GE 1-25	GE 1-40	GE 1-100
	Capacity at 20° crank angle before B.D.C.	tonne		10	25	40	100
R	Stroke fixed	Standard	mm	40	63	80	123
		Optional	mm	20,25,32,50,63	32,40,50,80,100	40,50,63,100,125	63,80,100,160
R	Stroke adjustable	Standard	mm	8 to 40	8 to 63	8 to 80	8 to 123
		Optional	mm	8 to 63	8 to 100	8 to 125	8 to 160
E	Throat	Standard	mm	160	200	224	280
		Deep	mm	224	280	315	430
Q	Shut height*	Standard	mm	200	250	280	333
		High	mm	315	400	450	560
S	Screw adjustment		mm	50	50	63	80
G × H	Slide face	Standard	mm	180 × 280	224 × 355	250 × 400	315 × 500
		Flanged	mm	315 × 400	400 × 500	450 × 560	560 × 710
P × P ₁	Slide face Opening Dia × Depth [Shank Hole]		mm	32 × 60	40 × 75	50 × 85	50 × 85
O	Clear distance between uprights [back opening]		mm		250	315	388/430
D	Height of table surface from floor		mm	800	800	800	900
FB × LR	Size of table	Standard	mm	315 × 500	400 × 630	450 × 710	560 × 800
		Deep	mm	400 × 500	500 × 630	560 × 710	710 × 800
			mm	400 × 630	500 × 800	560 × 900	710 × 1100
L × M × N	Opening in the table M × L × φN		mm	160 × 200	200 × 250 × 200	225 × 280 × 250	280 × 333 × 280/333
F	Bolster thickness		mm	65	75	80	100
A × B × C	Approximate size	Non-g geared	cm	111 × 74 × 235	142 × 110 × 272	188 × 134 × 313	250 × 160 × 380
		Geared	cm	111 × 74 × 225	138 × 110 × 263	184 × 134 × 313	240 × 160 × 380
			cm				
	Strokes per minute	Non-g geared	SPM	140	112	100	80
		Geared	SPM	70	56	50	40
	Total fly-wheel energy	Non-g geared	Nm	392.3	1569	3089	12238
		geared	Nm	784.5	3089	6178	24516

(Contd)

Model no.			GE 1-10	GE 1-25	GE 1-40	GE 1-100
Motor	Non-g geared	kw/rpm	0.75/750	2.2/750	3.7/750	7.5/750
	Geared	kw/rpm	0.75/1000	2.2/1500	3.7/1500	7.5/1500
Approximate weight	Non-g geared	kg	600	2200	4140	7500
	Geared	kg	750	2500	4500	8200
Die cushion capacity		tonnes	1.25	3.15	5	11

1. Shut height at standard maximum stroke is the distance between table surface and slide face with slide at bottom of stroke and adjustment up.
2. For strokes less than standard, the shut height will be increased by half the difference. For strokes more than standard, the shut height will be reduced by half the difference in stroke.

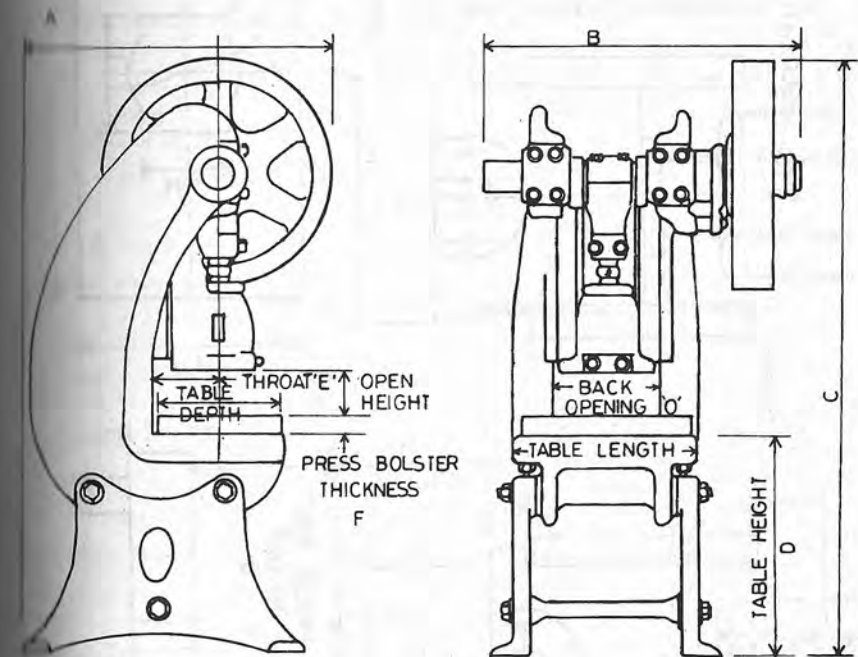


Fig. 13a Press specifications for 'C' frame presses

usually provided with a pneumatically operated friction clutch and brake for actuation of press stroke through push button or a foot switch. Single crank presses can be used for drawing operations by providing a die cushion under the table. Table I2 states specifications of HMT inclinable open gap 'C' frame presses ranging from 100 to 250 tonnes.

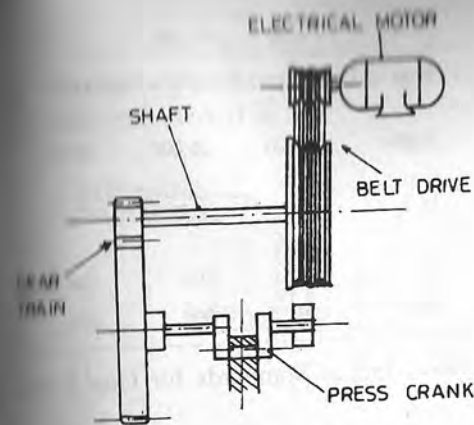
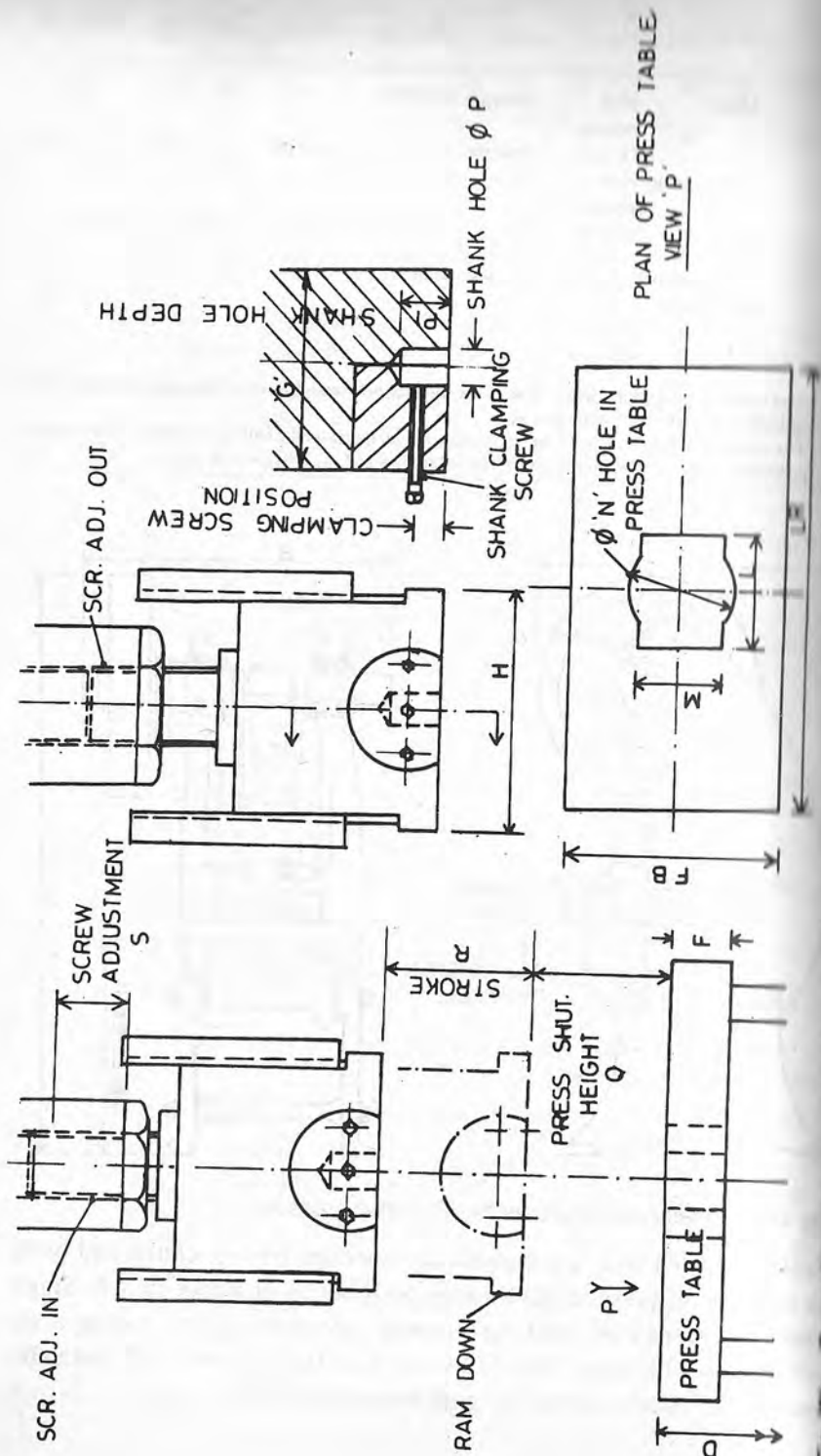


Fig. 14 Drive of geared press

Table 12 Specifications of H.M.T. Inclined Presses 100 to 250 tonnes

Model			P-100	P-160	P-200	P-250
Capacity at 6 mm above bottom of stroke	tonnes		100	160	200	250
Stroke of slide	Standard	mm	160	160	200	200
	Optional	mm	200	200	250	250
Strokes per minute			40	35	35	31
Main drive motor	KW		7.5	11	15	18.5
	RPM		1500	1500	1500	1500
Die Space:						
Shut height	Standard	mm	450	500	630	630
Bed to slide	Optional	mm	560	630	800	800
Adjustment of slide		mm	125	125	125	125
Area of slide (G $\times$ H)		mm	560 $\times$ 710	710 $\times$ 900	710 $\times$ 900	800 $\times$ 1000
Area of bolster (FB $\times$ LR)		mm	710 $\times$ 1120	800 $\times$ 1250	900 $\times$ 1400	900 $\times$ 1400
Thickness of bolster		mm	100	125	145	145
Slide face opening (Dia $\times$ length)		mm	80 $\times$ 75	80 $\times$ 75	80 $\times$ 75	80 $\times$ 75
Opening in bed (M $\times$ L)		mm	520 $\times$ 570	710 $\times$ 710	760 $\times$ 760	790 $\times$ 800
Frame:						
Type of frame			Welded	Steel-Gap		
Distance between uprights	mm		600	710	760	800
Centre of slide to back of gap [Throat]	mm		360	405	460	460
Height of bed from floor	mm		890	890	890	890
Height above floor (approx)	mm		3800	4315	4800	5000

(Contd)

Model		P-100	P-160	P-200	P-250
Floor space (A × B) (in straight position) (approx)	mm	2900 × 1350	3500 × 1685	3925 × 1800	4100 × 1900
Weight (approx)	kgs	11,000	18,200	26,000	28,500
Cushion: Capacity at 6.865 kg/mm ² pressure of air	tonnes	15.4	25.7	32.0	40.7
Stroke	mm	80	80	100	100
Weight (approx)	kgs	400	600	800	950

Fig. N7 in the last Section shows Indian Standards for Gap Frame Presses.

11.12 'H' Frame Press

'H' Frame presses are shaped like the alphabet 'H' with the table making the horizontal bridge of the 'H'. This structure is convenient for presses with long tables (Fig. I5). As the top beam housing the drive acts like a simply supported beam the deflection is much lesser than cantilever type

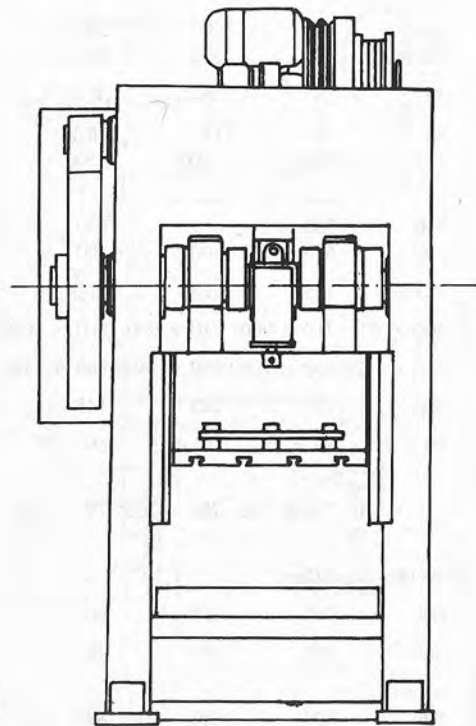


Fig. I5 'H' frame press

'H' frame presses, and the press is more sturdy. Presses with long tables are often provided with a drive at two points: two or more cranks or hydraulic cylinders (Fig. I6).

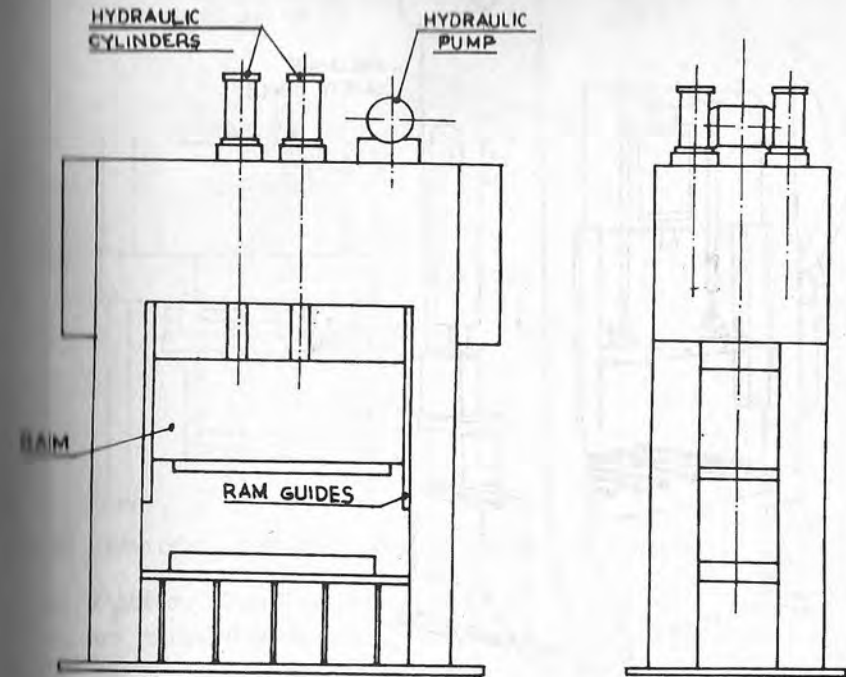


Fig. I6 Hydraulic 'H' frame press with four cylinders

'H' frame presses can be fed from front or rear only. Nor can the table be swivelled. This limits versatility of 'H' frame presses. Nonetheless 'H' frame construction is used widely for trimming presses (Fig. I7). These are equipped with pneumatic safety mechanism in which overloading of press ram breaks an easily replaceable safety pin. The pneumatic clutch provides protection against excessive torque which causes slipping of the clutch.

11.20 Multi-Action Presses

These use more than one rams. Even a single action press can be made more versatile by adding a die cushion.

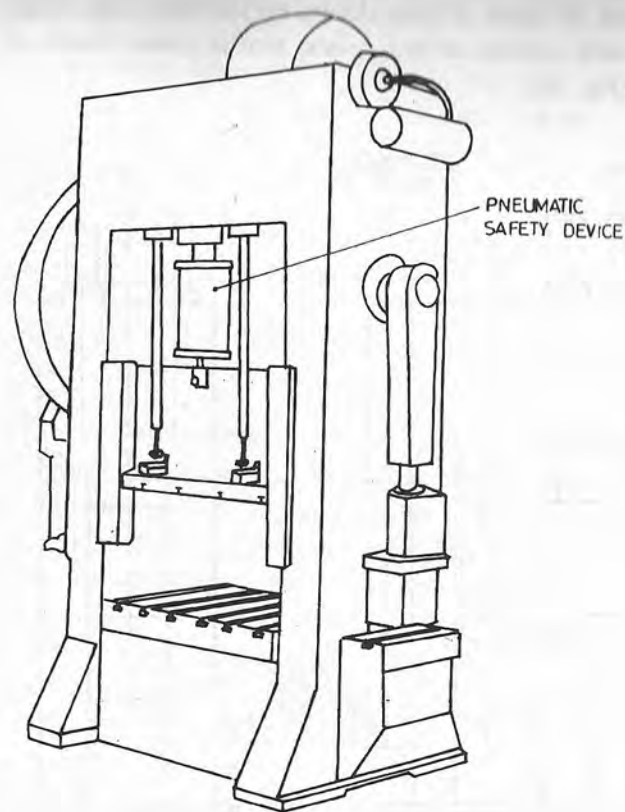


Fig. 17 Trimming press

11.21 Die Cushions

Die cushions are used widely for holding blank under pressure during drawing. They can also serve as automatic ejectors. Very small presses use a heavy spring or rubber pads as make-do cushions. Die cushions for bigger presses are provided with cylinders having the piston under constant pneumatic or hydraulic pressure (Fig. 18). The die cushion ram remains in outstroke position when the press ram is not in operation. During downstroke, the press ram pushes the die cushion piston rod (ram) downwards through workpiece sandwiched between press ram and die cushion (ram). Compressed air or hydraulic oil on the other side of the piston is driven out of the die cushion cylinder to atmosphere or oil tank through a safety valve (pressure relief valve). A compressor or an oil pump replenishes the discharged fluid to push the die cushion (ram) up again as the press ram withdraws.

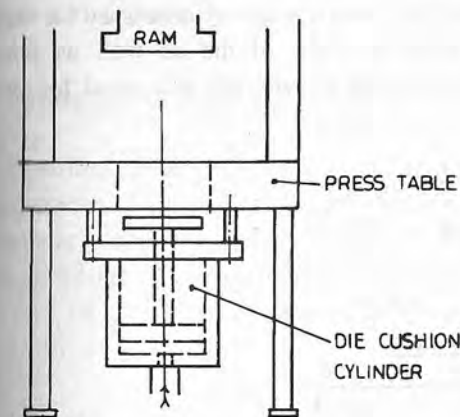
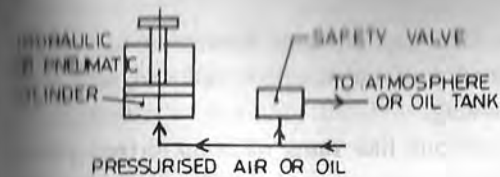


Fig. 18 Use of die cushion for adding upward ram to press

11.22 Double Action Presses

These are provided with two upper rams (Fig. 19). The outer ram is driven by a cam while the inner ram is driven by a crank or an eccentric. The cam driven outer ram has got a long dwell at the end of

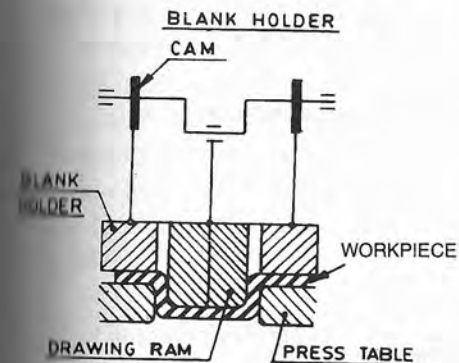


Fig. 19 Double action press with blank holder

the stroke. The outer ram is used for holding blank under pressure during draw (or fine blanking) by the inner ram. The position of the outer ram is adjusted to provide suitable gap between die and blank holder during the long dwell of the ram. The gap depends upon the thickness of the

sheet being drawn. The controlled gap prevents formation of wrinkles on the cup as the bigger diameter of the blank is reduced to a much smaller diameter of cup in drawing.

The inner drawing ram functions like rams of crank-driven presses described earlier. In double action presses used for drawing, the inner ram has got a very long stroke—double the maximum depth of the draw possible on the press. For half the stroke length is necessary for unloading the drawn cup. The cup must be clear of die as well as punch for unloading (Fig. 110). Double action presses are also used for precision fine blanking work.

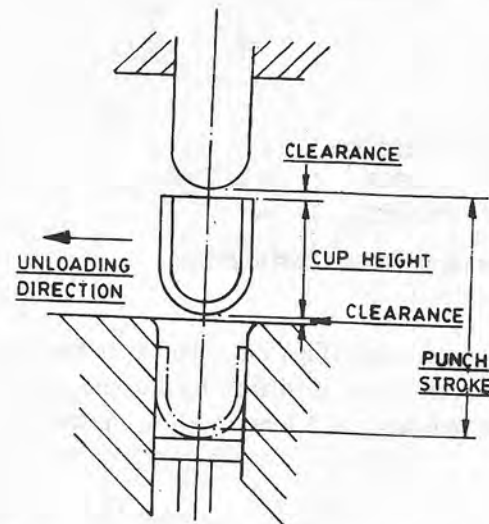


Fig. 110 Clearance required for unloading a drawn cup

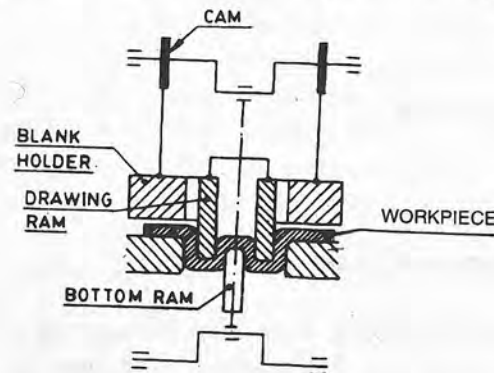


Fig. 111 Triple action press with two cranks

11.23 Triple Action Presses

These are provided with an additional drawing ram at bottom. Concomitant with the top ram the bottom ram provides an upstroke. The bottom ram is usually crank-driven (Fig. 111). It can be used for an additional draw, embossing, or ejection of workpiece. Even a die cushion can be used as bottom ram. Thus a double action press can be converted to a triple action press by adding a die cushion.

11.30 Special Purpose Presses

Large quantities inspire special purpose presses such as used for electrical laminations. Multiplicity of operations warrant multi-station presses with transfer mechanisms for automatic conveyance and positioning of work at successive work stations. Coining calls for heavy thrust and dwell at the end of the stroke which requires a knuckle joint instead of a cranked drive.

11.31 Notching Presses

Designed especially for circular laminations, these presses are provided with high speed ram operating from 200 to 1000 strokes per minute (Fig. 112). Notching presses are also equipped with a precision high speed indexing mechanism. During upstroke of the ram, the indexing mechanism revolves the stamping through the required angle. This allows usage of a single notching tool for piercing number of equispaced notches in a circular stamping. Separate indexing ring is required to notch stampings having different angular pitches. However indexing ring for 36 divisions (10° pitch) can be used for notching 18 (20° pitch) or 12 (30° pitch) divisions by using double or triple teeth indexing.

Notching presses are usually provided with a pneumatic cylinder to hold the blank in position during notching. Consequently, except a central locator, indexing ring and single notching die, no other tooling is required.

11.32 Lamination Presses

Multiplicity of operations required in electrical stampings warrant presses with automatic feeders, fail safe gadgets, and scrap and work disposal systems (Fig. 113).

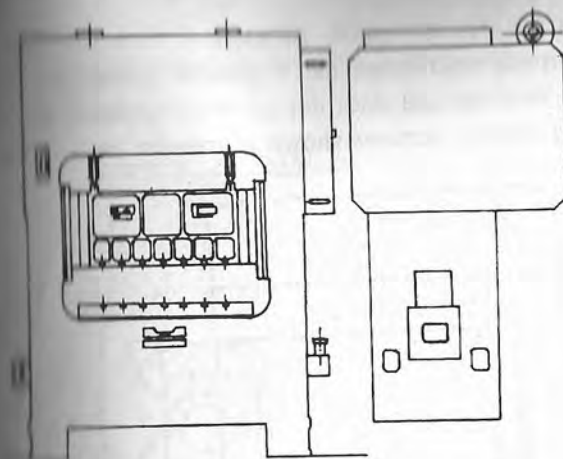
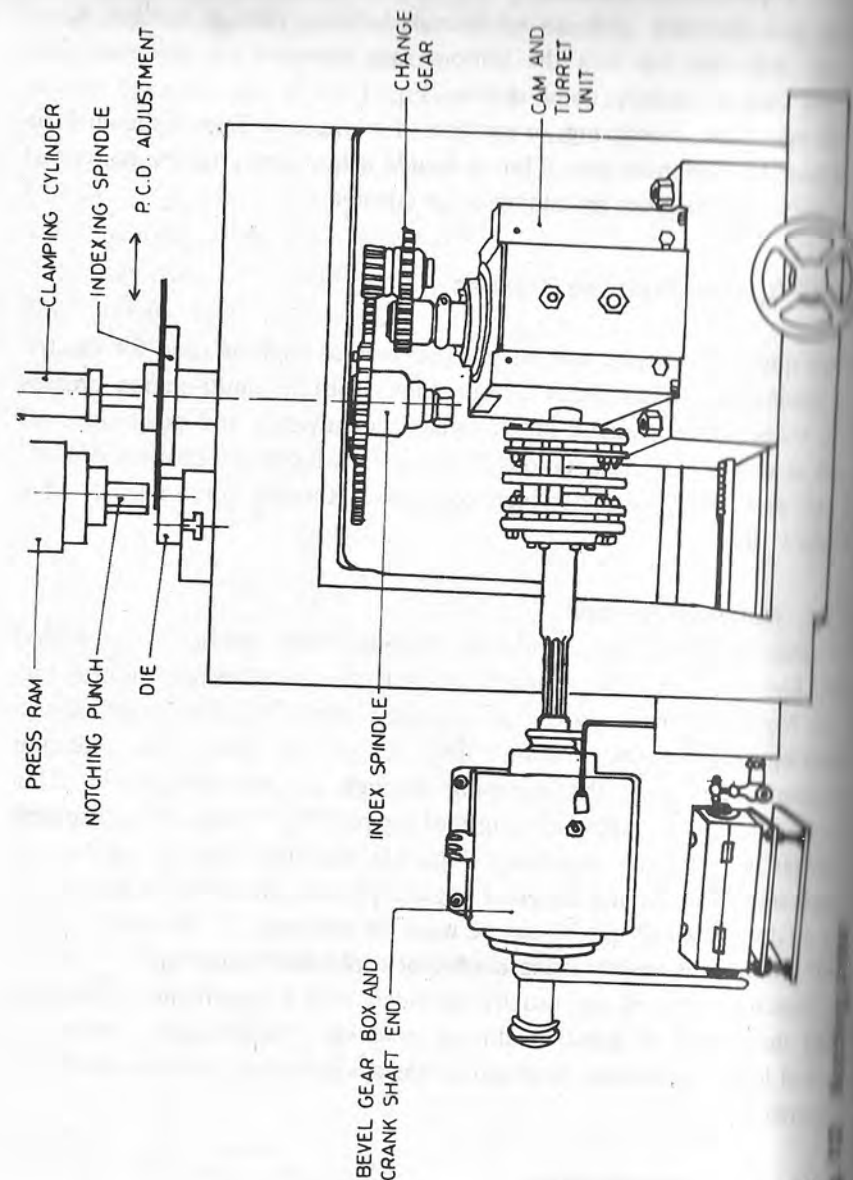


Fig. 113a High speed lamination press

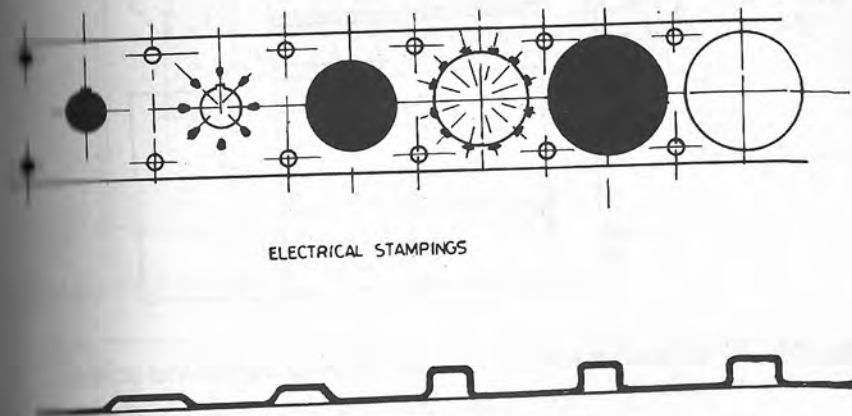


Fig. 113b Workpieces manufactured on lamination press

Such presses are equipped with automatic double-roll feeds and strip cutters, lamination blowers, etc. and operate at high speeds from 10 to 400 strokes per minute. They are provided with strip lubricator, stroke counters, and operator safety guards. The capacity is usually specified at 30° before the ram reaches the end of the stroke (bottom dead centre).

11.33 Transfer Presses

These multi-station presses are used for forming operations also. The strip is fed automatically through a double-roll feed to a blanking station outside the press frame. The grippers convey workpiece to successive

forming stations spaced at a certain pitch. As there is little time lapse between the tandem forming operations, the workpiece retains the heat generated during metal working and does not get workhardened due to cooling. The fixed pitch forming stations shown in transfer press in Fig.

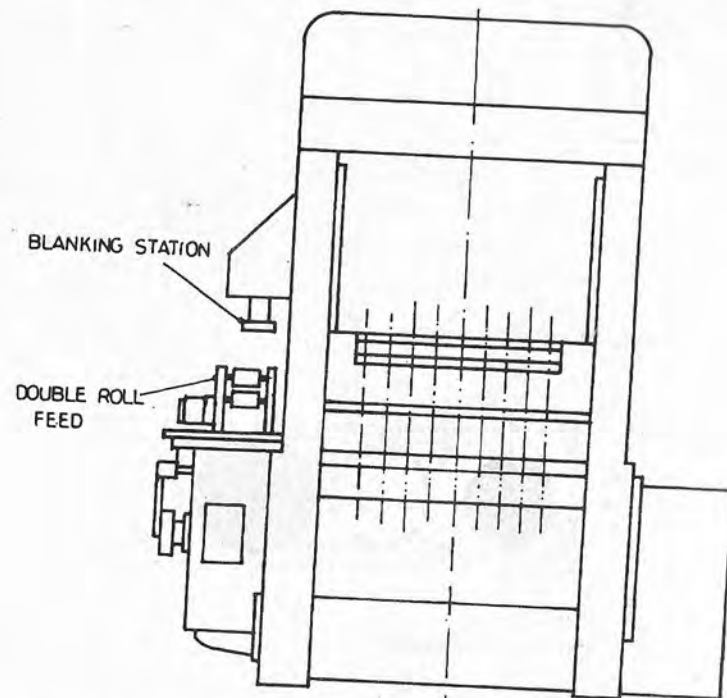


Fig. 114 Nine station transfer press with blanking station and double roll feed

I14 have capacity for drawing 50 deep with 8 tonne force. Top tool stations are provided with 20 mm height adjustment.

The press is driven from the bottom by two cranks. The cranks pull the ram towards the table during downstroke. This subjects the pitman at both ends to tension instead of compression. On the contrary, top drive presses push pitman to compression.

11.34 Knuckle Joint Coining Presses

Knuckle joint provides slow speed and high power near stroke end with upto 20° dwell at the end of the stroke (Fig. 115), and is eminently suitable for precision sizing, beading, and coining work. In some presses the coining ram moves from bottom to top, while other designs use conventional downstroke for coining operation. The press slide can be adjusted

position by moving the slide adjustment wedge. Table 13 cites classification of Ameteeep Knuckle Joint Presses ranging from 63 to 1600

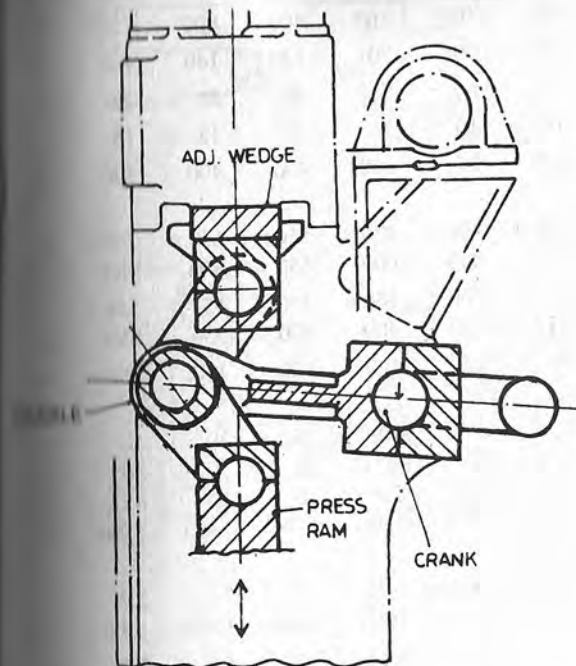


Fig. 115a Knuckle joint

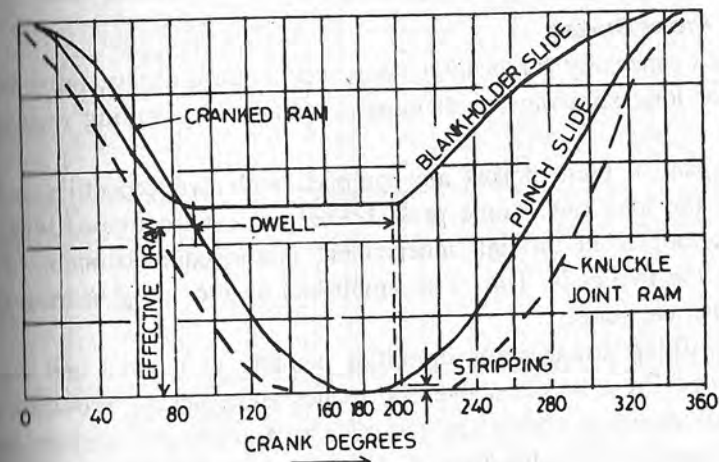


Fig. 115b Comparison of cycles of cranked and knuckle joint presses

Table I3 Specifications of Ameeteep Knuckle Joint Presses
(63–1600 tonnes)

Model PKC	PKC 63	PKC 100	PKC 160	PKC 400	PKC 800	PKC 1250	PKC 1600
Capacity (tonnes)	63	100	160	400	800	1250	1600
Stroke length (mm)	50	70	70	140	140	160	160
No. of strokes/min	60	60	50	40	30	25	18
Slide adjustment (mm)	10	10	15	15	15	15	15
Shut height over bolster (mm)	250	250	280	400	400	500	500
Bolster area (LB × FB) (mm)	350 × 350	400 × 450	430 × 600	550 × 650	650 × 800	750 × 950	800 × 1000
Slide area (H × G) (mm)	250 × 250	300 × 300	360 × 400	400 × 500	450 × 550	550 × 650	600 × 700
Bolster thickness (mm)	60	75	100	120	140	160	180
Bottom ejector force (tonnes)	3.15	4	10	15	30	50	61
stroke (mm)	25	30	30	50	50	50	50
Main motor (kw)	3.7	5.5	7.5	15	30	45	55
(rpm)	1500	1500	1500	1500	1500	1500	1500
Slide adj motor (kw)	Manual	Manual	0.75	1.5	2.2	3.7	3.7
(rpm)			1000	1000	1000	1000	1000
Reqd air pressure bar	5.5	5.5	5.5	5.5	5.5	5.5	5.5
kgf/cm ²							

11.35 Press Brakes

Designed especially for bending long section from sheets, press brakes have got long slim rams with integral clamps for securing rectangular shanks.

Mechanical press brakes are equipped with two eccentrics at both ends of the long ram. Some press brakes are even equipped with ram tilting arrangement through independent motorised adjustment of pitmans at the two ends. This is accomplished by providing bearing shoes with spherical seats.

Ram tilting arrangement simplifies bending of tapered and conical workpieces. Press brakes above 100 tonnes are generally provided with pneumatic clutch and brake and two speeds. Acute angles are bent better at lesser speeds. It is also better to bend large sheets at slower speed to avoid whipping.

Fig. I16 shows a mechanical press brake with important dimensions for various models.

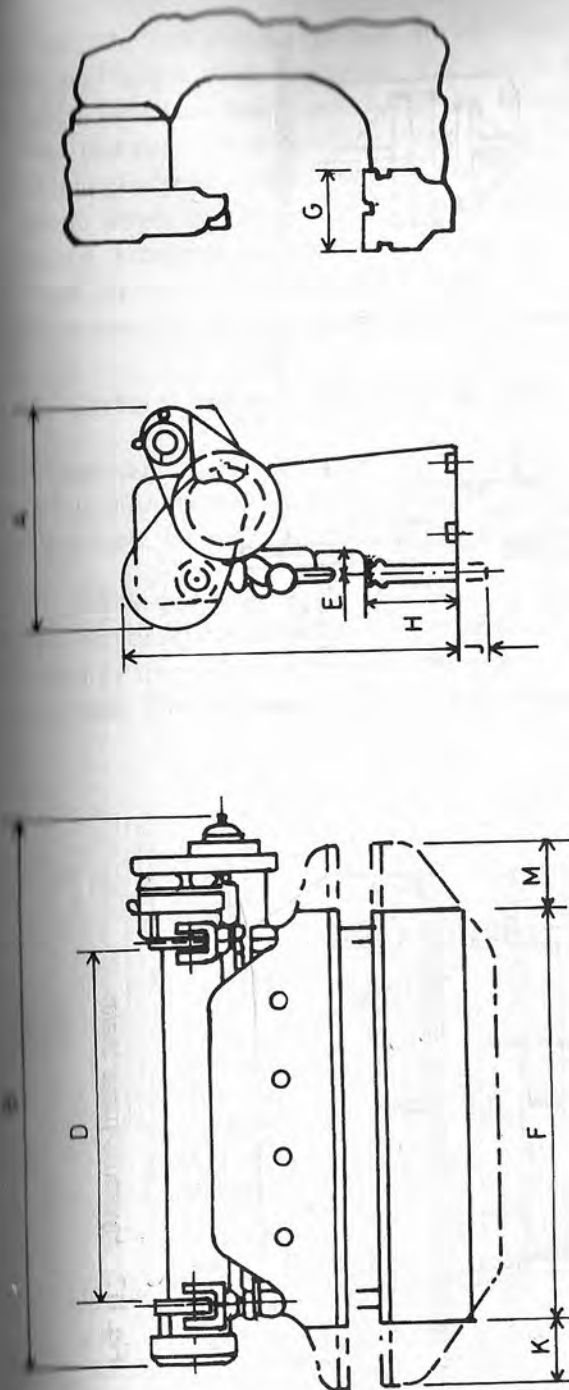


Fig. I16 Mechanical press brake

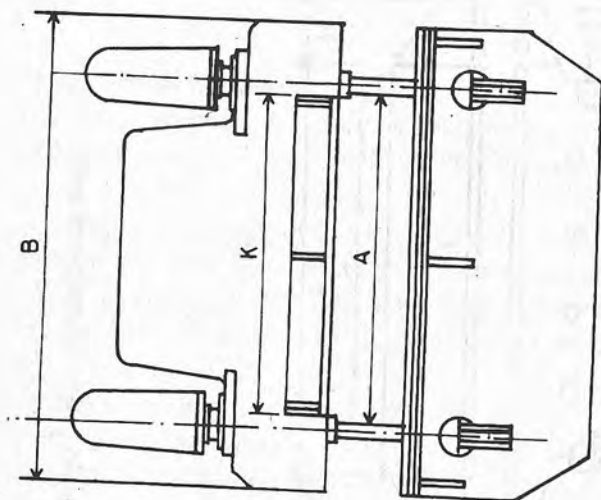
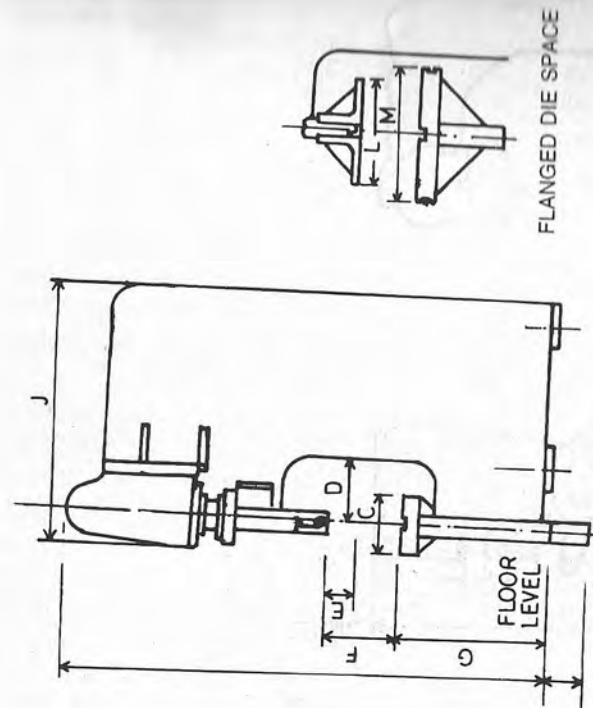


Fig. I17 Hydraulic press brake

Fig. I17 shows important dimensions of hydraulic press brakes. Hydraulic press brakes are actuated by two cylinders at both ends of the

ram. The ram can be operated in two types of cycles: continuous stroke and single stroke operation. The ram is maintained horizontal through a steel tape sensor which corrects level errors through micro-switches and control valves which direct more hydraulic oil to lagging hydraulic cylinder to correct the error.

Stroke length as well as ram up and down positions can be adjusted as desired through a pair of limit switches. The hydraulic press brake described above is not provided with any arrangement for tilting ram, which remains parallel to press table all the while.

11.40 Uniform Force and Speed Presses

Some operations such as forging, drawing, and bending call for application of uniform force over a long part of the stroke length. Cranked drives are unsuitable for such applications.

11.41 Friction Screw Presses (Fig. I18)

These comprises of a screw fitted with a flywheel at the top. The flywheel is driven by friction with either of the two friction discs on opposite sides of flywheel. The friction discs can be moved axially to engage with the

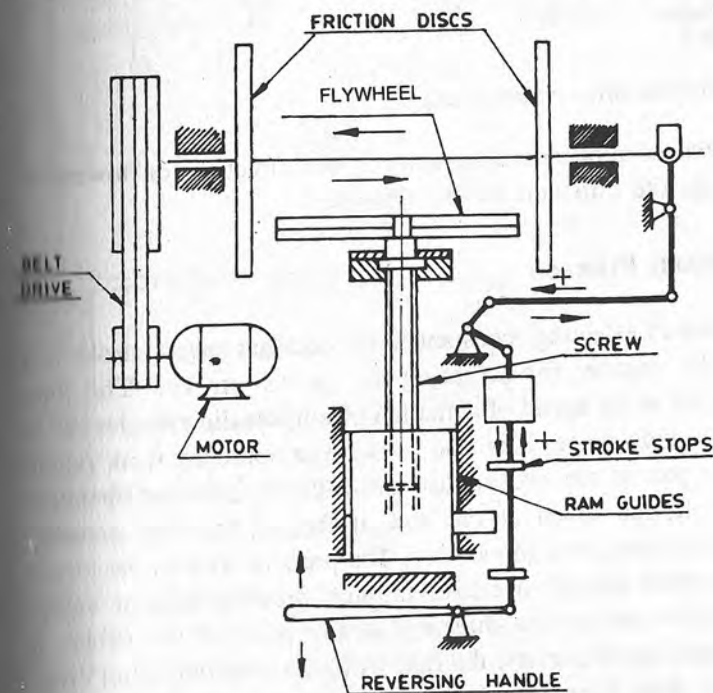


Fig. I18 Friction screw press

flywheel. Engagement with one friction disc drives the flywheel and the coupled screw in one direction, while engagement with the other disc drives the flywheel and the screw in the opposite direction. The screw engages with a nut fixed in the ram. Consequently rotation of screw in one direction effects downstroke while rotation in opposite direction effects upstroke of the ram.

Modern friction screw presses use electrical drive instead of friction discs to revolve the flywheel coupled to the drive screw (Fig. 119). The flywheel acts as a rotor of the squirrel cage electrical motor, stator coils

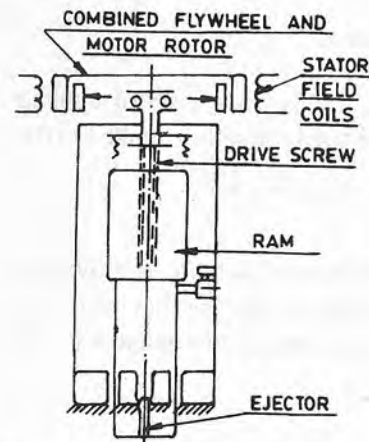


Fig. 119 Electrical drive screw press

rotate the flywheel rotor induction motor in one direction for downstroke and in the opposite direction for the upstroke.

11.50 Hydraulic Presses

Another method of effecting 'constant force, constant speed' stroke is to use a hydraulic cylinder for actuating the press stroke. The force (tonnage) as well as the speed of actuation of a hydraulic cylinder can be varied within a wide range. It is also possible to approach work rapidly during the idle part of the stroke, slow down during pressing operation and have the desired dwell at the end of the stroke. This enhances versatility of hydraulic press immensely. The press as well as the tooling can be safeguarded against overload through pressure control valves. Moreover the ram can reverse direction at any point of the stroke. In crank-driven mechanical presses, the ram will withdraw only after crossing the bottom dead centre. In bending operations with bottoming, a mechanical press can get jammed if workpiece thickness is excessive

the extra thickness prevents the ram from reaching and crossing the bottom dead centre. Consequently, hydraulic presses are more suited for bending work.

Heavy workpieces require considerable time for loading, unloading and positioning work on press table. This idle time can be used to build up energy reserve in the hydraulic system by using accumulators. This reduces pump size, and cost of the press drive.

11.51 Multi-cylinder Hydraulic Presses

Use of more than one cylinders permits distribution of force over a wider area. Fig. 120 shows a 2000 tonne hydraulic press with three hydraulic cylinders. The ram is guided by four pillars which also bear the tensile load during pressing. The four pillars construction allows access to table,

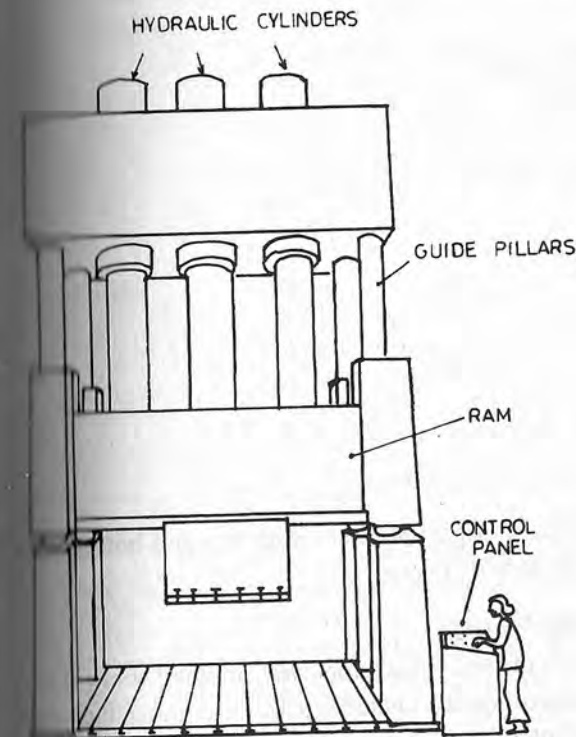


Fig. 120 Three ram hydraulic press

through the side gaps between the pillars. This renders four pillar presses more accessible than 'H' frame presses. Smaller presses often use only two pillars for guiding ram and securing the top frame mounted with a single hydraulic cylinder.

11.52 Multi-ram Compacting Presses

Powder metallurgical processes and ceramics work call for presses with two rams: one at top and the other at bottom. Both the rams operate in opposite directions compacting work materials between them. Hydraulic systems can be used conveniently for actuation of such multi-ram presses.

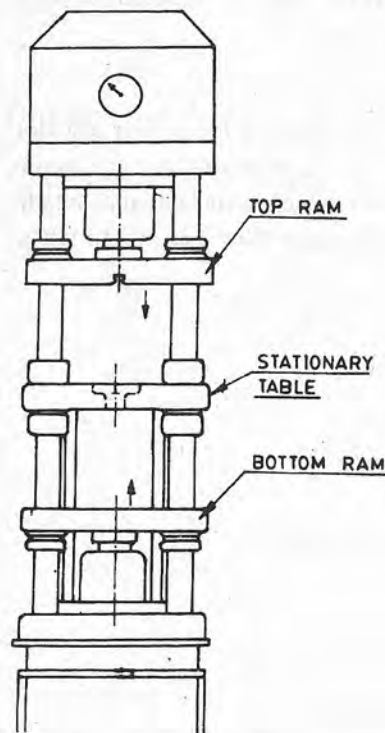


Fig. I21 Four pillar compacting press

Fig. I21 shows a four pillar compacting press with top and bottom rams with a stationary table plate in between.

11.53 Hydraulic Drawing Presses

Hydraulic presses are also recommended for deep drawing work due to their 'uniform force, uniform speed' characteristic throughout the stroke length. Nonetheless, except in very heavy work, hydraulic presses are rarely used for drawing work under 250 tonne loads. For in comparison with mechanical presses, hydraulic presses have got very slow speed and so, low productivity. Moreover, even in drawing there is maximum material flow near the end of the stroke when the largest outer periphery of the blank is reduced to smaller size of rim of the drawn cup. Cranked presses provide high energy near the end of the stroke and are much

more than hydraulic presses, and so widely used for drawing cups of smaller and medium sizes.

11.60 Press Selection Charts

Table I4 states the suitability of various presses for different operations along with requisites, advantages, and disadvantages. Table I4 rates various types of presses according to possible productivity for different operations.

Table I4 Suitability of Presses for Various Operations

Operation type	Press	Remarks
Cutting: Blanking, Piercing, Trimming	<i>Mechanical</i>	
	— Cranked/eccentric drive, single action presses	High speed production of electrical stamping
	— Lamination presses	High speed production
	— Notching presses	
	— Transfer presses	
Bending	<i>Hydraulic</i>	
	Single action presses	Slow, suitable for heavy work needing long loading, unloading time.
	<i>Mechanical</i>	
	Cranked/eccentric drive single action presses, preferably with die cushion	Risk of press jamming if sheet thickness is excessive in a bottoming operation
	Transfer presses	High speed production of multibend components
Forming	<i>Hydraulic</i>	
	Single action presses with or without die cushion	Slow, but no risk of jamming
	<i>Mechanical, cranked/ eccentric drive single action presses, preferable with die cushion</i>	
	Transfer presses	High speed production with multiple operations
Drawing	<i>Mechanical</i>	
	— Cranked or eccentric drive single action press with die cushion	Die cushion can be used as blank holder and for ejection
	— Cranked double action press with cam operated blank holder	Eminently suitable for single draw in one direction

(Contd)

Sr. no.	Operation type	Press	Remarks
4.	Drawing	— Cranked triple action press with cam operated blank holder	Eminently suitable for two draws in opposite directions
		<i>Hydraulic</i>	
		— Single action with die cushion	Die cushion used as a blank holder, and ejector
		— Double action press with hollow cylinder	Outer ram used as blank holder and inner one for drawing; slow
		— Triple action press with hollow cylinder at top.	Suitable for 2 draws in opposite directions; slow
5.	Coining, Embossing	<i>Mechanical</i>	
		Knuckle joint press	Eminently suitable
		<i>Hydraulic</i>	
		Single action press	Eminently suitable
6.	Forging and Extrusion	<i>Mechanical</i>	
		Friction screw press	Eminently suitable
		<i>Hydraulic</i>	
		Single action presses	Eminently suitable

12.00 MOUNTING AND SETTING PRESS TOOLS

Large press tools weigh in tonnes. It is necessary to provide handling devices such as eye bolts, spring loaded balls, and handles. In addition to

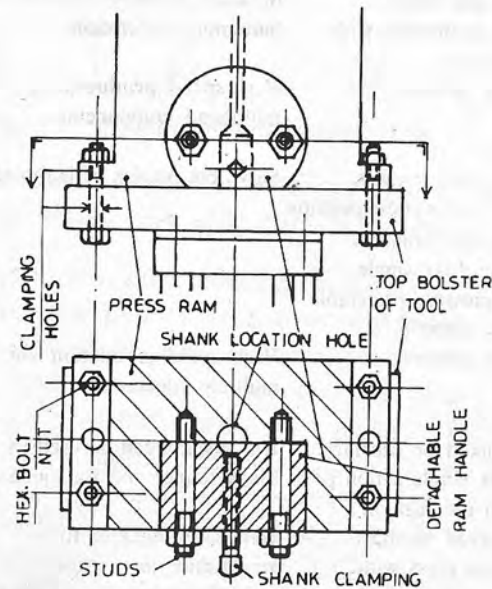


Fig. 122 Clamping heavy tools to press ram flange

Table 15 Productivity of Various Presses for Different Operations

Sr. no.	Press type	Blanking, piercing	Bending	Forming	Drawing	Coining, embossing	Forging, extrusion
1.00	<i>Mechanical:</i>						
1.10	Cranked/Eccentric Drive	*	*	*	*	*	*
1.11	Cranked/Eccentric Single Action	*	*	*	*	*	*
1.12	Cranked/Eccentric Double Action	*	*	*	*	*	*
1.13	Cranked/Eccentric Triple Action	*	*	*	*	*	*
1.14	Notching Presses	*	*	*	*	*	*
1.15	Lamination Presses	*	*	*	*	*	*
1.16	Transfer Presses	*	*	*	*	*	*
1.17	Knuckle Joint Presses	*	*	*	*	*	*
1.18	Friction Screw Presses	*	*	*	*	*	*
2.00	<i>Hydraulic</i>						
2.10	Single Action Presses	*	*	*	*	*	*
2.20	Double Action Presses	*	*	*	*	*	*
2.30	Triple Action Presses	*	*	*	*	*	*

* * * Eminently Suitable, High Productivity
 * * * Eminently Suitable, Medium Productivity
 * Can be used with low productivity/additional accessories
 — Unsuitable

shank clamping it is sometimes necessary to screw the top bolster directly to the ram face. This can be accomplished by providing holes/slots in the press ram flange (Fig. I22). The top bolster of a heavy press tool is provided with holes to match the ram holes/slots. Heavy tools can be secured rigidly to press ram with hexagonal headed bolts, nuts, and washers. Such clamping can withstand much more stripping force than mere shank clamping.

12.10 Mounting Press Tools

12.11 Very Light Press Tools

The tools weighing upto 20 kg can be lifted manually onto/from press table. After loading, the press tool on the table the shank is inserted in the location hole in the ram by slowly rotating the flywheel of press manually to effect slow downstroke of the press. Touch the ram the top bolster, by using the screw adjustment of the ram. Clamp the shank of the press tool with the screw provided in the ram front (Fig. I3b), taking care that the tool is oriented correctly for strip feeding.

Clamp the bottom bolster of press tool onto press bolster/table in the shank-in position. Take care that no part of clamp or clamping screws obstructs the path of strip feed.

12.12 Medium Press Tools

These tools weighing upto 60 kg can be handled manually by two persons. It is convenient to provide detachable handles on the sides of the press

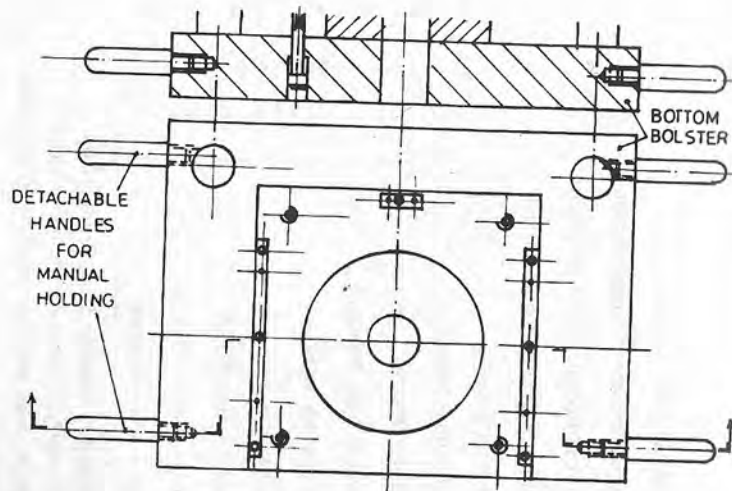


Fig. I23 Use of handles for handling medium press tools

tools (Fig. I23). Four handles are adequate for handling by two persons. Some small shops handle press tools upto 150 kg by providing more handles to facilitate manual transport of tool by four persons.

Higher presses are provided with split rams. Halved on the centre line of the location shank, the front detachable half is fixed onto the ram with hexagonal nuts and two studs anchored in the ram (Fig. I24).

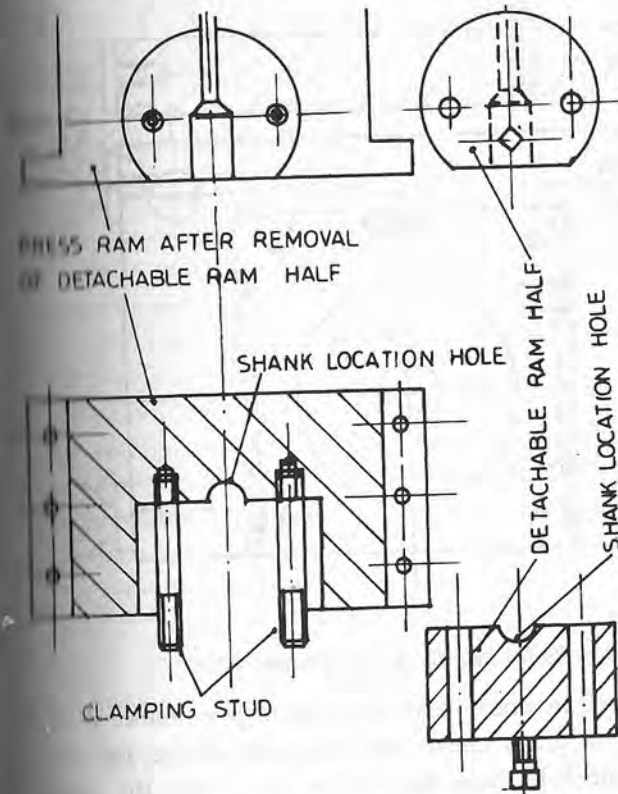


Fig. I24 Detachable ram half

For loading heavy press tools the detachable part of the ram is removed. The shank of heavy press tool is slid in location hole, the studs are clamped by hexagonal nuts to secure the shank to the ram. Note that gradual lowering of ram onto shank by revolving flywheel slowly is eliminated all together. It is rather irksome to move a heavy press tool on press table. Aligning the shank while lowering the ram is even more tedious.

After clamping the shank, the bottom bolster is secured to press bolster/table by suitable clamps as described in previous section (13.10).

12.13 Heavy Press Tools

These weigh in tonnes and cannot be handled manually. Such tools are provided with detachable eye bolts to engage with hooks of crane tackles. The sides of bottom bolster are provided with tapped holes to match threads of standard eyebolts (Fig. 125a).

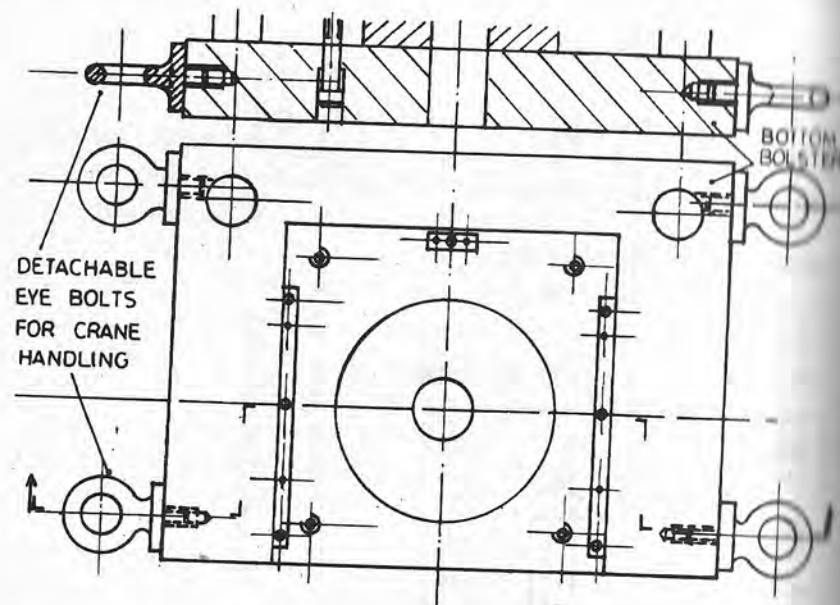


Fig. 125a Use of eye bolts for handling heavy press tools

Such tools are lifted by cranes and conveyed to press table. With the tool over-hanging from crane chains the tool-setter moves the tool to insert the shank in the half shank hole in the ram. Once the shank is aligned the detachable half of ram is screwed on but not clamped. The tool-setter pivots the tool around shank centre to align the clamping holes in top bolster with corresponding holes in ram flange (Fig. 122). Aligning the tool and ram clamping holes, the tool-setter inserts hexagonal head bolts into holes and clamps with hexagonal nuts and washers. At least two screws are tightened to secure top bolster to ram before crane lowers the press tool to rest it on press table. With top bolster secured to ram, the crane can release the tool.

The bottom bolster can now be clamped to press bolster/table by suitable clamps.

The author has devised an ingenious device for sliding heavy press tools manually on press table/bolster. The bottom bolster of heavy press

tool is fitted with spring-loaded balls which project below the resting surface of the bolster (Fig. 125b). The tool rests on balls without any contact with the press bolster/table. As rolling friction of balls is much

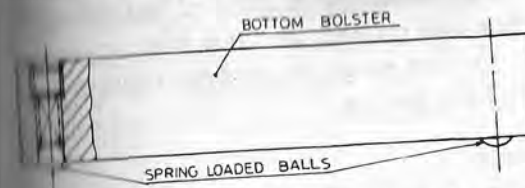


Fig. 125b Use of spring-loaded balls for manual sliding of heavy press tools

less than friction between press bolster/table and tool bolster surfaces, even a heavy tool can be slid manually on table to align shank with half shank hole in ram. The crane is used only to convey heavy tool to press bolster/table, and dump it there.

Even the crane can be replaced by a mobile hydraulic lift table. The hydraulic table is adjusted level with the press bolster/table, and tool is slid manually from hydraulic table to press floating on the balls.

The springs pushing the balls are such that they can support the weight of the tool easily. When the bottom bolster is secured to press bolster/table, the spring-loaded balls withdraw against springs into the bottom bolster, so that during press operation the bottom bolster rests fully on press bolster/table.

Large presses have tables with 'Tee' slots. These simplify clamping of bolsters considerably. Also, well distributed equitable clamping on bolster faces is ensured.

12.20 Setting Ram Position

If the press stroke is adjustable, the stroke should be set first. The

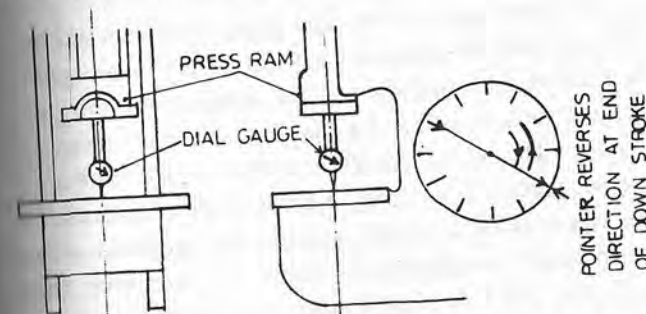


Fig. 126 Checking ram downstroke position by dial gauge

selected press stroke should be at least 3 to 5 mm more than the minimum stroke necessary for the operation. The ram should be brought to end of downstroke or bottom dead centre position for setting the tool.

The downmost position of ram stroke can be checked by a dial gauge (Fig. I26). It is a position when ram reverses direction from downward to upwards. So the needle of the dial gauge too reverses rotation direction at bottom dead centre (BDC) position.

12.21 Setting of Cutting Tools

Easiest to set, the tool-setter has only to bring down ram using screw adjustment. The ram should be lowered till the cutting punches are at least 1 mm into the corresponding die cut-outs. Even if the punches submerge a couple of millimetres more into the die cut-outs it does not matter. Tighten the lock-nut of the screw adjustment and the ram is set for cutting operation.

12.22 Setting of Bending Tools

Bottoming bending tools must be set precisely, particularly for crank or eccentric-driven power presses. Para C4.00 describes the effect of thickness variation in workpiece material. The bending tools should be set to permit bending the thickest blank within the variation range. In fact it is advisable to keep the gap between punch and die 0.5 mm more than the maximum workpiece thickness. The gap is adjusted slowly by bringing

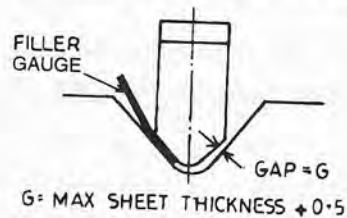


Fig. I27 Checking gap between bending punch and die

down the ram, using the screw adjustment. The gap can be checked by a filler gauge (Fig. I27). Setting the required gap the ram can be secured by tightening the locknut of the ram screw adjustment.

Hydraulic presses are more suitable for bending work as there is no fixed bottom dead centre. The stroke length and downstroke position of hydraulic ram can be set precisely by using electrical limit switches. For setting bending tools you only have to set downstroke position of ram 1–3 mm below the position required for minimum workpiece sheet thickness. For the hydraulic ram will simply sandwich workpiece between bending (bottoming) punch and die, and stop there even if the stroke is

at up to 3 mm more. This stoppage at strong positive block makes hydraulic presses ideal for bending work.

12.23 Setting of Drawing Tools

For drawing tools, ram must be set precisely to control cup depth. Furthermore, unlike bending tools, the drawing punch submerges into the die, and is not visible in the downstroke position. The punch is also secured by the blank holder. It is necessary to use setting pins which function in the same way as the cutter setting piece in milling fixtures. Both top and bottom bolsters of press tools are anchored with co-axial setting pins. The setting pins are made press fit in the bolsters. The end faces of the shouldered pins are ground square. There is usually a gap of 0.5 mm between the faces of setting pins in top and bottom bolsters in downstroke position of the tool (Fig. I28). For setting the tool, the ram

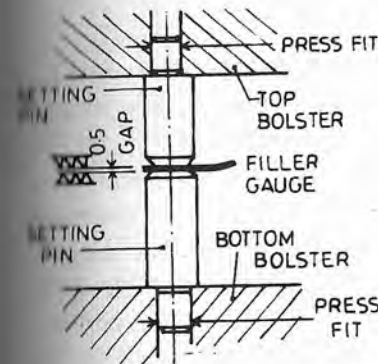


Fig. I28 Using setting pins and filler gauge

is slowly lowered till the gap between the pins is 0.5 mm. The gap is checked by a filler gauge. After setting, the ram should be secured by screw adjustment locknut.

Setting pins can also be used conveniently for bending and forming tools. If used for cutting tools, it is convenient to keep the face of the setting pin in bottom bolster level with the cutting die. The setting pin face should be ground level with the die during each resharpening. The setting face of the pin in top bolster should be ground suitably to maintain the relative difference with the resharpened punch face. The face of the top setting pin should be about 1.50 mm above the resharpened punch face in working position. In resharpening position, the top tool is turned upside down, resting on top bolster; the top pin face will be 1.5 mm below the ground cutting punch face.

Setting pins can be placed anywhere in an easily accessible part of the tool.

Computer-Aided Design of Press Tools

Computer-aided systems can reduce drafting time to one-tenth the time required with a board and tee-square or a drafting machine. Although the popular Computer Aided Design Programme 'Auto-CAD' takes a lot of space of the computer hard disks, it speeds up design work immensely. Later releases of Auto-CAD are more demanding. For example, Auto-CAD Release 10 can be used on an IBM-Compatible Computer with Intel 8086, 80386, 80186, 80188, 80286, 80386 (SX or DX) or 80486 (SX or DX) chips with a 360 KB floppy disk and 20 MB hard disk to store the Auto-CAD program. Of course, there should be a graphics board compatible with IBM EGA (Enhanced Graphics Adapter), VGA (Video Graphics Array), 8514/A; or Hercules monochrome graphics. A maths co-processor chip (or floating point chip FPU) is also necessary for Auto-CAD calculations. Addition of a mouse facilitates control of cursor, and a printer can help production of the compiled drawing on paper.

Auto-CAD Release 11 cannot operate on Intel 8086, 8088 or 80186 chips. One version of Auto-CAD can be used on Intel 80286 chip while the other version calls for Intel 80386 (SX or DX) or 80486 (SX or DX) chip. Even the computer must be compatible with 720 KB floppy disk. No maths (or FPU) chip is required for computers using Intel 80486 DX chip. Graphics boards suitable for Auto Release 10 can also be used for Auto-CAD Release 11.

Auto-CAD programme requires at least 7 MB free space on the computer's hard disk. If more than one computer drives are available, it is better to load Auto-CAD on the drive with more free space.

J1.00 LOADING AUTO-CAD ON COMPUTER

First a new file titled *Acad* is created. For loading Auto-CAD Release 10 each floppy disk of the programme is inserted into the drive and its contents are copied on the hard disk of the computer by command `copy a:/**`

After finishing with the first disk the second disk is loaded. You only have to press (F3) (Enter) to repeat DOS Command for copying the disk. After copying all the disks you can start Auto-CAD operation by command `'acad'`.

Auto-CAD Release 11 is loaded by inserting the programme floppy disk in the drive and using command `a: install`. The computer asks you to specify the drive and the directory, and other identification data such as dealer's name and phone number. If the space on the computer hard disk/s is not enough you can install only the important files you need. A sub-directory for the installed files is created automatically. Error in selection of file can be corrected by pressing the spacebar which changes YES to NO, or NO to YES. The reserve video bar can be moved up or down by using the cursor keys. You have only to press *Enter* button to confirm the choice of file. One after another all the floppy disks are installed completely or partially (selected files). Presently *Install* programme suggests some changes in configuration system (CON FIG SYS). You have to press *Y* (yes) if you agree with the suggestions and *N* (no) if you don't. Auto-CAD also suggests creation of batch file `'ACAD 386 BAT'` which helps you start the programme with command `'acad 386'`.

J2.00 CONFIGURATION

To couple graphics board, mouse, digitizer (input device), printer or plotter you have to press the *Enter* key. The computer screen displays nine choices of video displays. Depending upon the compatibility of the graphics board available, you choose the suitable display by typing its serial number, e.g. 7 for IBM Enhanced Graphics Display (EGA).

After you have selected display the computer asks whether you want a status line, a command area, screen menu area. If adequate screen area is available you answer 'Yes' by pressing *Y* key. If screen area is insufficient you can do away with prompt or/and menu area by pressing *N* (no) to make most of the available screen area. Next comes the choice of the background: light or dark. As white background gives more eye strain usually black background is selected by pressing *Y* key. The following

stage involves choice of colours. If you want different colours for different parts *Y* is pressed. *N* (no) gives black and white combination.

J2.10 Input Configuration

Inputs can be broadly classified as Mouse or Digitizing tablet. A wide variety of digitizers are available. Two or three button mice are usually compatible with Microsoft serial or Bus Mouse digitizer. The digitizer tablets built in computers are generally compatible with Summagraphics 330 Series digitizer. The last question the computer asks: whether you want to adjust the mouse scaling parameters? If the screen area is adequate for the intended drawing press *N* (no).

J2.20 Output Configuration

J2.21 Dot Matrix Printer

It can be used for printing the processed drawing. The output can be rotated through 90° so that the width of the paper becomes the height on the monitor screen. You can calibrate the printer, choose units (inch/millimetre), select origin, and enter width and height of the drawing. Although dot matrix printout can do for checking the drawing, it is preferable to plot working drawings on a plotter. For this you need a postscript compatible printer.

J2.22 Pen Plotter

It can be configured from Auto-CAD by using postscript device.

On completing configuration Auto-CAD summarizes the current configuration stating the type of video-display, digitizer, plotter, or printer. Then comes the menu with eight numericalized commands and *Q* for exit. The selected/revised configuration can be stored in *Acad Cfg* file by pressing key *Y* (yes) to save the drawing.

J2.30 Menus

The next stage displays main menu on the monitor screen with numericalized choices.

- 1 : Begin a NEW drawing
- 2 : Edit an EXISTING drawing
- 3 : Plot a drawing
- 4 : Printer Plot a drawing
- 5 : Configure Auto-CAD

- 6 : File Utilities
- 7 : Compile shape/font description file
- 8 : Convert old drawing file
- 9 : Recover damaged drawing
- 10 : Enter selection/exit Auto-CAD

J3.00 AUTO-CAD OPERATION

Auto-CAD installed on computer hard disk can be activated by typing command `c:\acd 386` at DOS prompt. Pressing *Enter* runs the batch file and loads Auto-CAD in less than 15 seconds. The main menu cited in the last paragraph (J2.30) appears on the screen. Pressing key '1' for new drawing press *Enter*. Auto-CAD prompts you for the name of the drawing which can be typed and passed on to memory by pressing *Enter*.

J3.10 Drawing Editor

This appears on the screen (Fig. J1). The *Status Line* at top displays current position: layer number, type of mode, and X-Y coordinates. Pressing key (F8) alternately shows and removes the mode (ortho).

The right hand marginal area displays various commands for instant reference. Choice can be made by moving pointing device vertically to the desired item (command) of the menu. By pressing the extreme left button of mouse (or tip button of stylus) you can see the sub-menu of the item (commands). The main menu can be revived again by moving the highlight bar to Auto-CAD at top and pressing pick key.

J3.20 Command Area

Command Area along the bottom margin of screen is used for displaying the commands you type. The area also shows what information is required by the computer to execute the command. For example, if you type command *line* and press *Enter* the command area displays (asks) *From* (what) point.

The starting point, usually the intersection of the cross-hairs, can be moved along the screen by moving the pointing device. Pressing the first (pick) button you confirm the starting point and command area asks 'To' point. You move the picking device to choose the second point. On selection of the second point you press pick button again to obtain the line joining the two points on the screen.

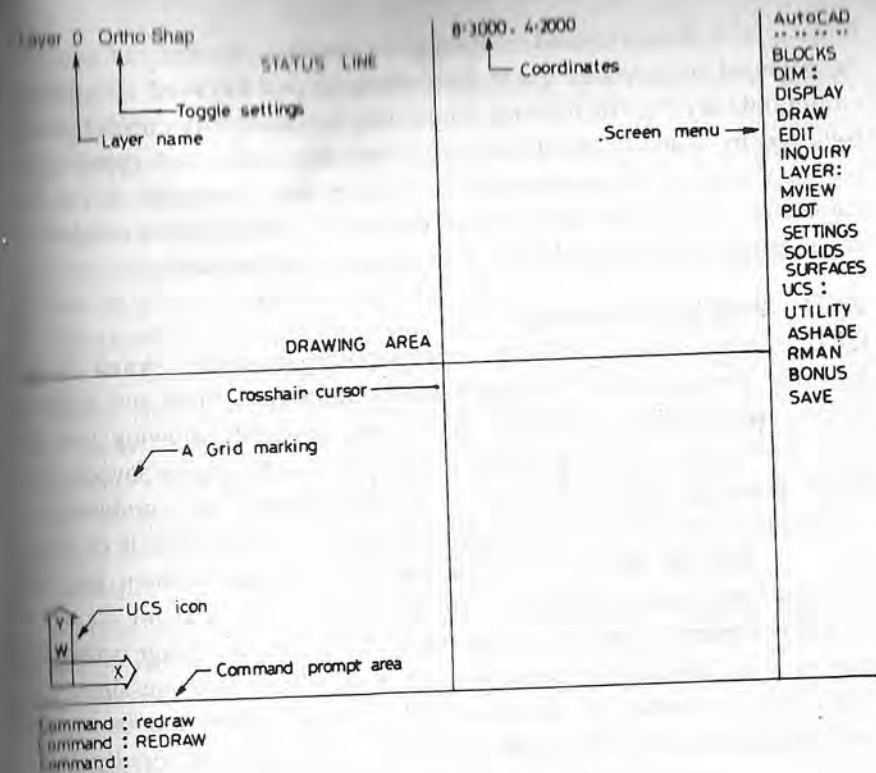


Fig. J1 Drawing (graphics) editor layout in CAD

J3.21 Text Screen

It can be used if the command area cannot accommodate both: drawing and text. Pressing *Flip-Screen* key *F1* replaces graphics screen instantly with the text screen with 24 latest lines of text. You can change-over instantly (flip) to graphics screen again by pressing key *F1*.

J3.22 UCS (User Coordinate System) ICONS

In the left hand corner of the drawing editor screen can be used conveniently for three-dimensional drafting. In case of an obstruction the icon can be switched off by command: *USCICON* followed by option command *off*. Latest coordinates of a moving point can be displayed continuously on screen by pressing key *F6* and typing command *coords on*.

J3.30 Drafting with Auto-CAD

We have to choose the degree of accuracy by typing command *snap* followed by option *spacing* command (say 1''). The cursor now hops by

spacing (1'') chosen instead of moving continuously. An array of dots can be obtained as a visual guide by command *grid* followed by spacing command (say 1''). The drawing area can be confined by command *limits* followed by *x* and *y* coordinates of lower left corner and upper right corner. You can reduce scale of drawing on computer screen by command *zoom* followed by option command *a* (all). Option *window* of *zoom* enlarges the desired part of the drawing on the screen.

J3.31 Multi-Layer Drawings

Layer control system facilitates superimposing computer stored drawings one above another. The layers can be numbered, titled and allotted different distinguishing colours. A machine assembly drawing can be superimposed by electrical wiring diagram, hydraulic piping layout, etc. These drawings can be drafted on different layers and combined or segregated at will. Layer control can be used for drawing details of press tools by drafting bolsters, die, stripper, guides, punch plate, etc. on different layers, and combining them for the assembly drawing.

Layer control dialog box shows current layer. The first layer is usually numbered 0. Moving the cursor pointer to new layer and pressing pick readies the computer for the next 'Layer Name' which can be typed. Beginning from zero, all the following layers are numbered serially: 0, 1, 2: You can allot different colours to different layers through 'Select Colour' menu which displays the first seven of the many available choices.

When you have finished with the layer exit by picking OK box, and go for the next layer: number, name, colour, etc.

For creating new layer you use commands: *Layer* then *set*. The layer is then allotted number, name, and colour.

For passing on the drawing on any layer to memory you have to type command *save*.

J3.32 Common Commands

Command *pline* comes handy for creating polygons.

Auto-CAD is programmed for ten geometric object snaps under command: *object snap*. You can specify centre (CEN) of a circle or an arch, end points (END) of arc or line; or their middle point (MID), perpendicular (PER), degree (QUA), tangent (TAN) nearest point (NEA), intersection (INT), or insertion point (INS) for a block or text. The computer will call for the requisite data such as: intersection point of what.

You can create a part/detail drawing in one corner of the monitor screen and move it to required position by command: *move* giving coordinates of 'from' and 'to' points.

Symmetrical drawing can be drafted fast by drawing only a small part and using command *mirror* and specifying the line about which the drawing is to be mirrored.

Similarly, command *array* enables symmetrical division in specified number of parts around the specified centre.

Command *filet* facilitates connecting straight lines by the specified radius '*r*'. You can 'Hatch' part of the drawing by specifying the periphery and the hatching style. Circles can be drawn by specifying their centre (*cen*), radius (*r*) or diameter (*d*). Command 'ellipse' and furnishing coordinates of ends of major and minor axes can generate an ellipse on the screen. Drawing can be elongated (distorted) in desired direction by using command *stretch* and giving the distance (extent) of the stretch.

During trial and error part you can erase errors by using command *undo*. The finalized drawing can be stored in memory by command *save* followed by accommodation in suitable existing file or creating a new one.

Command *block* comes handy for quick drawing of number of similar figures at various locations in drawing. For example, if a component has got eight holes of same size you only have to draw a circle once and convert it into a block. Just specify insertion points (centres) for the remaining seven holes to draw them presently.

You can choose line types for different layers; lettering style, size and angular orientation for notes and dimensions; and position of text/dimension. Command *Dtext* promotes faster editing of text. Similarly *gtext* changes text to block outlines without words. For dimensioning a drawing first the scale has to be selected by command: *dimscale* in such a way that the dimension is readable on the computer screen. Command *dim* followed by choice command *hor* (horizontal) or *ver* (vertical) and inputs about pick points for dimension lines, and dimension text incorporate dimensions in the drawing. Dimensions can be given continuously (Con) or from base line (BAS).

Command *adesk-b* in Auto-CAD Release 11 facilitates quick drafting of border and title-block. Alternatively you can compile a title *block* as you like, and move it to desired position on the drawing.

The following list includes 138 commands in alphabetical order.

AUTO-CAD COMMANDS

APERTURE	FILES	REDEFINE	ZOOM
ARC	FILL	REDO	3DFACE
AREA	FILLET	REDRAW	3DMESH
ARRAY	FILMROLL	REDRAWAL	3DPOLY
ATTDEF	*GRAPHSCR	REGEN	
ATTDISP	GRID	REGENALL	
ATTEDIT	HANDLESS	REGENAUTO	
ATTEXT	HATCH	RENAME	
AXIS	HELP/?	*RESUME	
BASE	HIDE	REVSURF	
BLIPMODE	.ID	ROTATE	
BLOCK	IGESI	RSCRIPT	
BREAK	IGESOUT	RULESURF	
CHAMFER	INSERT	SAVE	
CHANGE	ISOPLANE	SCALE	
CHPROP	LAYER	SCRIPT	
CIRCLE	LIMITS	SELECT	
COLOUR	LINE	*SETVAR	
COPY	LINETYPE	SHAPE	
DBLIST	LIST	SHELL/SH	
DDATTE	LOAD	SKETCH	
DDEMODES	LTSCALE	SNAP	
DOLMODES	MEASURE	SOLID	
DDRMODES	MENU	STATUS	
DDUCS	MININSERT	TABLET	
DELAY	MIRROR	TABSURF	
DIM/DIMI	MOVE	TEXT	
DIST	MSLIDE	TEXTSCR	
DIVIDE	MULTIPLE	TIME	
DONUT	OFFSET	TRACE	
DOUGHNUT	OOPS	TRIM	
DRAGMODE	ORTHO	U	
DTEXT	OSNAP	UCS	
DVIEW	*PAN	UCSICON	
DXBIN	PEDIT	UNDEFINE	
DXFIN	PLAN	UNDO	
DXFOUT	PLINE	UNITS	
EDGESURF	PLOT	VIEW	
ELEV	POINT	VIEWS	
ELLIPSE	POLYGON	VIEWPORTS	
END	PRALOT	VPOINT	
ERASE	PURGE	VPORIS	
EXPLODE	QTEXT	VSLIDE	
EXTEND	QUIT	WBLOCK	

8.33 Command Methods

Commands can be effected in seven different ways as follows:

1. Typing the command.
2. Picking command from the side screen menu.
3. Using dialog boxes of pop-down menus.
4. Picking icon from digitizing tablet overlay menu.
5. Using a multibutton pointing device or auxillary device.
6. Using script Autolist or ADS (Auto-CAD Development Systems).
7. Using abbreviated commands with Academic Pgp file.

14.00 THREE-DIMENSIONAL DRAWINGS

It is necessary to activate coordinate display using key 'F6' and selecting 'DrawingTools' from the pop-down menu. Choose snap (say $\frac{1}{32}$ ") and grid (say 1") and 'ortho' toggle for engineering drawings; and pick *OK* box for confirming the choice. For symmetrical components it is convenient to keep origin (0,0) at the centre of the drawing. Choosing limits, the lower left and upper right corners to suit component dimensions you command *vports* to divide screen into 2, 3 or 4 parts. The next command *vpoint* is used to allot the screen parts to front, side, top, and isometric views (Fig. J2).

Three-dimensional drawings can be executed by three different methods as follows:

1. Drawing various views and stating depth in plane square to drawing plane as thickness.
2. Drawing isometric view.
3. Using solid modelling.

This book describe only the last method.

14.10 Solid Modelling

In cheaper AME lite version, of Auto-CAD Release 11 you pick and load *AME lite* from pop-down menu and await upto half a minute for installation in the computer.

Component drawing is compiled by selecting basic shapes (box, cylinder, cone, sphere) and adding (joining) or subtracting (for holes) them.

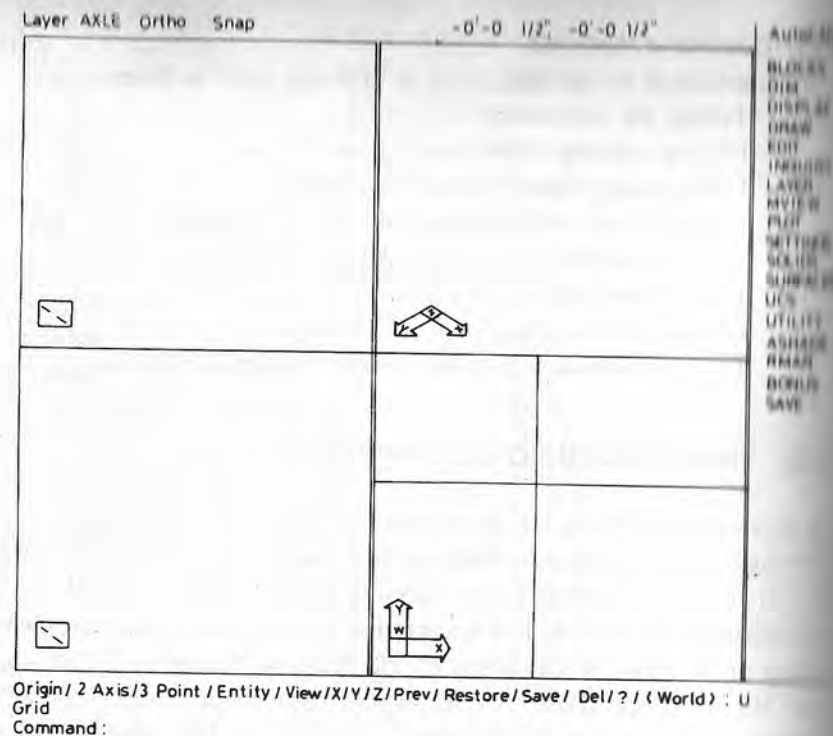


Fig. J2 Division of screen for 3 dimensional drawing

Cubes, and columns can be created by using command *solbox* (solid box). You specify coordinates of one corner of the cube and choose command *L* giving length along *X* axis, width along *Y* axis and height along *Z* axis to create a box on the screen.

Similarly cylinders can be drawn by using command: *solcyl* (solid cylinder), and feeding centre coordinates of one end, diameter or radius, and length. It is convenient to place the origin at the centre of one end of the cylinder.

For example for drawing component shown in Fig. J3 we choose origin at bottom front corner of the 24 mm square, and giving command *solbox* state corner 0, 0; give command *L* and state length 24 along *X* axis, width 24 along *Y* axis and height 200 along *Z* axis to draw the square box. For drawing the cylindrical ends you command: *solcyl* followed by the coordinates of the centre of end (12,12,200 for top cylinder) radius (10) and height (50).

You will have to pause to allow Auto-CAD and the supplied input to its solid model database, evaluate boundaries and compute tessellation

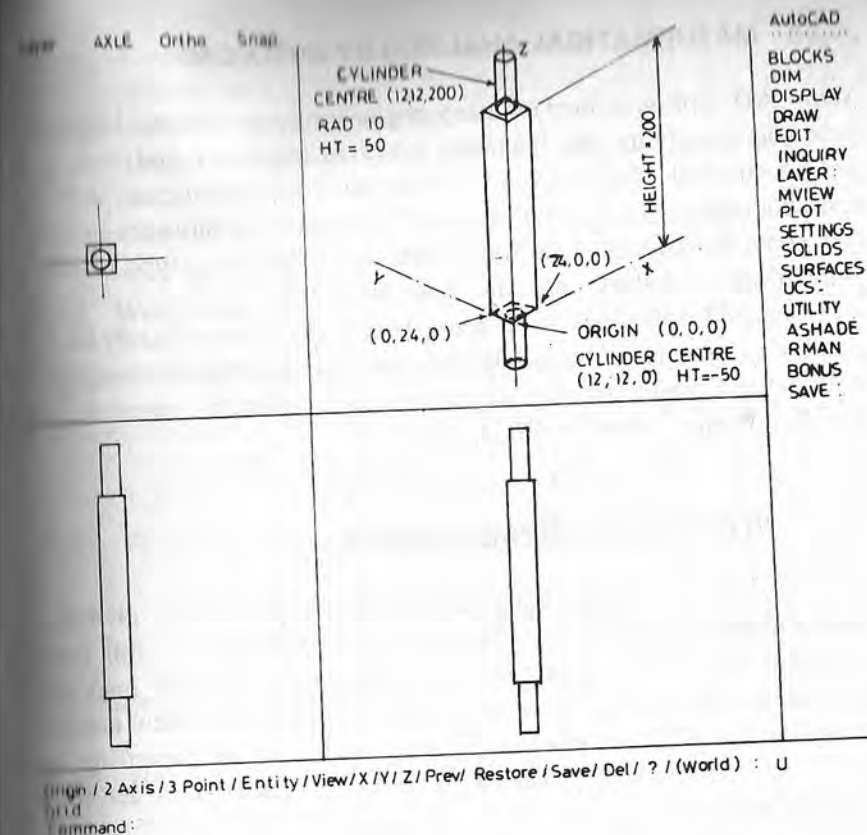


Fig. J3 Solid modelling

before it can produce the cylinder on the screen. Bottom cylinder can be produced similarly by stating end centre coordinates (12, 12, 0) radius (10) and height (-50).

Other useful commands are *solfill* for internal corner radii and *solint* (solid intersection) for end radii of solid boxes. Command *solsub* (solids subtraction) for creating holes and cavities, *solunion* (solid union) to join two solids, *solmesh* to convert solids into meshed objects, *hide* to remove invisible (dotted) lines, *shade* for shading. You can get architectural perspective views of object by command *dview* and specifying camera to object distance.

You can move drawing on the screen by pressing *F8* followed by command *pan*, and giving the present and required positions. You can rotate objects by command *rotate* and specifying the axis and angle of rotation. Command *move*, *array*, *mirror* detailed earlier can also be used conveniently in three-dimensional drawings.

In fact, Auto-CAD provides more than one way of drafting.

J5.00 MATHEMATICAL ANALYSIS BY AUTO-CAD

Auto-CAD is programmed for many engineering calculations. Command *area* and specifying the boundary gives us perimeter and area in a two-dimensional drawing. Solids listing command *solist* gives information about edges, faces, and volume of the object. It furnishes information about the Constructive Solid Geometry (CSG) tree, type of model (wire frame) and shade, material, node level, etc.

Command *solmassp* (solid mass properties) comes handy for calculating volume, mass, bounding box coordinates, centroid, moments of inertia, their products, and radii of gyration; principal moments, and X-Y-Z directions about centroid.

J6.00 PLOTTING AUTO-CAD DRAWING

Sophisticated Auto-CAD plotters can deploy upto six pens giving six colours in the plotted drawings. There are seven types of lines: full, centre line (dots and spots), spotted one, and four types of dotted lines with different spacing. Unlike matrix dot printer in plotters, the view need not be rotated by 90°. You only choose the scale to suit the paper/film size to be used and indicate whether the hidden (dotted) lines are to be removed or not.

Both matrix printer and plotter being line drawing devices they cannot show the shading you can impart and display on computer screen. If a shaded illustration is required it is necessary to photograph the shaded picture on computer screen using f_{16}^1 aperture and $\frac{1}{30}$ second exposure on a camera steadied on a tripod stand.

J7.00 COMPUTER-AIDED DESIGN OF PRESS TOOLS

Special software programmed for design of press tools can automate the following functions of a designer.

- (a) Checking workpiece drawing for feasibility of manufacture from sheet metal, using press tools.
- (b) Finding blank size for bent, formed and/or drawn workpiece.
- (c) Selection of the type of press tool to be used.
- (d) Finding out angle of orientation, margins, pitch, material utilization.
- (e) Deciding disposition of punches, and shank centre.

- (f) Computing shear forces and sizes of die, stripper, screws, dowels, etc.
- (g) Selecting press, die set, top.
- (h) Drafting assembly drawing, bill of materials, detail drawings, etc.

Computer-aided die design comprises the following stages.

J7.10 Workpiece Checks

- Inputs** Sheet thickness, material strength, workpiece dimensions
- Checks** Minimum size of slot/hole, margins for slot/hole, bend and cup radii

J7.20 Find Developed Length/Blank Size

- Inputs** Sheet thickness, Material strength, bend/cup radii, workpiece dimensions such as bend angle and cup height
- Outputs** Blank shape and size

J7.30 Nesting

- Inputs** Sheet thickness, sheet form (coil or flat), grain direction
- Outputs** Blank orientation, margin, bridge, pitch, strip width, layout on flat sheet, material utilization values

J7.40 Strip Layout

- Inputs** Workpiece blank shape and size, number of pieces required per annum
- Outputs** Selection of type of die, disposition of various punches, i.e. strip layout

J7.50 Die Design

- Inputs** Blank thickness shape and size, material strength, number of pieces required, presses available
- Outputs** Assy. Drg., Bill of Materials, Detail Drgs.

Numeric data of detail drawing can be fed conveniently to electro discharge wire cutting machine for computer-aided manufacture (CAM) of die elements. Thus CAD/CAM minimizes human error in transferring (copying) workpiece/die dimensions at various stages of die design manufacture.

The following paragraphs give further details of the various packages used for die design automation.

J7.60 Workpiece (Technology) Check Module

It examines the feasibility of the workpiece for the requisite press operations: can it be produced easily from sheet metal? The module identifies complex geometrical regions difficult or impossible to produce, and checks workpiece according to the programmed rules. Unacceptable areas are identified and possible changes are suggested. For example, if a blank shows 1.0 dia hole in 3.0 mm thick mild steel sheet the module will indicate that the hole size is unacceptable and should be changed to 6 dia (twice the sheet thickness).

J7.70 Developed Length/Blank Size Module

Developed length module is fed with bend radius, angle, sheet thickness and tensile strength of the blank material. It computes bend allowances and gives developed profile of flat blank before bending.

For drawn cups inside radius joining cup bottom and vertical wall, cup dia and height, flange dia and connecting radius along with material thickness and tensile strength are fed to the computer to obtain the blank diameter.

J7.80 Nesting Programme

This optimizes material utilization without compromising the requisites of grain direction for the following operations such as bending. The programme comprises of six modules.

J7.81 Geometric Input Module

This can be fed with geometric data about blanks by creating a blank drawing by any graphics package with a data exchange facility. Alternatively, the input can be fed in interactive form by giving details of each individual entity.

J7.82 Graphic Interface Module

Converts the geometric data into numerical form and transfers the data to the database module through the graphic editor. The editor divides the blank into straight lines with coordinates of both ends, arcs with coordinates of centre and both ends, and radius, and circles with coordinates of centres and radii.

J7.83 Database Module

Stores information about blanks, strength of blank materials and information received from graphic interface module in the form of three-dimensional arrays. Each detail has information about entity, loop and blank.

J7.84 Nesting Module

Comprises of three sub-modules: single blank, single row nesting; single blank, double row nesting; and multi-blank, single row nesting. Simple blanking tools use single blank, single row nesting [Fig B24a, b]. Single blank, double row nesting [Figs B24d, e; B25c, d] calls for reversal of strip and double pass if strip cut from a sheet is used. Alternatively, two sets of punches and dies are necessary if coiled strip is used, as coil reversal is just not possible. Naturally, the press should have capacity for shearing two blanks simultaneously. Multi-blank, single row layout [Fig. J4] avails

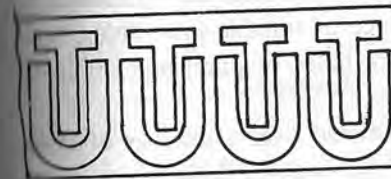


Fig. J4 Multi-blank single row nesting

of scrap area of bigger blank to obtain another smaller blank from the scrap strip. Thus two or more different types of blanks are produced simultaneously with every stroke of the press. Extracting blank information from database module, nesting module processes it to generate nest with due regard to grain direction, margin and bridge requisites. During processing, nesting module interacts with the optimization module.

J7.85 Optimization Module

Uses modified one-dimensional unconstrained non-linear programming for quick computation of material utilization for various nests.

J7.86 Output Module

Receives data from nesting and optimization modules, and displays the nest drawing through graphic interface module. It also displays the angle of orientation of blank, pitch and strip width, material utilization for each configuration, and specifications of the selected press.

Bends should be made preferably across grains. Angle between bend line and grain direction should not exceed 45° . Workpieces with no bends can be oriented in any convenient direction for optimum material utilization.

When flat sheets of standard sizes are used the optimization module computes overall material utilization for the entire sheet taking into account the wastage in width as well as length.

J7.90 Strip Layout Module

It selects the type of die from inputs such as sheet thickness, precision required in blank, complexity of blank profile, and quantity required per annum. It examines the blank profile for machining processes to be used and divides it into small convenient shapes. Weaker sections of tool are checked for stress and deflection. Dies for blanks up to 300 mm can be wire cut in a single pass. Bigger and/or complicated blanks are divided into simpler shapes for easy manufacture of punch.

Internal features of blank such as holes and slots are examined for piloting in progressive tools. In the absence of suitable pilot holes, scrap area of strip is pierced with suitable pilot holes or pitch notches in the very first stage of the progressive tool.

Close falling holes in blank are distributed over a number of stages to avoid a weak section in the die. If the width of die cross-section between two cutting edges is less than twice the die plate thickness, an idle stage is introduced to avoid a weakening of die, stripper, punch plate, etc.

Cutting and forming stations are arranged in such a way that the pressure is loaded uniformly. Sometimes it is necessary to split cutting a single blank in two operations to avoid weak slender section in die [Fig. J5]. In addition to taking above decisions the strip layout module also takes care of positive, interference-free, scrap disposal in the strip layout itself.

J8.00 DIE DESIGN PACKAGE

It comprises of the following modules:

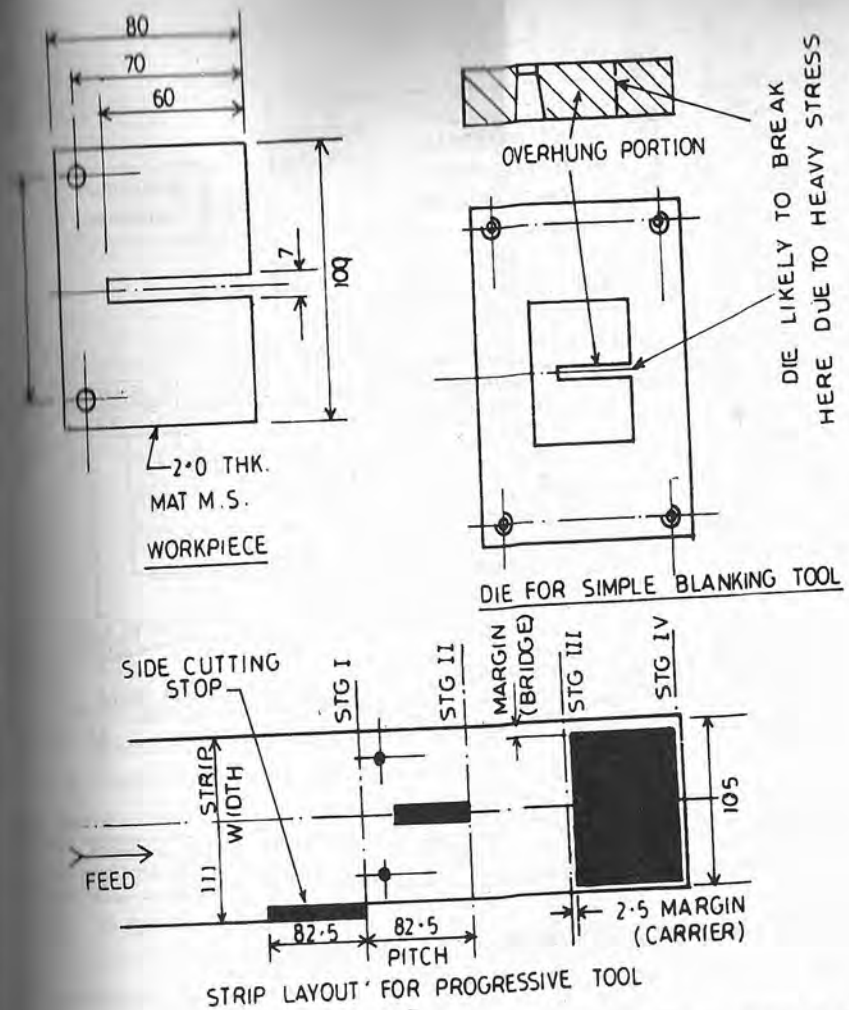


Fig. J5 Dividing slot piercing into two operations to avoid weakening die

J8.01 Database Module

It is stored with libraries of standard die elements. These store information about I.S. standard punches, die bushes, die sets, springs, screws, dowels, etc.

J8.02 Computer-Aided Die Design Module: CADDs

The design software selects the type of die suitable for given quantity and quality. The precision required in the blanking as well as the shape of the blank also determines the type of die [Fig. J6].

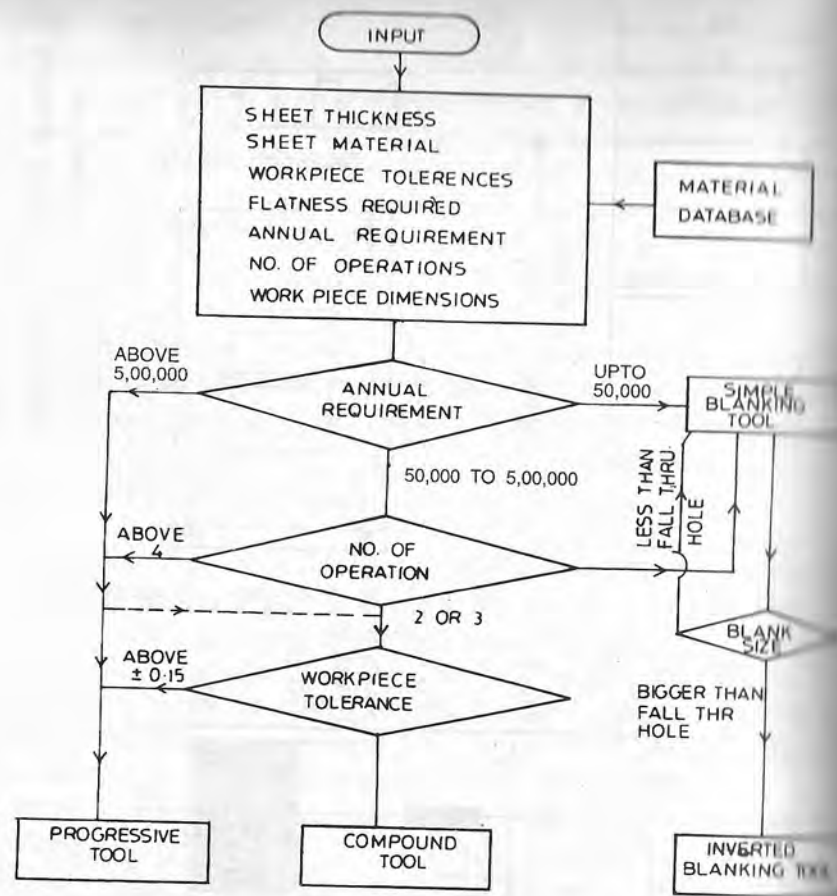


Fig. J6 Selection of type of die

Table J1 Requirement and Type of Die

Sr. no.	Annual requirements	Die type
1	Upto 50,000 Nos	Simple blanking, separate piercing & bending dies if necessary
2	50,000–5,00,000	Compound tool
3	above 5,00,000	Progressive tools with segmental, inserts type construction

The precision demanded by the workpiece also determines the type of tool.

Table J2 Workpiece Tolerance and Type of Die

Sr. no.	Workpiece feature	Tolerance	Die type
1	Blank profile hole position and centre distance	± 0.1	Compound die
2	Blank profile hole position and centre distance	above ± 0.15	Progressive tool or simple die

Another criterion for selection of the type of die is the number of operations necessary to obtain all the features of the blank.

Table J3 No. of Operations and Type of Die

Sr. no.	No. of operations	Type of die
1	1	Simple blanking die
2	2, 3	Compound die
3	4 or more	Progressive die

The programme also chooses the type of the stripper according to the thickness of the blank. Spring stripper is chosen for sheets thinner than 0.5 mm while a fixed stripper is used for sheets thicker than 0.5 mm. All these choices are made automatically by the software.

The programme also selects the type of stop. End stop is most common. A circular blank profile calls for two end stops. Where side-cutting is possible, side-cutting (trimming) stop can be used conveniently in progressive tools. The designer only indicates possibility or otherwise of trimming the strip and the design software automatically selects the suitable type of stop.

Blanking tools are automatically designed inverted when the blank size exceeds the fall through hole size in press table.

Design check module finds out the centre of pressure, tonnage required, stripping force and decides dimensions of punches, dies, stripper, punch plate, etc. It also determines the number and sizes of screws, dowels, springs, knockout pins, the guide pillars. The springs and knockout (thrust) pins are placed symmetrically around the punches. The screws and dowels are placed at equal pitch on a straight line with adequate margin from die/punch plate sides and parallel to feed direction. When the die/punch plate length is not integer multiple of the screw pitch, the pitch is adjusted to place one screw at mid-length of die/punch plate.

The design package computes geometrical parameters of punch and die from each stage of strip layout, and determines the die layout and tool shut height.

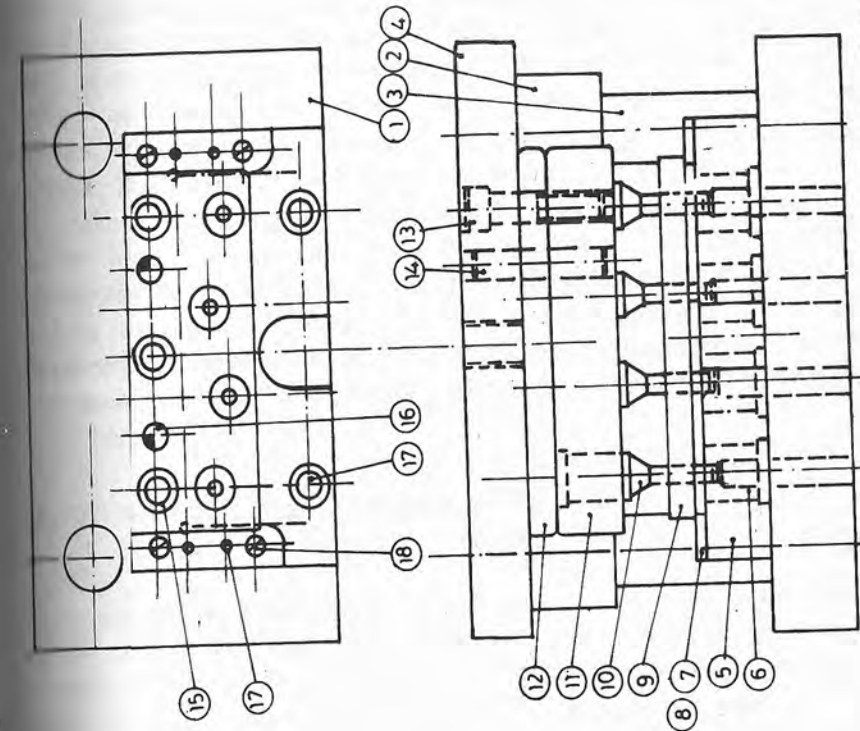
It also selects suitable die set from the database and standard punches and die bushes from the libraries to compile the bill of materials.

The assembly drawing comprises of numerous layers for various die elements such as bolsters, punch plate, stripper guides, dies and punches. The programmer can select any sectional plane for elevation.

The output module displays strip layout, plan, and elevation of press tool and bill of materials.

In detailing the individual layers are used for drafting the die elements.

CADDS developed by Mr V.K.D.V. Prasad and Prof S. Somasundaram of Indian Institute of Technology, Bombay was implemented on Apollo (Nexus-3000) workstation. The input can be provided through any standard graphic package with data exchange format (DXF). Implementation was accomplished by interfacing Auto-CAD for external programme in AutoLISP and FORTRAN. AutoLISP was used to create standard part libraries through parametric programming.



Sr. No.	DESCRIPTION	Qty	MAT	SIZE / SPEC
17	ALLEN SCREW	2	12.9stl	M8 X 30
16	DOWEL	2	std	PR 85
15	ALLEN SCREW	2	12.9stl	M8 X 45
14	DOWEL	2	std	PR 84
13	ALLEN SCREW	4	12.9stl	M8 X 35
12	BACK PLATE	1	16MnCr5	105 X 58 X 10
11	PUNCH PLATE	1	M.S.	105 X 58 X 22
10	PUNCH	4	HCHC	STD : C0850
9	STRIPPER	1	M.S.	105 X 45 X 13
8	REAR STOP	1	C 105	101 X 20 X 4
7	SIDE GUIDES	2	C 105	50 X 16 X 4
6	DIE INSERT	1	HCHC	STD : 2081
5	DIE HOLDER	1	M.S.	127 X 67 X 22
4	TOP BOLSTER	1	M.S.	STD : RP 1207 T
3	GUIDE PILLAR	2	16MnCr5	STD : 20100
2	GUIDE BUSH	2	16MnCr5	STD : 20040
1	BOTTOM BOLSTER	1	M.S.	STD : RP1207 B
	DESCRIPTION	Qty	MAT	SIZE / SPEC

PIERCING TOOL FOR HINGE

Fig. J7 Assembly drawing and bill of materials drafted using CAD die design programme

Manufacture of Press Tools

K1.00 MANUFACTURE OF CUTTING TOOLS

The method of manufacture depends upon the size and shape of punch and die. Cylindrical punches and corresponding dies/inserts can be manufactured easily on lathe and cylindrical grinder, and assembled in punch plate and die holder. Nonetheless, the centre distances between punches and corresponding holes must be exactly equal otherwise the punches will not enter the stripper and die holes. Although a little variation (0.01–0.02) in centre distance would not prevent assembly it will make the die clearance around the punch unequal leading to uneven burr in workpiece. Of course, all the constituents, i.e. punch plate, stripper and die can be jig bored separately very accurately, but this can increase the tool cost immensely. Moreover, if the centre distance tolerances in blank are wider (say ± 0.1) the tool can be manufactured much more economically by using a tool milling or a vertical milling machine for jig boring.

K1.10 Assembly of Die, Stripper, and Punch Plate for Jig Boring

To ensure that the centre distances in stripper, punch plate and the die match exactly, the three plates are assembled together one above another and jig bored together on a milling machine. Naturally, the holes should be square with the plates' faces. So stripper, punch plate, and die plates are ground on surface grinder to make both faces of each plate parallel within 0.005 mm. It is also advisable to grind at least two edges of each plate square to the plate faces (Fig. K1). The edges should also

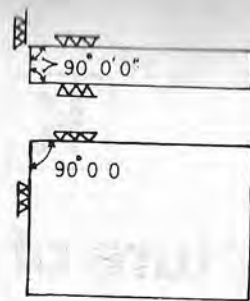


Fig. K1 Grinding two edges and two faces of punch plate, die and stripper jig boring

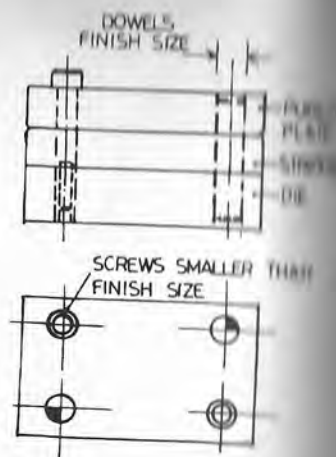


Fig. K2 Assembly of punch plate, stripper and die for jig boring

be square with each other, to facilitate marking with a vernier height gauge on a surface plate.

It is customary to assemble the three plates temporarily for jig boring by welding two tacks at the interfaces. The tacks can be chiseled and ground off to disassemble the plates after jig boring. Alternatively, the press tool designer can keep the sizes and centre distances of fixing screws and dowels for top tool and bottom tool equal. The toolmaker can then drill and ream the holes in the three plates together. The drilled and tapped hole sizes for screw should be smaller than those stated on assembly so that the holes can be enlarged to a bigger finish size later. The dowel holes should be drilled and reamed to final size. The plates can then be assembled for jig boring as shown in Fig. K2.

K1.11 Prevention of Drag in Jig Boring

The holes to be jig bored should not be marked by a centre punch as the dent of the punch tends to pull the twist drill to make it concentric with the dent. Consequently the errors inevitable in manual marking and punching will cause errors in jig boring. The punch plate should be marked only with two square centre lines to show the approximate position of the centre of the hole to be jig bored. In case the toolmaker has already dented the punch plate by a centre punch it is advisable to use a centre drill first to prevent the drag due to the dent.

K1.20 Machining Non-Circular Profiles

For non-cylindrical punches and dies, roughing is done usually by sawing. If a vertical band saw is not available the profile is roughed by drilling holes leaving 0.5 mm finishing allowance from the required profile.

The material between the holes is sawn by hacksaw to separate the internal piece from the die. The circular undulations left by the drilled holes can be filed off or milled off.

If a bandsaw is available, the die is drilled with only one hole for passage of the sawing blade. The bandsaw blade is inserted through the hole and welded again. The internal profile of blank can be rough sawn leaving 0.5 mm allowance for finishing. This eliminates filing of the drilled hole undulations completely and saves a lot of time. If the table of the bandsaw is inclinable the $1\frac{1}{2}^\circ$ fall through taper in die can also be roughed by sawing (Fig. K3).

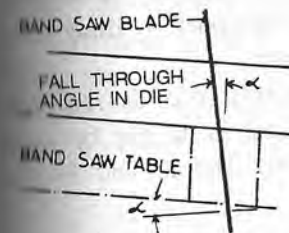


Fig. K3 Sawing fall through angle in die by tilting saw table

The punch shape can be sawn without drilling any holes. Usually 0.5 mm allowance is left for finishing. Either the die or the punch is finished to size, and hardened to serve as a master for the mating part.

K1.21 Hardened Die as Master in Blanking Tools

In blanking tools it is advisable to finish the die first. The die is hardened and used as a gauge for finishing the punch.

The unhardened roughed up punch is forced a short distance into the hardened die cut-out. This peels off the extra material on punch and burnishes the penetrated depth of the punch. The rest of the punch length is filed off a little above the burnished band on the punch. The punch is then penetrated more deeply into the die. Again the remainder length of the punch is filed off a little above the burnished band. Thus, by penetrating a punch a little further every following time the entire punch working length is passed through the hardened die. The punch is

reduced further by filing to provide the die clearance between punch and die.

K1.22 Checking Die Clearance

The die clearance can be checked by a filler gauge. At least two pairs of diametrically opposite points should be inserted with filler gauges having thickness equal to the required die clearance. Very fine clearances can be checked by a cigarette foil or paper or film of requisite thickness.

K1.23 Using Hardened Punch as a Master

After providing the clearance, the finished punch can be hardened. The hardened punch can be used to shape punch plate cut-out by forcing punch into punch plate and filing cut-out to burnished level as done earlier for punch. Only the punch plate cut-out should be a little tight on the punch, so that no filing is required after passing the punch through the punch plate. Similar method can be used for finishing the stripper also. Only the stripper should be made slide fit with punch by filing off a little material after passage of the hardened punch.

While assembling the top and bottom tools on bolsters of die set, filler gauge or paper or foil or film packings are inserted in the gap between punch and die for uniform die clearance all around. The top and bottom tools are dowelled to bolsters in this position.

Filing machines with inclinable table can speed up filing die clearances and the $1\frac{1}{2}^\circ$ angle below the straight land.

K1.30 Segmental Dies

Die segments are usually designed in such a way that die profile can be ground. For precision work an optical profile grinder is used. The die and punch profile is enlarged 10 to 50 times. The profile grinder is provided with a pantograph mechanism. Manual movement of the pantograph stylus along an enlarged profile moves the grinding wheel/machine table in a similar manner by a much lesser distance depending upon the enlargement ratio. Thus by drawing die/punch profile accurately to enlarged scale, and tracing the stylus accurately on the enlarged profile, we can move the grinding wheel/machine table precisely in the desired manner to grind punch/die segments accurately. Even $1\frac{1}{2}^\circ$ angle below the straight land of die can be ground in the same setting. The enlarged profile is also used for dressing grinding wheel to the required form precisely.

K1.31 Use of Plastic Metal for Punches Assembling

It is convenient to use a plastic metal (araldite) for assembling the punches as described in para B9.35 (Fig. B62).

K1.40 Electrical Discharge Machining (E.D.M.)

Sparking in a gap between two electrodes erodes both the electrodes. By controlling the gap between the electrodes and the passing current, the rate of erosion can be controlled. By substituting a die for one electrode it can be eroded, electrical discharge machined, precisely. The other electrode serves as an eroding, E.D. machining, tool. In spark erosion machines, the electrode is made similar to cutting punch. In E.D. wire cutting machines a fine 0.1 to 0.25 mm ϕ wire serves as other electrode: E.D.M. Cutting Tool.

K1.41 Spark Erosion

Spark erosion or electrical discharge machining (E.D.M) is a process in which the metal is removed by thermal effect of electrical discharges across a gap between the (tool) electrode and the workpiece. The cutting point is submerged in a dielectric liquid such as paraffin or transformer

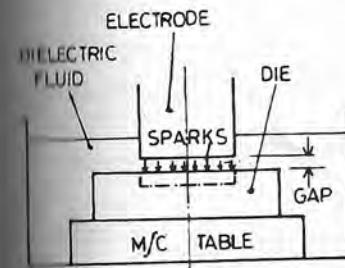


Fig. K4 Reducing tools

oil (Fig. K4). It is widely used for machining diecasting, forging, wire drawing dies, and press tools. Special purpose equipment employing E.D.M. process is available for drilling deep holes of small diameters (0.765 mm ϕ X 300 mm deep), removal of broken drills and taps, and tapping hardened steel parts.

As it is possible to erode hardened steels, it is ideal for finishing the parts distorted in heat-treatment. Such parts are machined roughly, heat-treated, and then finished by spark erosion. Furthermore, the process produces a hard layer on the eroded surface. The hardness of the layer is generally six to seven points higher (on Rockwell C' scale)

than the base material. The layer, 0.025 to 0.125 mm thick, leads to long life, exceeding that of nitrided steels.

K1.411 Finish and Dimensional Accuracy Spark erosion can produce sharp corners and fine details, eliminating handwork, and reducing polishing time. Appearance and dimensional accuracy is of better quality than conventional machining methods. With proper cast finish of 0.5 micron can be obtained. Cavities can be produced within ± 0.05 . In press tools, die clearances can be easily controlled within 0.1 mm to 0.08 mm by using correct gap between the electrode and the die. Even finer clearances can be achieved by using undersized electrodes. For clearances above 0.08 mm it is necessary to use oversized electrodes.

K1.412 Electrodes Wear of an electrode is an inherent hazard in spark erosion machining. As a result, the end of the electrode near the workpiece diminishes in cross-section, and will produce a undersized cavity if used again. To overcome this difficulty, the worn electrodes are used for roughing and very little material is removed by the finishing electrode (Fig. K5).

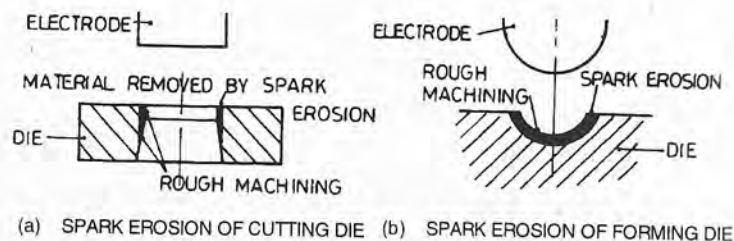


Fig. K5 Spark erosion of cutting and forming dies

The wear also depends upon the electrode material. Brass, a popular electrode material, has poor wear factor. Some materials like copper and copper-tungsten have better wear factors. Tips of these materials are widely used for spark erosion of press tools. For diecasting dies, large electrodes are made of zinc or tin alloys sprayed with a layer of copper. Carbon electrodes have a good wear factor. In spite of good wear factor, carbon electrode tapers down 0.12 mm after eroding a 50 mm deep cavity.

Choice of Electrode Material

Following are the considerations for selection of electrode material:

1. **Wear factor** Useful life of an electrode and the number of stages or electrodes required to complete the erosion depends upon the wear factor of the electrode material.
2. **Machinability** Simplifies manufacture.
3. **Castability** If the material can be cast, the subsequent machining can be reduced.
4. **Power consumption** For the same amperage, rate of erosion of different electrode materials varies considerably.

Materials like carbon having high rate of erosion can cut down the erosion time.

Let us now examine various materials in the light of the desired properties stated above:

Brass Despite poor wear factor it is widely used because it can be easily cast and machined.

Copper Very good wear factor but is difficult to cast and more difficult to machine than brass. Penetration rates and cost are higher than those of brass. Copper sprayed electrodes are cheaper and equally efficient.

Copper-Tungsten Good wear factor. It can be milled, ground and brazed. Penetration rate is higher than in copper or brass, but it is quite expensive.

Carbon (Graphite) Good wear factor, can be easily machined even on wood-working machinery. For the same amperage, stock removal rate is thrice that of brass. For big electrodes, sections can be glued together.

Zinc or Tin Alloys Sprayed with Copper These possess same wear factor and penetration rate as copper but cost much less.

In diecasting, forging, drawing and other dies with varying cross-section of cavity copper-sprayed electrodes are used widely for spark erosion. Where the requirement of the dies is more or/and recurring they prove much more economical than solid electrodes.

Manufacture of Copper-Sprayed Electrodes A solid copper electrode is manufactured by milling or other conventional machining methods. This electrode is used as a model for manufacture of plaster moulds. The model can also be used for finishing of the die. If a die already exists it can also be used as a mould for spraying copper.

For deep complicated cavities, three or four electrodes are required. Their sizes are adjusted by acid-etching to suit the various rates employed during formation of a cavity. Using the smallest possible size of wire for deposition of small particles, copper is sprayed into the moulds to 2.5 mm thick layer. To prevent oxidation of copper during spraying the temperature should not be allowed to rise. This can be achieved by having a number of moulds and spraying, in a sequence, only a small amount of copper in each; so that by the time the cycle is completed the mould sprayed first has cooled down. Temperature control can also be achieved by water cooling.

After depositing 2.5 mm thick copper in the mould, the remainder cavity is filled by spraying cheaper materials like zinc. The filler can be deposited at a faster rate and a brass plug can be inserted in position while spraying. The plug can later be machined to facilitate mounting of the electrode on the machine. Copper tubes are also inserted for dielectric fluid which continuously flushes clear the eroded metal particles. Insertion of the tubes, however, leads to pips which can be removed later by grinding or spark erosion.

Layton Metal Spraying Process In this process first a male model replica of an electrode, is made of materials such as epoxy resins, plaster, hardwood or easily formed metals like lead.

Moulds are made of special heat-resisting epoxy resin and aluminium filler (developed by Ciba (A.R.L.) Ltd, Duxford, Cambridge). The model is placed in a mixture of these materials to form the cavity. The mixture with the model in position is allowed to set for a period of 24 hours at room temperature. A curing operation is then carried out in an oven at a temperature of 100°C for a further period of 24 hours. An electrode is then sprayed in the same manner as described earlier.

The moulds can later be used as a fixture for machining of the electrode.

Greater part of material is removed by sprayed electrodes and the solid electrode is used only for finishing. For limits above ± 0.25 mm sprayed electrodes can be used also for finishing the die.

K1.413 Spark Erosion of Press Tools using Tipped Electrodes Tipped electrodes are mostly used for the manufacture of press tools. A tip of the electrode material is fitted to a roughly machined punch. The tip along with the punch is then finished to size for die clearances between 0.02 mm to 0.08 mm (Fig. K6). For lesser die clearance, the cross-section of the electrode only is reduced in size and made smaller than that of punch. Simplest method of doing this uniformly all around the electrode

is 'acid-etching'. For clearances above 0.08 mm the electrode along with the punch is machined oversize in cross-section. After spark erosion of the die, the punch can be detached from the electrode, and finished to the required size.

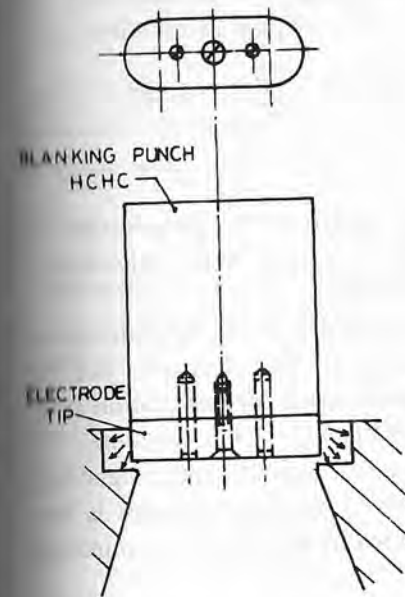


Fig. K6 Tipped electrode for spark erosion

The die is roughly machined first keeping minimum possible material for spark erosion. In case of press tools mounted on pillar die sets, alignment is facilitated by mounting the punch along with the electrode on the top bolster of the die set. The die is fitted on the bottom bolster. The guide pillars can be used for the alignment while fitting the bottom bolster on the machine table and the top bolster to the electrode holding spindle of the machine. But it must be remembered that for effective erosion, the electrode must be positively insulated from the die. So the guide bushes should be removed. If a linear ball bearing is used, the top tool can be insulated from the bottom tool by removing the ball cage. Spark erosion machines are specified by the weight of the electrode which the spindle can hold.

K1.414 Spark Erosion Machines These resemble vertical drilling machines in configuration.

Following are the capacities of a Wickman Erodomatic Machine

1. Maximum quill stroke	145 mm
2. Work table area	445×375
3. Area of top of base available for work	760×555
4. Maximum daylight, quill to base	505
5. Maximum daylight, quill to table	315
6. Throat, quill to column	305

Electrode Design

1. **Length** This depends on the depth of the penetration required. Normally electrode length = three times thickness of the work piece + 35 (for mounting).
2. **Spark Gap Allowance** The electrodes are made undersize to ensure proper spark gap between the electrode and the workpiece. The spark gap depends upon the penetration range selected. Seven ranges are available on the machine. The coarsest denoted by a single triangle is used for roughing at high penetration rate. The finest denoted by seven triangles is used for the best surface finish obtained by eroding at the minimum penetration rate.

The following table gives the spark gaps required for eroding a round hole in a hardened steel plate with a brass electrode

Range no.	Diametrical Spark gap
1	0.60
2	0.50
3	0.30
4	0.15
5	0.10
6	0.05
7	0.025

A round electrode would be made undersize by the amount equal to the diametrical spark gap for the range used.

3. Let us consider a case where 12.500ϕ hole is to be eroded in a hardened steel plate with brass electrode in four stages. (Three roughing and one finishing electrodes in ranges 2, 4, 6, 7). If finishing is done in Range No. 7 of the machine: Finishing electrode diameter = $12.50 - 0.025 = 12.475$ dia, i.e. Finish size - Diametrical gap.

For semi-finishing in Range No. 6

$\therefore$ Electrode dia = $12.475 - 0.1 = 12.375$

For semi-roughing in Range No 4,

Electrode dia = $12.375 - 0.3 = 12.075$

For roughing in Range No 2;

Electrode dia = $12.075 - 1.0 = 11.075$

Electrode is held in a chuck with 12.5ϕ capacity. Electrode is provided with $12 \phi \times 35$ long shank for holding.

K1.42 Electrical Discharge Wire Cutting Machine

Electrical discharge wire cutting machines are like electrical discharge vertical band saws. A 0.1 to 0.25 diameter wire is guided along a

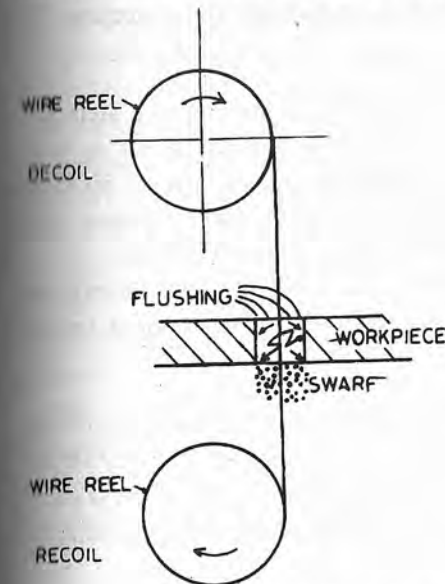


Fig. K7 Electrical discharge (spark) wire cutting

programmed track (Fig K7). Electrical discharge between wire and workpiece in the gap filled with insulating fluid effects erosion of workpiece material along the programmed path to produce the desired shape of die cavity/punch shape.

K1.421 Wire as a Cutting Tool The brass or superalloy wire is subjected to wear; so it is run continuously. The wire is unwound from one reel and runs around a system of pulleys which stretches the wire. The wire can be used only once and the worn wire is discarded after use. The speed of the wire depends upon the thickness of the workpiece to be cut. The wire is guided between two nozzles. The top nozzle can be adjusted vertically to suit the thickness of the workpiece.

The workpiece is mounted on a coordinate table which can be programmed by numerical control to move along the required path to produce the desired profile. The path can be monitored by a pantograph mechanism which can be fitted with a pencil or a pen. The pencil draws the path followed by table (wire) to desired scale. The profile traced in the monitor can be checked by scale for correctness.

K1.422 Cutting Draft Angle It is possible to cut the draft angle (fall through taper) upto 30° in the workpiece. This facilitates finishing the die cut-out on wire cutting machine. It is also possible to wire cut parallel punches from a solid plate thicker than the punch length by keeping the draft angle zero.

K1.423 Water as Dielectric Fluid In addition to serving as a dielectric fluid, water also serves as a coolant. During erosion, water is contaminated with swarf of tiny eroded particles of the workpiece. So these wire cutting machines are provided with water treatment equipment with coarse and fine filters to remove particles bigger than 0.005 mm.

Wire cutting machines of smaller sizes have 'C' type cantilever machine frames while bigger machines are provided with portal frames supported at both the ends.

K1.424 Operation As in a vertical band saw, it is necessary to provide a hole for passage of wire before work can be commenced. Fig. K7 shows a hole for wire passage. The wire first moves linearly to the nearest point of required cut-out periphery before traversing along the programmed path.

The electronic control system of wire cutting machines displays various parameters on the numerous dials and screens, and automatically stops the machine if something goes wrong. The displays point the error and a hooter is sounded if the error is not corrected within a certain time limit.

Although wire cutting machines function like electrical discharge bandsaw the precision numerical control for table movement assures high accuracy and the draft angle facility cuts down the manufacturing time considerably. Once a programme is recorded on tape it can be used a number of times. As such, it is a great asset in the manufacture of gang slotting tools for electrical laminations in which a number of similar slotting punches are required. Even dies for gang slotting can be manufactured in one piece instead of segmental construction which requires laborious, time consuming, profile grinding with precision dependent on the skill of the operator traversing the stylus along an

enlarged profile. Wire cutting uses numerical control system for accurate movements, eliminating human errors altogether.

K2.00 MANUFACTURE OF BENDING AND FORMING TOOLS

Simple forms can be machined easily on milling machines and ground on the tool and a cutter or a profile grinder. Punches and dies are marked using vernier height gauge, milled or filed, hardened, and ground or polished. Spherical endmill can be used to obtain the desired corner radii in non-cylindrical dies and punches. These radii and milled surfaces of the dies are finished manually using tiny grinding wheels of a variety of shapes. Human skill becomes an important factor in finishing less accessible crevices.

Irregular forms can be finished by using spark erosion machining. (Ref. Section K1.41). The electrode is a male mirror image of the die to be eroded (Fig. K5b). It is necessary to use a number of electrodes with only the finishing electrode being an exact mirror male replica of the die. Roughing and semi-finishing electrodes are smaller. As the electrodes wear considerably during erosion, worn out electrodes can be used for roughing.

Bending tools which are stressed less than 80 N/mm^2 can be made of cheaper, easier to machine case hardening steels. Bending and forming tools need not be as hard as the cutting tools. Punches and dies can be hardened and tempered to RC 55-58.

K3.00 MANUFACTURE OF DRAWING TOOLS

Cylindrical drawing tools can be machined on centre lathes and finished on cylindrical grinders. Rectangular and odd-shaped dies and punches call for copy milling for roughing, and spark erosion for finishing.

K3.10 Die Sinking Machines (Fig. K8)

These are special purpose vertical milling machines with hydraulic copying facility. The vertical movement of the milling cutter is controlled by a stylus traversing the master or a template. As the stylus force is only a fraction of a kilogram, the master can be made of wood or plaster of Paris. The master is mounted in line with the workpiece (punch or die) on the machine table. During copy milling, die sinking, the machine table traverses in a longitudinal feed. The stylus moves vertically along the

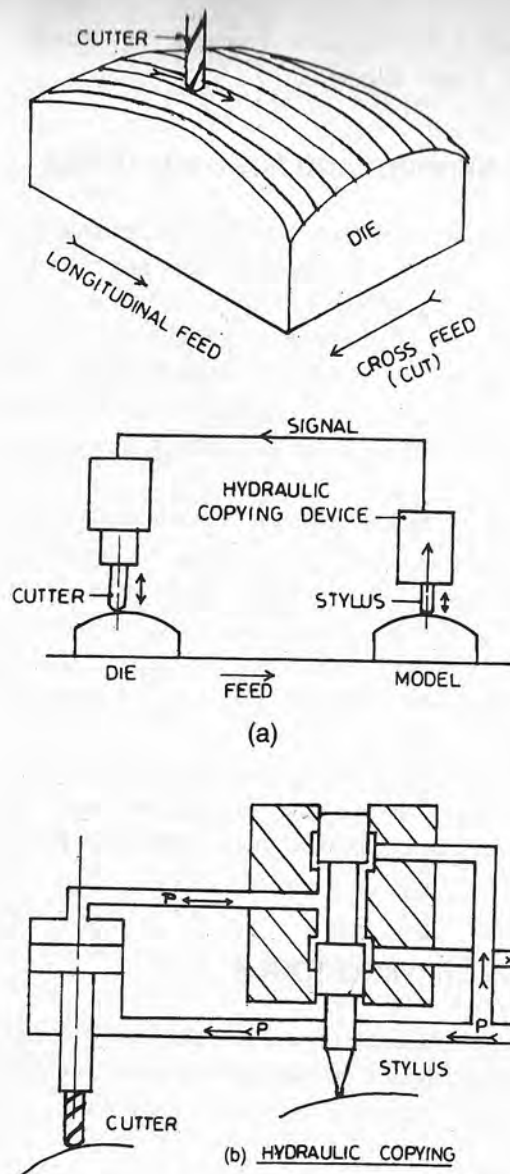


Fig. K8 Die sinking

master profile and hydraulic copying system moves the cutter spindle vertically by an equal distance. As the longitudinal feed is also controlled by hydraulic copying system, the table slows down during steep inclines and comes to a standstill while the stylus traverses a vertical face. The combination of controlled vertical motion of cutter and horizontal

strokes of table produces a profile identical to the master in the vertical plane.

At the end of the longitudinal stroke, the table moves in a transverse direction by a small amount like cross feeding in cylindrical and surface grinders. After cross feed, the table transverses longitudinally in an opposite direction. During this stroke, the vertical profile in the adjacent part of the master is copy milled. Thus, by effecting a number of longitudinal feeds with cross feeds at both ends of the longitudinal stroke the entire area of the master can be reproduced on the workpiece.

When the number of dies required is large, a copy milling machine with more than one cutting heads is used. In these machines, the movement of a stylus on a single master moves identically two or more cutter spindles to produce two or more replicas simultaneously.

Machines with mirror image arrangement allow opposite hand copying. For example, the master of right foot shoe mould can also be used for copy milling left hand shoe mould.

As copy milling machines are used extensively for forming and forging die cavities and mould impressions, they are called die sinking machines.

For milling female die cavities, it is convenient to produce a male master from wood or even clay. This can be used as a pattern to mould a plaster of paris female counterpart. The plaster of paris female can be used as a master for milling workpiece (die or punch). A rotary attachment permits cylindrical copying with a flat template.

Earlier die-sunk punches and dies were polished manually using small grinding wheels. It is now common to finish milled punches and dies to smooth surface by spark erosion.

Tools should be tried out before hardening by using blanks of material softer and thinner than workpiece. Dies for steel work can be tried out on a couple of aluminium workpieces to check the form and dimensions before hardening.



Process Planning

As workpiece quantities and tool costs in press work are usually high, considerable economy can be effected by choosing an appropriate sequence of operations and the right type of tooling. The process plan should take into account the total cost: material, tooling, labour (time). Process planning generally includes the following considerations:

1. Quantity required—total and annual
2. Workpiece—shape and size
3. Workpiece—dimensional tolerances
4. Workpiece—material limitations
5. Equipment available for manufacture

L1.10 Quantity Required

A cutting tool made of hardened high carbon high chromium steel with 3 mm straight land can produce 5,00,000 to 6,00,000 mild steel blanks. The life of bending, forming, and drawing tools is nearly fourfold: 20,00,000 to 25,00,000 pieces. If the total or annual requirement is same as the tool life stated above, it will be economical to make simple separate tools for various operations. If the quantity required is much lesser, cheaper blanking tools such as steel rule die (Ref. Section B7.20), or white metal punch and HCHC die combination (Section B7.10) can be used conveniently. If the blank is very large, and the requirement is small, it is economical to shape the blank roughly using a rubber die and machine the blank edge to proper size later.

Forming and drawing tools can be made of hardened HCHC steel if quantities required are more than 5,00,000. For a smaller batch, production tools can be made of case hardening steels (16 Mn Cr 5) with the working surface case hardened to 0.6 mm to 1.2 mm depth. This reduces the material as well as the machining cost for tools considerably.

When workpiece requirement exceeds 50,00,000 it is better to use a progressive tool for producing blanks.

L1.20 Workpiece—Shape and Size

Workpieces which are not flat call for bending, forming, or drawing. The number and type of operations depend upon the final shape of the workpiece.

Workpiece size will determine the form of the material. If the workpiece width is less than 400 mm, it can be blanked from a strip. If the blank size is bigger than 400 mm it is convenient to use sheared pieces of sheet slightly bigger than the blank for blanking, since a very wide strip is heavy and also difficult to feed manually. However if the press is equipped with an automatic roll or gripper feed (Ref. Section B8.00) the operator is not subjected to fatigue and a coil of suitable width can be used as a raw material.

L1.30 Workpiece—Dimensional Tolerances

If the dimensional tolerance of the workpiece is lesser than the die clearance required for cutting, it is necessary to include a shaving operation for finishing it to size. Alternatively, the blanks can be produced by fine blanking (Refer Section B9.10).

For cups having tolerance lesser than drawing die clearance, it is necessary to iron the cup for finishing. Similarly if the bent workpiece has got close tolerance for the bend angle, it is necessary to provide some adjustment in the tool to compensate for spring back by trial and error or add an operation for correcting the bend angle later.

L1.40 Workpiece—Material Limitations

Maximum possible elongation limits the deformation possible in drawing or forming. If the workpiece calls for considerable deformation, the deformation should be divided into a number of stages. It should be remembered that each operation causes some work hardening and reduces the deformation possible in the next stage (Refer Section D14 Table E3). If the workpiece calls for considerable deformation, it might become work hardened beyond permissible limits, and unworkable before the final shape is accomplished. It is then necessary to anneal the workpiece to remove workhardness completely to facilitate further distortion of the workpiece. Full hard rolled stainless steel sheets must be annealed before commencing drawing.

L1.50 Equipment Available for Manufacture

It may not be possible to buy new equipment for a workpiece unless the requirement is very very high. Consequently, the equipment available in the press shop should be used even if it is a little uneconomical. It might be necessary to split up operations to facilitate use of a smaller press. On the other hand, gang blanking/bending can be used if the press available has got a much higher capacity than required for a workpiece. Thus if a workpiece calls for 25 tonnes blanking force and only a 100 tonnes press is available, it is economical to blank four pieces at a time or use a progressive tool if the quantity required is large enough to justify it.

L2.00 OPERATIONS SEQUENCE

The manufacturing operations can be broadly divided as follows:

L2.10 Preparatory Operations

Shearing sheets to strips/coils, or square/rectangular pieces with adequate margins around blank. This converts a big sheet into a form convenient for handling. If the blank is to be bent later the strips/rectangular pieces should be cut in such a way that the blank is bent across the grain direction: direction of rolling, i.e. the longer side of rolled sheets (Fig. L1). Of course the grain direction can be identified easily, visually at glance.

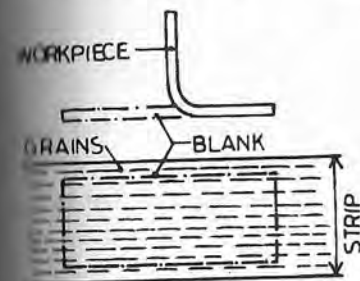


Fig. L1 Cutting strips for bent workpieces

L2.20 Cutting Operations

These shape the periphery of a flat sheet to requisite shape for the final form. If the workpiece is flat in the final form, the outside periphery is finished to size. The workpiece can be pierced with holes at this stage if the holes do not lie in the region subjected to distortion in the following

operations. In case of such holes, the workpiece is pierced after distortion (forming or drawing). For example (Fig. L2) the flange holes in a drawn

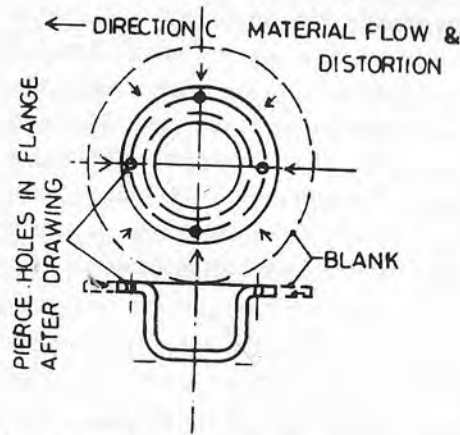


Fig. L2 Piercing holes in distorted portion after deformation

cup lie in an area which undergoes maximum material flow: blank dia 143 reduced to the flange dia 80 during drawing. As such, it is advisable to pierce flange holes in the cup (Fig. L2) after drawing. It is also convenient to trim the drawn components after final draw.

Thus some cutting operations such as trimming and piercing are carried out after the forming operations; while blanking and some piercing operations precede the forming operations.

L2.30 Forming Operations

L2.31 Bending

Bending operations should take into account spring back and the need for corrective operation. If more than one bends are involved the sequence will be easily determined by ease in loading and unloading workpiece in press tools (Fig. L3).

L2.32 Forming

Forming operations such as flanging and beading are usually carried out last. When material distortion required exceeds the elongation limits of workpiece material it is necessary to anneal workpiece to restore its ductility, and divide forming in two or more operations.

L2.33 Drawing

Necessary drawing operations, too, depend upon workpiece material limitations. Table E3 can be used to determine the percentage reduction in the following draws.

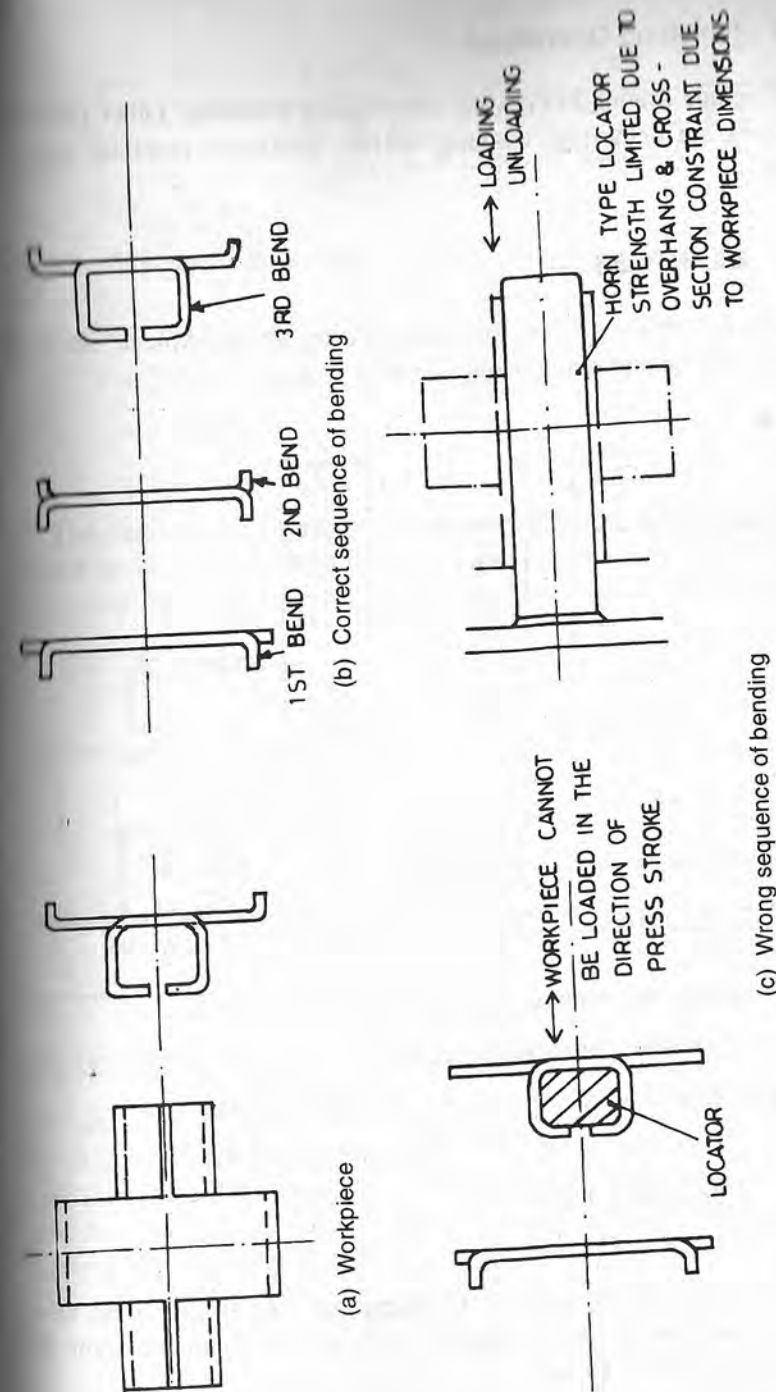


Fig. L3 Sequencing bending operations

L2.40 Finishing Operations

These include ironing in drawing, shaving and trimming. Other finishing operations are deburring, washing, surface treatment: painting, plating, coating.

L3.00 EXAMPLES

Example L1 Plan process of manufacture for workpiece shown in Fig L4 if the annual requirement is 50000 Nos.

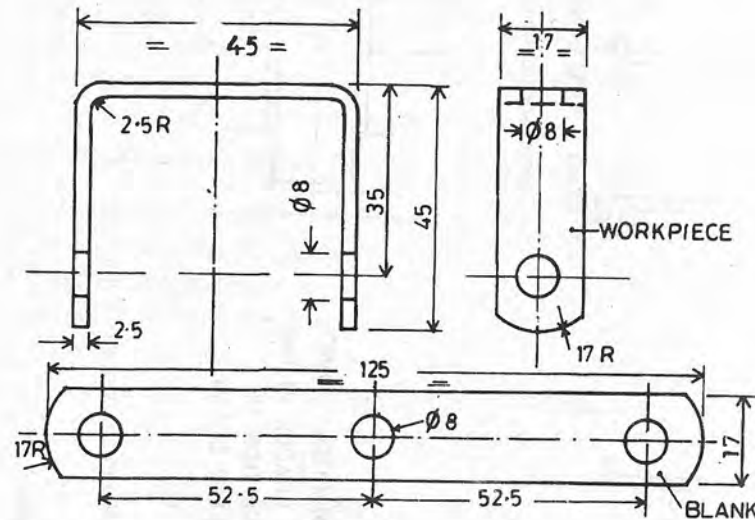


Fig. L4 Workpiece and blank for example L1

Solution Calculate developed length L .

$$\begin{aligned} L &= 45 - 2(2.5 + 2.5) + \pi(2.5 + 2.5 \times 0.33) \\ &\quad + 2\{45 - (2.5 + 2.5)\} \\ &= 35 + 10.4 + 80 \\ &= 125.4 \approx 125 \text{ mm} \end{aligned}$$

As the blank will be bent to 'U' shape later, the strips should be cut in such a way that the grain direction is parallel to length 125 mm. The strip width should be 17 mm.

The first operation would cut the workpiece to length 125 mm with the radius 17 mm at ends. The same tool can be used for piercing three Nos of 8 dia holes. Fig. L5 shows the strip layout.

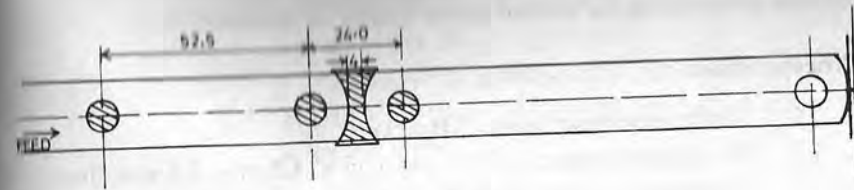


Fig. L5 Strip layout for workpiece in Fig. L4

$$\text{Press capacity} = V = f_s \times S$$

$$V = 300 \times 2.5 \left(3 \times \pi \times 8 + \frac{2 \times 60}{360} \times \pi \times 34 \right)$$

$$= 83252 \text{ N}$$

$$= 8.3 \text{ Tonnes}$$

The bending tool should ensure that the 8 dia holes at both ends should be in one line after bending. This can be ensured by locating in those holes while loading (Fig. L6). The top of the locating pins is ground

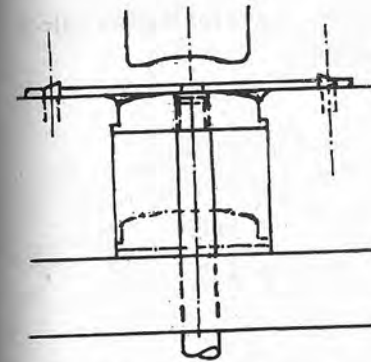


Fig. L6 Bending tool with inclined location pins

inclined. This allows the blank to emerge from the pins easily during bending. The bending punch holds the blank sandwiched above the ejector before it emerges from the 'inclined top' location pins. The punch as well as the ejector are provided with a curvature to compensate for spring back inherent in 'U' bending.

$$\text{Bending Force} = \frac{2.66 L T^2 f_t}{W}$$

$$V_{bc} = \frac{2.66 \times 17 \times 2.5^2 \times 400}{45}$$

$$= 2512 \text{ N}$$

$$\approx 0.25 \text{ Tonnes}$$

The process can be written down briefly as follows

Process Sheet

1. Workpiece description : Bracket
2. Workpiece material : M.S. sht 1 m × 1.5 m × 2.5 mm thick
3. Workpiece tensile strength : 400 N/mm²
4. Workpiece elongation : 23%

Sequence			
Op. no.	Operation	Tooling	Tonnage required
1	Slit sheets to 17 mm wide × 1.5 m strips		
2	Pierce three holes of 8 dia and cut to length 125 mm with end radius 17 mm	Cropping and piercing tool	8.3
3	Bend to channel	Channel bending tool	0.28
4	Wash		
5	Cadmium plate		

Example L2 Determine the manufacturing sequence for the workpiece shown in Fig. L7. Tensile strength = 340 N/mm².

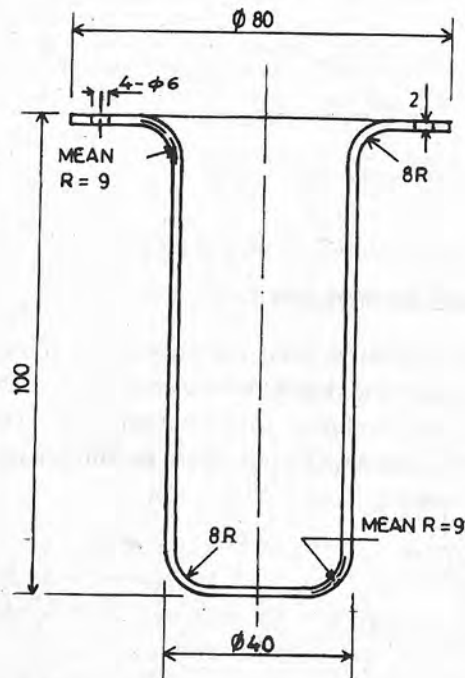


Fig. L7 Workpiece for example L2

$$\begin{aligned}
 \text{Cup Area} &= 0.7854 \{40 - 2(8 + 2)\}^2 \\
 &+ 4.94 \times 9 \times 20 + 6.28 \times 9^2 \\
 &+ \pi \times (40 - 2) \{100 - 2(8 + 2)\} \\
 &+ 4.94 \times 9 (40 + 2 \times 8) - 6.28 \times 9^2 \\
 &+ \pi (40^2 - 28^2) \\
 A &= 15807.12 \text{ mm}^2 \\
 \text{Blank } \phi &= \sqrt{1.273 A} = 141.85 \text{ mm} \\
 &= 142 \text{ mm}
 \end{aligned}$$

Blanking press tonnage = V

$$\begin{aligned}
 V &= \pi \times 141.85 \times 2 \times 340 \times 0.75 \\
 &= 227274 \text{ N} \\
 &\approx 23 \text{ Tonnes}
 \end{aligned}$$

For 45% reduction in the first draw

$$\begin{aligned}
 \text{Cup } \phi &= 141.85 \times 0.55 \\
 &\approx 78.01 \text{ mm}
 \end{aligned}$$

$$\text{Drawing force} = \pi d T \left(\frac{D}{d} - 0.6 \right) f_t$$

$$\begin{aligned}
 V_{dc} &= \pi \times 78.01 \times 2 \left(\frac{141.85}{78.01} - 0.6 \right) 340 \\
 &= 203040 \text{ N} \\
 &\approx 20.3 \text{ Tonnes}
 \end{aligned}$$

From Table E3

$$\begin{aligned}
 \text{Cup } \phi \text{ (2nd stage)} &= 78.01 \times 0.8 \\
 &= 62.41 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Force} = V_{dc} &= \pi \times 62.41 \times 2 \left(\frac{78.01}{62.41} - 0.6 \right) 340 \\
 &= 86656 \text{ N} = 8.66 \text{ Tonnes}
 \end{aligned}$$

$$\text{Cup } \phi \text{ (3rd stage)} = 62.41 \times 0.85 = 53.048 \text{ mm}$$

$$\begin{aligned}
 \text{Force} = V_{dc} &= \pi \times 53.05 \times 2 \left(\frac{62.41}{53.05} - 0.6 \right) 340 \\
 &= 65327 \text{ N} \approx 6.6 \text{ Tonnes}
 \end{aligned}$$

$$\text{Cup } \phi \text{ (4th stage)} = 53.05 \times 0.88 = 46.68 \text{ mm}$$

$$\begin{aligned}
 \text{Force} = V_{dc} &= \pi \times 46.68 \times 2 \left(\frac{53.05}{46.68} - 0.6 \right) 340 \\
 &= 53487 \text{ N} \approx 5.4 \text{ Tonnes}
 \end{aligned}$$

$$\text{Cup } \phi \text{ (5th stage)} = 46.68 \times 0.92 = 42.95 \text{ mm}$$

The material has become unworkable before the final 40 ϕ is reached. So the workpiece needs to be annealed to restore its ductility. It can be done after the second draw itself when cup ϕ is 62.41 mm.

After annealing, it is possible to reduce cup ϕ by 45%.

Third stage cup $\phi = 62.41 \times 0.55$
 $= 34.32$ mm possible

Cup can be drawn to finish size of 40 ϕ

$$\begin{aligned} \text{Drawing force} &= V_{dc} = \pi \times 40 \times 2 \left(\frac{62.41}{40} - 0.6 \right) 340 \\ &= 82054 \text{ N} \\ &\approx 8.3 \text{ Tonnes} \end{aligned}$$

Holes in the flange can be pierced after the final, 3rd draw

$$\begin{aligned} \text{Piercing force} &= V = 4 \times \pi \times 6 \times 2 \times 340 \times 0.75 \\ &= 38453 \text{ N} \\ &\approx 3.8 \text{ Tonnes} \end{aligned}$$

Process Sheet

1. Workpiece description : Flanged cup
2. Workpiece material : Low carbon (0.08) steel
Sht. 1 m $\times$ 1.5 m $\times$ 2.0 mm thick
3. Workpiece tensile strength : 34 Kgf/mm
4. Workpiece elongation : 27%

Sequence

Op. no.	Operation	Tooling	Tonnage required
1	Slit strips 148 mm wide		—
2	Blank 141.85 ϕ	Blanking tool	23
3	Draw to 78.01 ϕ	Drawing tool	20.3
4	Redraw to 62.41 ϕ	Drawing tool	8.6
5	Anneal		
6	Draw to 40.00 ϕ	Drawing tool	8.3
7	Pierce 4 holes in Flange	Piercing tool	3.8
8	Wash		
9	Powder coat in grey		

L4.00 EXERCISES

The following pages show sheet metal workpieces for which reader can devise a manufacturing plan. The drawings also indicate possible toolings.

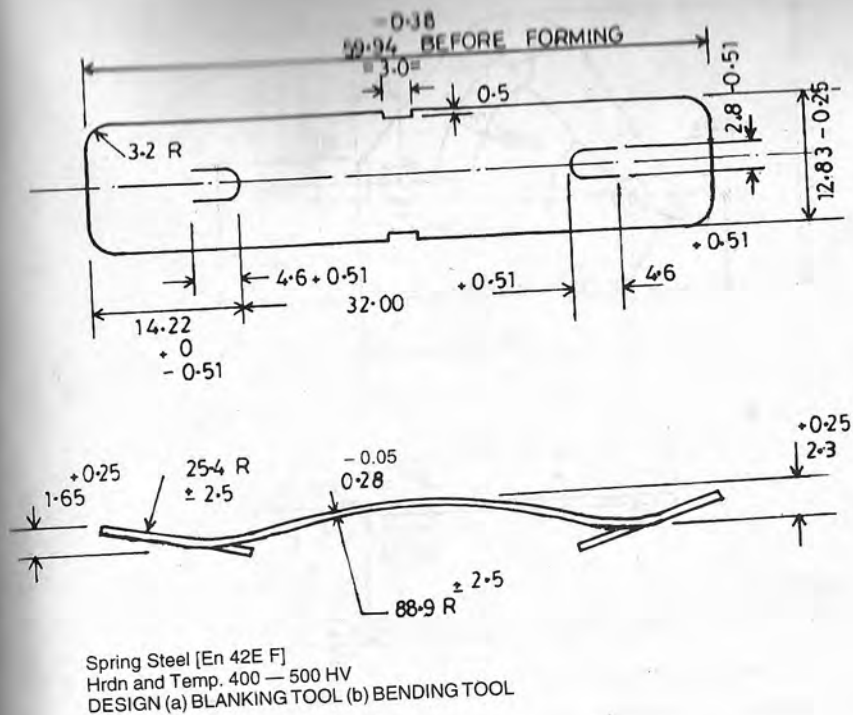


Fig. L8 Workpiece (spring) for exercise

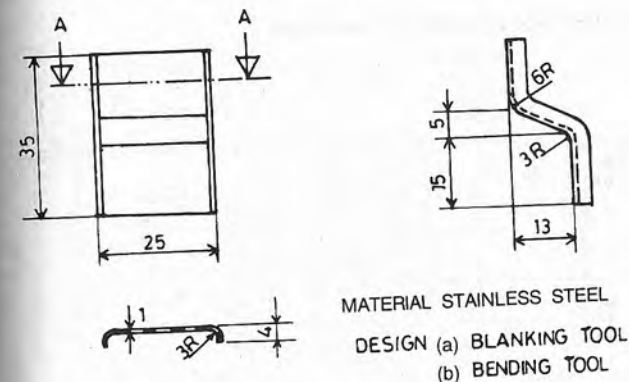
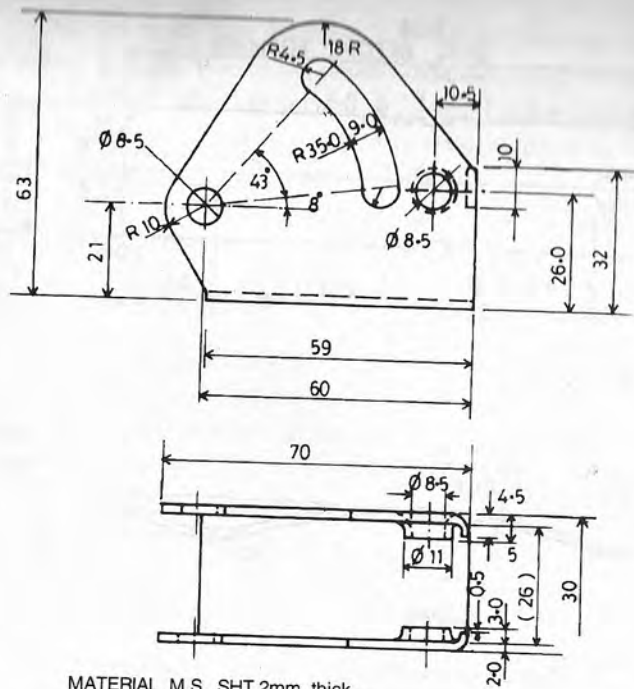


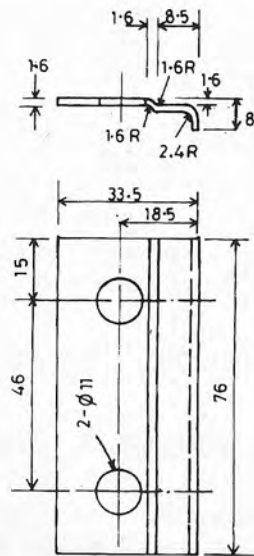
Fig. L9 Workpiece (stopper) for exercise



MATERIAL M.S. SHT 2mm thick

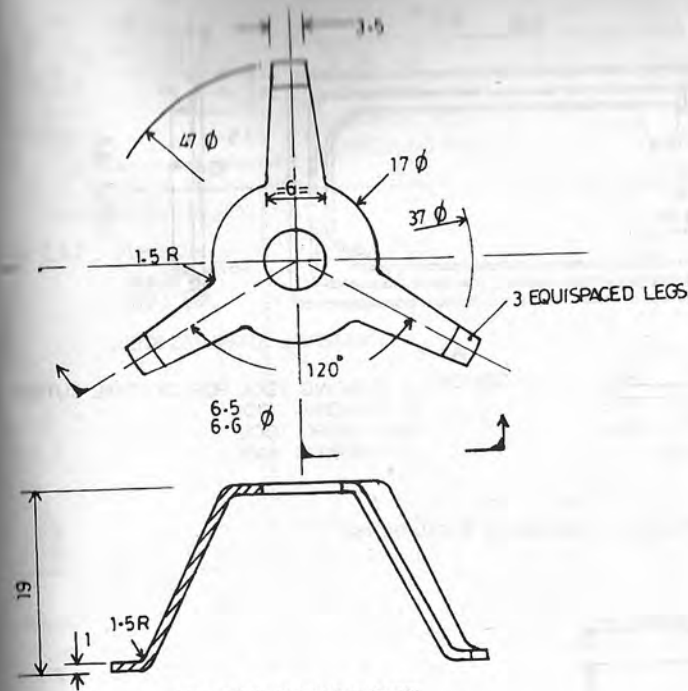
- DESIGN (a) BLANKING TOOL
(b) PIERCING TOOL
(c) BENDING TOOL
(d) FLANGING TOOL

Fig. L10 Workpiece (swivel bracket) for exercise



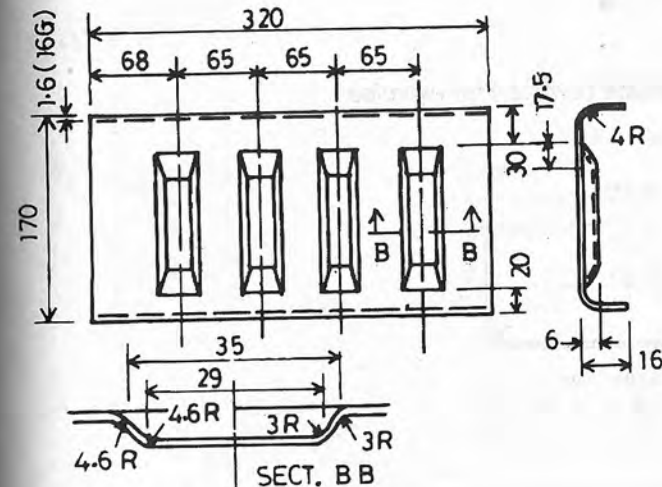
MATERIAL ALUMINIUM
DESIGN (a) BLANKING TOOL
(b) BENDING TOOL

Fig. L11 Workpiece (angle) for exercise



MATERIAL SPRINGS STEEL
DESIGN (a) BLANKING TOOL
(b) BENDING TOOL

Fig. L12 Workpiece (tripod spring) for exercise



MATERIAL STAINLESS STEEL
DESIGN (a) CROPPING TOOL
(b) FORMING TOOL
(c) BENDING TOOL

Fig. L13 Workpiece (seat panel side) for exercise

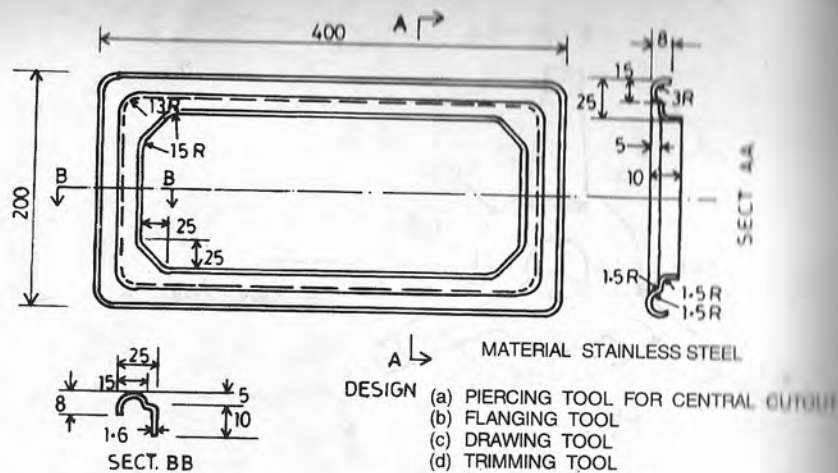


Fig. L14 Workpiece (seat box) for exercise

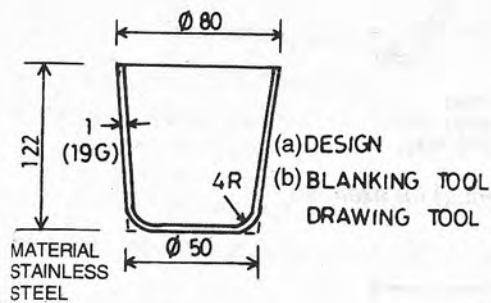


Fig. L15 Workpiece (tumbler) for exercise

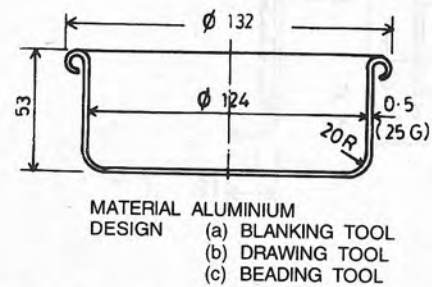


Fig. L16 Workpiece (bowl) for exercise

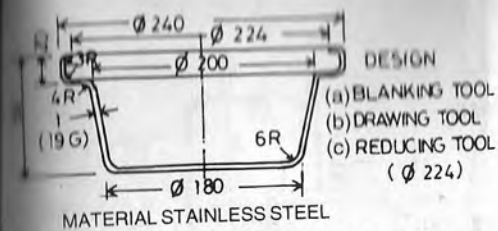


Fig. L17 Workpiece (lid) for exercise

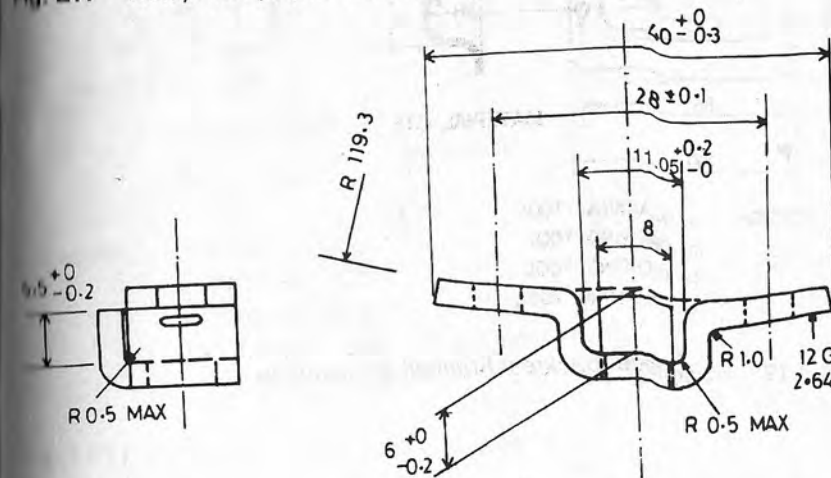
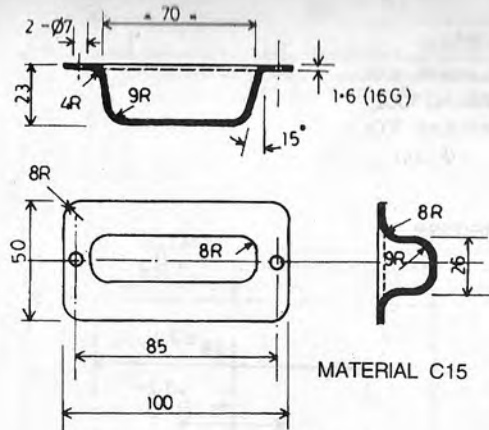
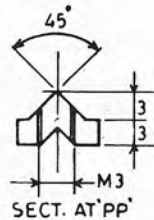
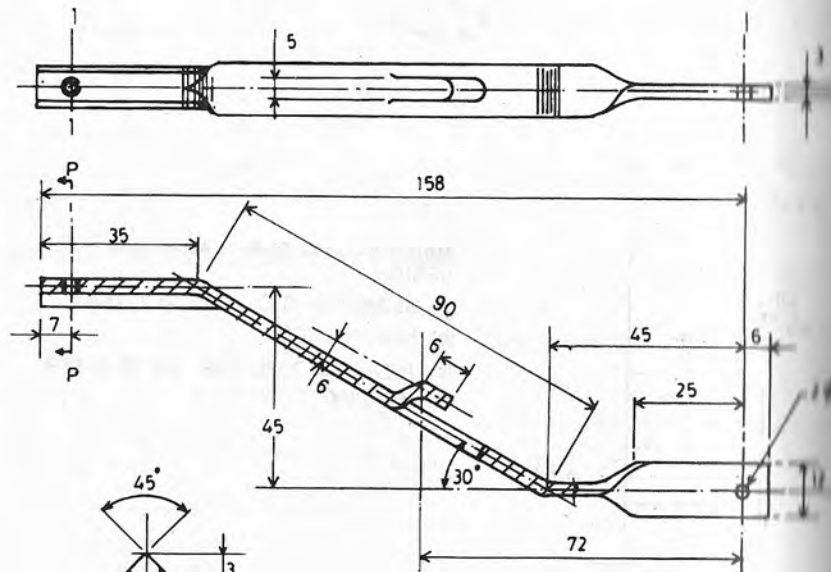


Fig. L18 Workpiece (handle bracket) for exercise



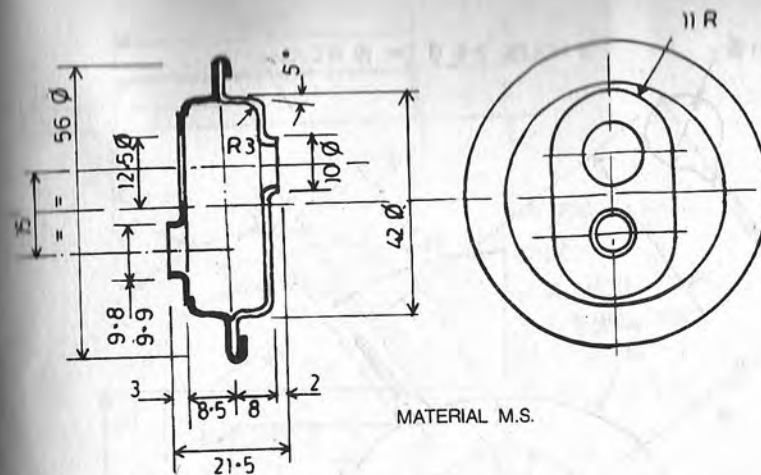
- DESIGN (a) BLANKING TOOL
(b) DRAWING TOOL
(c) PIERCING TOOL
(d) TRIMMING TOOL

Fig. L19 Workpiece (backrest bracket) for exercise



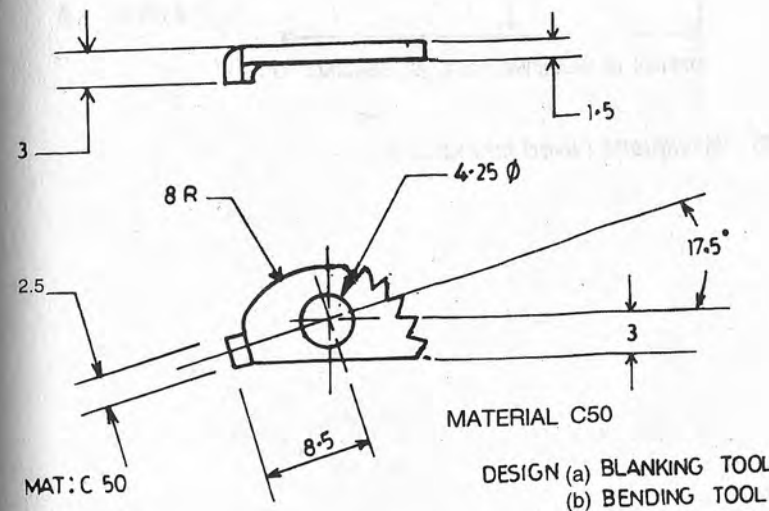
- DESIGN (a) PROGRESSIVE BLANKING TOOL
(b) BENDING TOOLS FOR 30° & 3 × 45°
(c) TWISTING TOOL RIGHT HAND END
(d) PIERCING AND BENDING TOOL FOR 6 × 6 PORTION

Fig. L20 Workpiece (lever) for exercise



- DESIGN (a) BLANKING TOOL
(b) DRAWING TOOL
(c) PIERCING TOOL
(d) FLANGING TOOL (9.8 / 9.9 φ)
(e) ASSEMBLY TOOL

Fig. L21 Workpiece (suction bulb) for exercise



- DESIGN (a) BLANKING TOOL
(b) BENDING TOOL

Fig. L22 Workpiece (toothed plate) for exercise

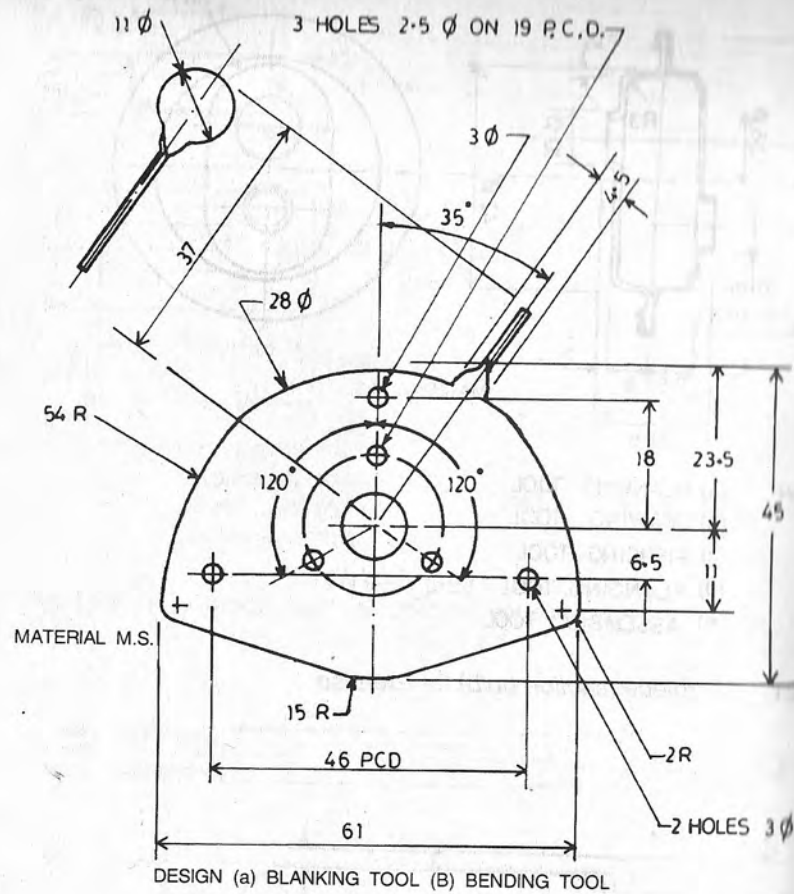


Fig. L23 Workpiece (lever) for exercise

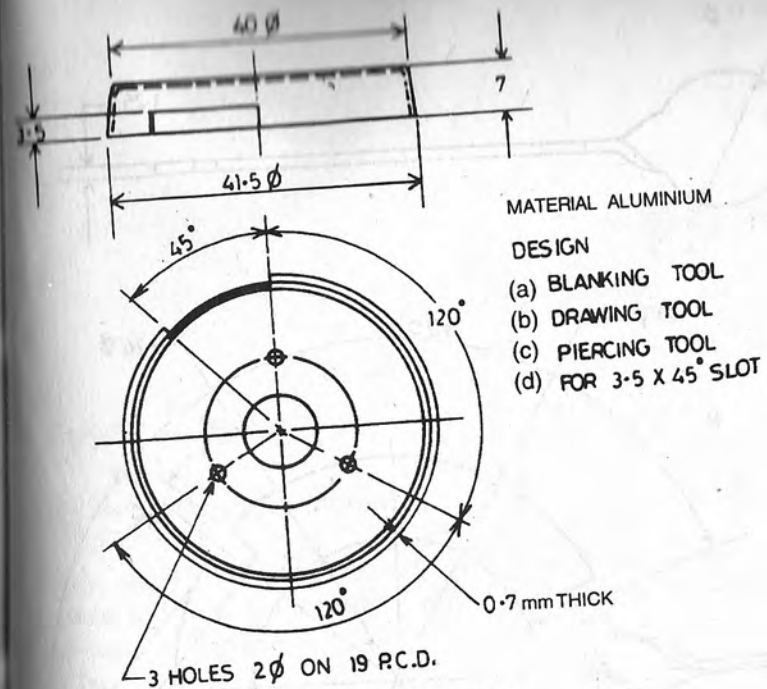
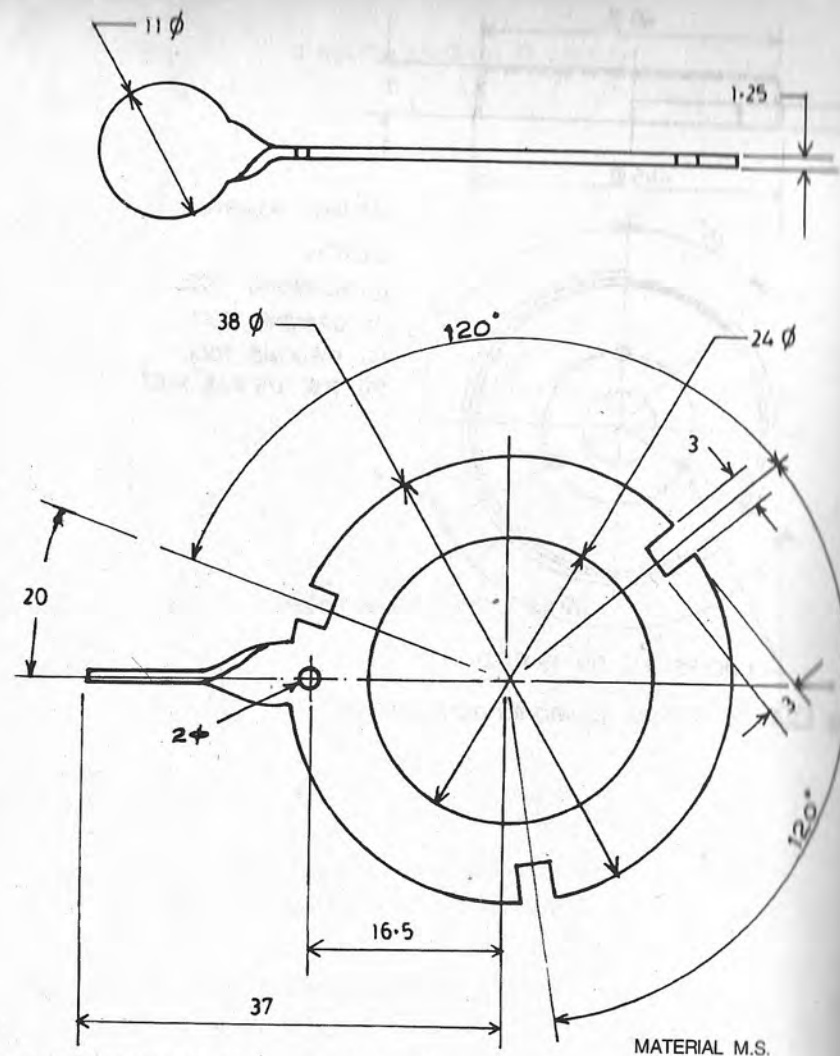


Fig. L24 Workpiece (cover) for exercise

Appendix



DESIGN (a) BLANKING TOOL (b) BENDING TOOL

Fig. L25 Workpiece (indexing plate) for exercise

M1.00 MATERIALS

M1.10 Workpiece Materials

Press work uses sheets or strips as a raw material for pressed components. The following tables gives the important properties of sheets for various tempers.

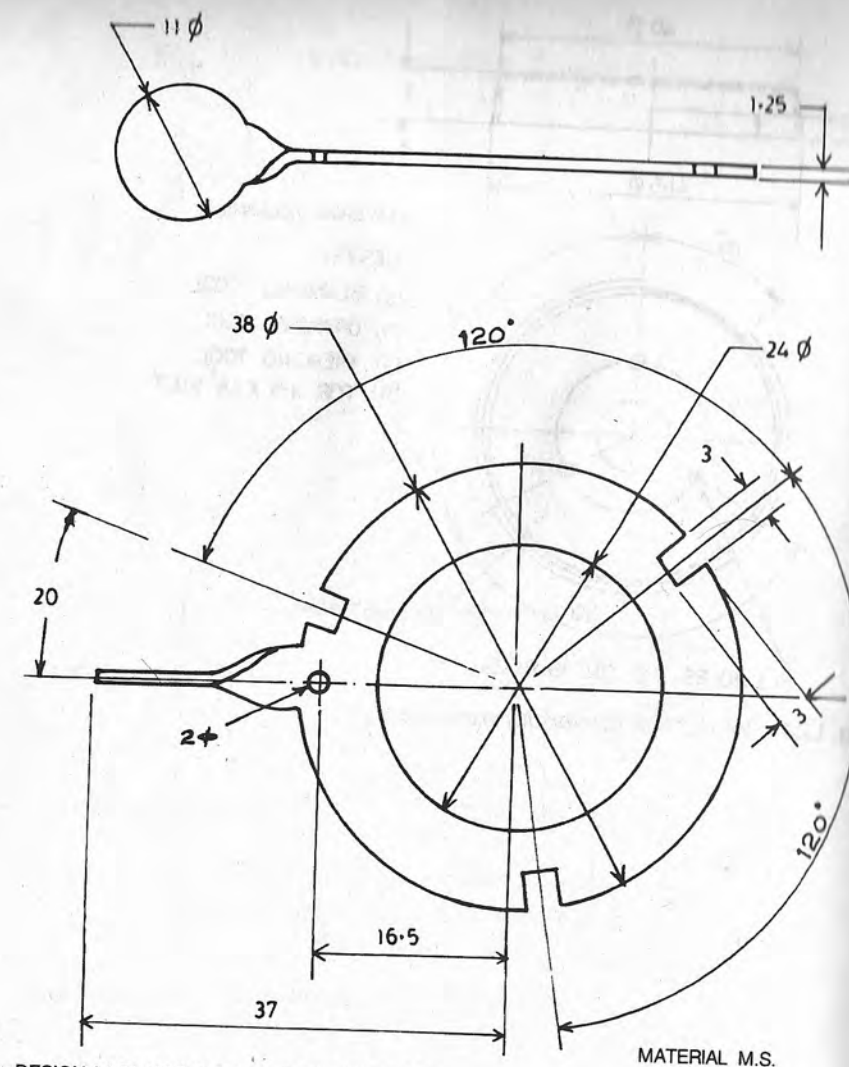
M1.11 Non-ferrous Materials

No marked yield point when yield stress is not stated

Sr. no.	Description	Temper/ Hardness	Elongation %	Ultimate strength N/mm ²		Yield strength N/mm ²
				Tensile	Shear	
1.	Aluminium 99.8% [19500]	0	23	88	60	—
		1/2 Hard	8	110	70	—
		Full Hard	5	120	80	—
2.	Aluminium-Mg 4.5% Mn 1% Cu 0.1% [54300]	0	13	260	180	—
		1/4 H	8	300	200	—
3.	Aluminium-Cu 3.5% Mn 0.4%, Mg 0.4% Ni and Zn 0.2% each, Cr 0.3% [53000]	W	15	380	250	—
4.	Aluminium-Bronze Cu 95%, Al 5%	0	30	420	280	—
		1/2 H	20	540	360	—
		H	10	660	440	—
5.	Duralumin Cu 4.4%, Mn 0.75% [24345]	W	1.5	390	260	—
6.	Common Brass Cu 63% Zn 37%	0	40	28	19	—
		1/2 H	15	38	25	—
		H	3	45	30	—

(Contd)

Appendix



DESIGN (a) BLANKING TOOL (b) BENDING TOOL

Fig. L25 Workpiece (indexing plate) for exercise

M1.00 MATERIALS

M1.10 Workpiece Materials

Press work uses sheets or strips as a raw material for pressed components. The following tables gives the important properties of sheets for various tempers.

M1.11 Non-ferrous Materials

No marked yield point when yield stress is not stated

Sr. no.	Description	Temper/ Hardness	Elongation %	Ultimate strength N/mm ²		Yield strength N/mm ²
				Tensile	Shear	
1.	Aluminium 99.8% [19500]	0	23	88	60	—
		1/2 Hard	8	110	70	—
		Full Hard	5	120	80	—
2.	Aluminium-Mg 4.5% Mn 1% Cu 0.1% [54300]	0	13	260	180	—
		1/4 H	8	300	200	—
3.	Aluminium-Cu 3.5% Mn 0.4%, Mg 0.4% Ni and Zn 0.2% each, Cr 0.3% [53000]	W	15	380	250	—
4.	Aluminium-Bronze Cu 95%, Al 5%	0	30	420	280	—
		1/2 H	20	540	360	—
		H	10	660	440	—
5.	Duralumin Cu 4.4%, Mn 0.75% [24345]	W	1.5	390	260	—
6.	Common Brass Cu 63% Zn 37%	0	40	28	19	—
		1/2 H	15	38	25	—
		H	3	45	30	—

(Contd)

Cr. no.	Description	Temper/ Hardness	Elongation %	Ultimate strength N/mm ²		Yield strength N/mm ²
				Tensile	Shear	
7.	Cartridge Brass Cu 70% Zn 30%	0 1/2 H H	45 20 5	280 360 410	190 240 280	
8.	2/1 Brass Cu 64%, Zn 36%	0 1/2 H H	45 20 3	280 380 470	190 260 320	
9.	Phosphor-Bronze Sn 5-6% P - 0.4%	0 1/4 H 1/2 H H	45 35 10 4	310 360 390 560	210 240 260 380	
10.	Silicon Bronze Cu 96%, Si 3% Mn 1%	0 1/2 H H	— — —	360 480 630	240 320 420	
11.	Copper 100%	0 1/2 H H	35 10 —	220 250 300	150 160 170	
12.	Beryllium Copper Strips Be 1.85% Cu 0.25%	W 1/2 H H	40 10 4	420 600 700	280 400 470	
13.	Cupronickel Cu 80% Ni 20%	0 1/2 H H	40 10 5	270 330 410	180 220 280	
14.	Gilded Metal Cu 85%, Zn 15%	0 1/2 H H	35 7 3	250 310 360	170 210 240	
15.	Nickel 99%	0	40	380	260	
16.	Nickel Silver 18% Ni	0 1/2 H H	16 23 30	197 — —	197 — —	
17.	Nimonic Cr 20%	—	—	820	540	
18.	Magnesium 99%	0	—	190	130	
20.	Magnesium-Mn 1.5%	0 M	12 8	220 250	150 170	
21.	Magnesium-Zinc- Zirconium	M	8	250	170	
22.	Monel 40% Soft Cu 30% Mn 1%	0	22	480	320	

M1.12 Ferrous Materials

Sr. No.	Description	Temper/ Hardness	Elongation %	Ultimate strength N/mm ²		Yield strength N/mm ²
				Tensile	Shear	
1.	Mild Steel [C25Mn75]	0	22	520	400	280
2.	Low Carbon Steel C 0.07% Extra Deep Drawing Steel [Co7]	0	27	340	270	210
3.	0.2 Carbon Steel Steel En 2C(C20)	0 1/4 H 1/2 H H	27 26 24 —	360 410 480 630	290 310 340 420	240 260 260 410
4.	0.4% Carbon Steel En 8(C40)	0	18	480	380	310
5.	0.5% Carbon Steel (C50)	0	13	680	540	380
6.	Spring Steel 0.8% Carbon (C80)	0	—	650	510	—
7.	0.9% Carbon Steel (C90)	0	54	680	550	—
8.	Austenitic Stain- less Steel En 58 A	0	30	550	440	—

M1.20 Press Tool Materials

This section provides details of the materials used for press tools, cutters, and machine elements.

M1.21 Mild Steel

Most of the parts which do not require any hardening are made from this cheap material. The parts which require only hard skin can also be made of mild steel. Mild steel parts are case hardened to provide a tough exterior. Therefore, guide pillars and bushes, as well as cheap bending and drawing dies and punches used for non-cutting operations can be made of case hardened mild steel.

M1.22 Carbon Steels

High carbon steel (0.85% C) can be water hardened to 61 RC hardness. So sturdy piercing and blanking punches can be made from high carbon steel. The main disadvantage of this steel is high distortion in heat-treatment. Nonetheless, simple sturdy punches and dies can be ground after hardening to remove the heat-treatment distortion. Such punches and dies can be made from high carbon steel.

High tensile medium (0.4%) carbon steel (C40) is used mostly for quality fasteners such as allen screws and other elements subjected to high tensile stresses.

M1.23 High Carbon, High Chromium (HCHC) Non-Shrinking Tool Steel

As the name implies this steel gets little distorted in heat-treatment. Consequently, all delicate punches and dies which can not be ground after hardening are invariably made for HCHC steel. It is well-nigh impossible to finish small closed profiles of blanking dies. Such dies must be made from non-shrinking tool steel. Similarly, slender punches are made of HCHC to minimize distortion during heat-treatment.

HCHC is also used for other slender cutting tools such as broaches and shear blades. High carbon high chromium non-shrinking steel is the best and the costliest material that one can choose for the cutting elements in press tools.

M1.24 Cast Iron

Use of cast iron can save considerable machining. However, the strength of cast iron is lesser than mild steel. So heavier sections are required. Cast iron is used mostly for top and bottom bolsters of Pillar Die Sets. Drawing dies for non-ferrous materials can also be made of cast iron.

M1.25 Rubber

Rubber pads are fast replacing heavy springs in drawing tools. Rubber can be used judiciously even for operation of spring strippers in cutting tools. One sq cm of rubber can provide 700 N compressive force. Moreover, unlike springs rubber pads are practically immune from any damage in operation. Use of too many big rubber pads can, however, waste a lot of press energy on compressing the rubber pads. The area of the rubber pads should hence be limited to provide 10% to 15% of the blanking force for rubber strippers.

The table on page M6 gives compositions, heat-treatment details, and applications of metals used for cutting tools and machines.

M1.30 Sheet and Wire Gauges

SWG no.	Thickness (mm)	SWG no.	Thickness (mm)
0	8.23	6	4.88
1	7.62	7	4.47
3	6.4	8	4.06
4	5.89	9	3.66
5	5.39	10	3.25

(Contd)

SWG no.	Thickness (mm)	SWG no.	Thickness (mm)
11	2.95	31	0.295
12	2.64	32	0.274
13	2.34	33	0.254
14	2.03	34	0.234
15	1.83	35	0.213
16	1.63	36	0.193
17	1.42	37	0.173
18	1.22	38	0.152
19	1.02	39	0.132
20	0.91	40	0.122
21	0.81	41	0.112
22	0.71	42	0.102
23	0.61	43	0.091
24	0.56	44	0.081
25	0.51	45	0.071
26	0.46	46	0.061
27	0.42	47	0.051
28	0.38	48	0.041
29	0.35	49	0.030
30	0.31	50	0.025

M2.00 BRIDGE AND SIDE MARGINS FOR BLANKING

The distance between two blanks is called the bridge while the distance between the scrap hole and strip side is called side margin. Both, bridge and side margins can be kept equal and denoted by S . This depends upon the strip thickness as well as the blank size. In general the side margin should not be less than the strip thickness. Nor should it be less than 1.5 mm for steel (2 mm for aluminium). Fig. M1 gives the suitable margins for steel strips.

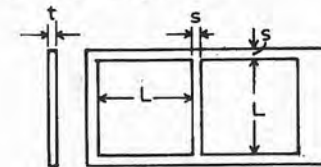


Fig. M1 Bridges and Margins for blanking strips

Strip Thickness (mm)

Blank Size (mm)	0.3	0.5	0.8	1.0	1.5	2.0	3.0
20	1.5	1.5	1.5	1.5	1.5	2.0	3.0
60	1.5	1.7	1.7	2.0	2.0	2.0	3.0
125	2.0	2.2	2.2	2.5	2.5	2.8	3.0
200	2.2	2.2	2.5	2.5	2.8	2.8	3.0
300	2.5	2.5	2.8	2.8	3.0	3.0	3.2

Note Values stated above are for steel strips. For Aluminium strips multiply by 1.33.

Tool Steels

Material	Composition							Heat treatment			Applications	
	C	Si	Mn	Cr	Ni	W	V	Mo	Medium	Temp. °C		Hardness RC
High speed steel (Super rapid extra) 18%	0.75	0.35	0.35	4.3	—	18	1.6	1%	Oil	1290	65	Metal cutting tools, Drills
High speed steel (Super rapid extra) 22%	0.8	0.35	0.35	4.3	—	22	1.6	—	Oil	1300	66	High tensile metal cutting tools, Milling cutters
Cold die steel (Ammutit)	1.0	0.35	0.8	1.0	—	1.5	—	—	Oil	810	65	Cold cutting dies and Punches
Hot die steel (WKZ)	0.32	0.25	0.35	2.5	—	9	0.5	—	Oil	1120	48	Forging and Hot Working Dies
Carbon steel (MN 85)	0.85	0.25	0.87	—	—	—	—	—	Water	810	61	Standard cutting tools
High tensile steel (C50)	0.60	0.35	0.8	—	—	—	—	—	Oil	900	57	Machine screw, Tie bars, etc.
Collet steel (C85)	1.0	0.3	0.5	1.2	—	—	—	—	Oil	700	47	Collets and Spring plates
Non-shrinking steel HCHC (Special K)	2	0.35	0.35	1.2	—	—	—	—	Oil	950	62	Broaches, Shear blades, Heavy dies

M3.00 DIE CLEARANCE FOR BLANKING

Material	Die clearance/side
Mild Steel	2.5% – 5%
Aluminium/Copper	1% – 1.5%
Brass	1.25% – 2.5%

In piercing, the punch should be made equal to drawing size and the die clearance should be added on die.

In blanking, the die should be made equal to drawing size and the die clearance should be deducted from die size to obtain punch size. See Examples B3 and B4 in Section B for further details.

M4.00 BUTTON DIES

These can be used as inserts in soft die holder to serve as a cheap piercing die.

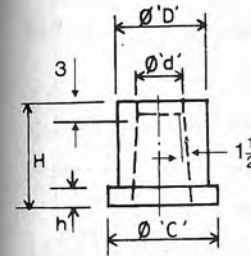


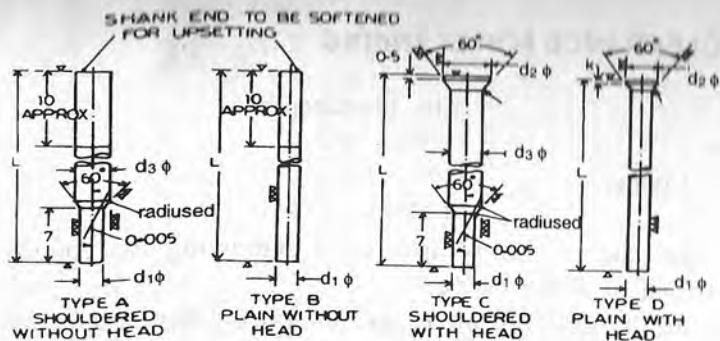
Fig. M2 Die buttons

Die Buttons [Fig. M2]

Sr. no.	Bore d (mm)	O.D. D (mm)	Height H (mm)	Collar	
				Dia c (mm)	Height h (mm)
1.	2.5 – 5	16	25	20	3
2.	6 – 8	20	25	25	3
3.	9 – 12	25	25	31	3
4.	13 – 17	32	32	37	3
5.	18 – 22	38	32	43	3
6.	23 – 28	44	32	49	4
7.	29 – 35	56	35	63	4

M5.00 STANDARD PUNCHES

Standard punches are divided in four categories (Fig. M3). Types A and B are headless. Type 'A' is shouldered [stepped] while type 'B' is parallel



MATERIAL: HIGH CARBON HIGH CHROMIUM (HCHC) STEEL
HARDENED TO RC 58-60

Nominal Size d_1 h_6	d_2		d_3	k	Length L							
	Type C	Type D			Type A		Type B		Type C		Type D	
0.50	3	0.9	2	0.2	35	70	35	70	35	70	35	—
0.55		1.0										
0.60		1.1										
0.65		1.2										
0.70 to 0.75	3	1.3	2	0.2	35	70	35	70	35	70	35	70
0.80 to 0.85		1.4										
0.90 to 0.95		1.6										
1.00 to 1.10		1.8										
1.15 to 1.30	3	2.0	2	0.5	35	70	35	70	35	70	35	70
1.35 to 1.50		2.2										
1.55 to 1.70		2.5										
1.75 to 1.90		2.8										
1.95 to 2.00	4.5	3.0	3	0.5	60	70	60	70	60	70	60	70
2.05 to 2.20		3.2										
2.25 to 2.50		3.5										
2.55 to 2.95		4.0										
3.0 to 3.4	—	4.5	—	0.5	—	—	60	70	—	—	60	70
3.5 to 3.9		5.0										
4.0 to 4.4		5.5										
4.5 to 4.9		6.0										
5.0 to 5.4	—	6.5	—	0.5	—	—	60	70	—	—	60	70
5.5 to 5.9		7.0										
6.0 to 6.4		8.0										
6.5 to 7.4		9.0										
7.5 to 8.4	—	10	—	1.0	—	—	60	70	—	—	60	70
8.5 to 9.4		11										
9.5 to 10.4		12										
10.5 to 11.4		13										
11.5 to 12.4	—	14	—	1.0	—	—	60	70	—	—	60	70
12.5 to 13.4		15										
13.5 to 14.4		16										

Fig. M3 Standard round piercing punches

or plain. The headless punches can be ground with an inclined flat. [Refer Fig. G11] to suit the position of the clamping screw. With the inclined flat, the punch can be replaced quickly without removing press tool from press. Headless punches are kept soft at shank end to enable peening.

Types 'C' and 'D' are provided with 60° chamfered head and 0.2 to 1 mm parallel land for grinding level with punch plate. Type 'C' is shouldered [stepped] while Type 'D' is plain parallel. Shouldered punches are provided with 7 mm parallel cutting length connected to the shoulder by 60° chamfer with radiused corners.

M6.00 STANDARD PILLARS (Fig. M4)

Guide pillars are generally made of mild steel and case hardened. The bottom part is slightly bigger than the guiding diameter which is slightly smaller. Both the diameters should be concentric within 0.01 mm T.I.R. Fig. M4 tabulates the standard sizes of pillars.

M7.00 STANDARD BUSHES (Fig. M5)

The guide bushes, too, are made from mild steel and case hardened. Standard bushes can be classified as plain solid, stepped solid and ball types. Fig. M5 illustrates the standard guide bushes.

M8.00 MINIMUM BEND RADII

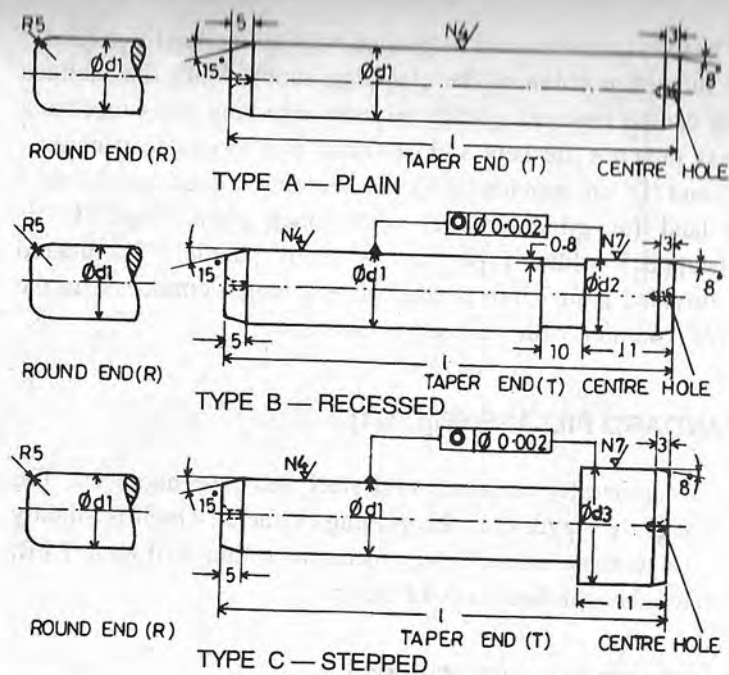
Radii stated are in multiples of the workpiece thickness T .

Material	Temper/Hardness			
	Dead Soft	1/4 Hard	1/2 Hard	3/4 Hard
Steel	0.5 T	T	2 T	4 T
Aluminium	0.25 T	0.5 T	0.8 T	1.5 T
Brass	0.5 T	T	1.5 T	3 T
Copper	T	1.5 T	2 T	3 T

The radii stated above are for bends across the direction of rolling. For bends along the direction of rolling, multiply above values by 4.

M9.00 DEVELOPED LENGTH CALCULATIONS

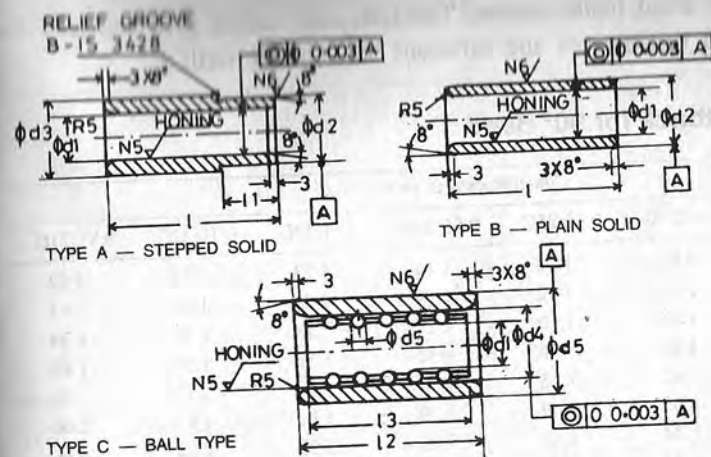
For a 90° bend, the developed length can be found by deducting setback from the sum of the lengths of the arms of the right angle bend (Refer Section C Example C3). The setback depends upon the material thick-



d_1 h_4	d_2 p_6	d_3 p_6	l_1	l									
15	15	26	20	100	120	130	140	150	160				
16	16	26	20	100	120	130	140	150	160				
19	19	30	25	130	140	150	160	170	180	190	200		
20	20	30	25	130	140	150	160	170	180	190	200		
24	24	38	32	140	150	160	170	180	190	200	220		
25	25	38	32	140	150	160	170	180	190	200	220		
30	30	44	40	150	160	170	180	190	200	220	240	260	
32	32	44	40	150	160	170	180	190	200	220	240	260	
38	38	56	50	160	170	180	190	200	220	240	260	280	300
40	40	56	50	160	170	180	190	200	220	240	260	280	300
48	48	68	63	190	200	220	240	260	280	300	350		
50	50	68	63	190	200	220	240	260	280	300	350		
63	63	82	80	200	220	240	260	280	300	350	400		
80	80	100	100	240	260	280	300	350	400	450			
100	100	120	125	260	280	300	350	400	450	500			

MATERIAL: SUITABLE CASE HARDENING STEEL WITH A MINIMUM CASE
DEPTH OF 0.8 mm
HARDNESS 58-62 HRC

Fig. M4 Standard pillars for die sets



d_1 H_5	Types A and B				Type C				
	d_2 p_4	d_3	l		d_4 p_4	d_5 p_4	d_6	l_2	l_3
15	26	32	19	30, 50, 75	23	36	4	70	62
16	26	32	19	30, 50, 75	24	36	4	70	62
19	30	36	24	35, 50, 75	27	47	4	80	70
20	30	36	24	35, 50, 75	28	47	4	80	70
24	38	44	30	40, 60, 80	32	52	4	90	80
25	38	44	30	40, 60, 80	33	52	4	90	80
30	44	50	36	50, 70, 90, 110	38	60	4	100	90
32	44	50	36	50, 70, 90, 110	40	60	4	100	90
38	56	62	46	60, 80, 100, 120	46	70	4	110	98
40	56	62	46	60, 80, 100, 120	48	70	4	110	98
48	68	78	56	70, 90, 110, 125	60	80	6	125	112
50	68	78	56	70, 90, 110, 125	62	80	6	125	112
63	82	92	70	90, 110, 125	75	95	6	140	125
80	110	110	85	100, 125, 150	92	114	6	160	140
100	120	130	105	125, 150, 180	112	137	6	180	160

Fig. M5 Guide bushes for pillar die sets

ness and the bend inside radius. The following tables give setbacks for various sheet thicknesses and different bend inside radii.

M9.10 Setback for 90° Bend

Inside rad. (mm)	Sheet thickness (mm)/SWG					
	0.46/27G	0.51/25G	0.56/24G	0.61/23G	0.71/22G	0.81/21G
0.75	1.0	1.08	1.16	1.23	1.38	1.52
1.00	1.05	1.12	1.19	1.26	1.48	1.63
1.25	1.10	1.16	1.22	1.28	1.59	1.74
1.50	1.20	1.265	1.32	1.38	1.51	1.84
2.0	1.42	1.48	1.54	1.60	1.72	1.84
2.5	1.63	1.69	1.79	1.81	1.93	2.06
2.75	1.74	1.80	1.86	1.92	2.04	2.16
3.25	1.95	2.01	2.07	2.15	2.26	2.38
3.5	2.06	2.12	2.18	2.25	2.36	2.47
4.0	2.28	2.34	2.40	2.46	2.58	2.70
4.5	2.49	2.55	2.61	2.67	2.79	2.91
4.75	2.595	2.655	2.72	2.78	2.90	3.02
5.00	2.70	2.76	2.82	2.89	3.01	3.13
5.25	2.81	2.865	2.93	3.00	3.12	3.24
5.5	3.01	2.98	3.03	3.11	3.23	3.34
6.0	3.22	3.20	3.24	3.33	3.45	3.56
6.5	3.43	3.41	3.45	3.55	3.66	3.77
7.0	3.64	3.63	3.66	3.77	3.88	4.00
7.5	3.85	3.85	3.81	3.99	4.09	4.21
8.0	4.06	4.07	4.08	4.21	4.31	4.43
9.0	4.48	4.51	4.50	4.65	4.75	4.87
11.0	5.86	6.17	5.34	6.30	5.63	6.31
12.5	6.52	6.83	6.00	6.96	6.29	6.97

Inside rad. (mm)	Sheet thickness (mm)/SWG				
	0.91/20G	1.02/19G	1.22/18G	1.42/17G	1.63/16G
0.75	1.68	1.83	2.13	2.43	—
1.00	1.78	1.94	2.23	2.53	—
1.25	1.88	2.05	2.34	2.64	2.95
1.5	2.00	2.16	2.45	2.75	3.06
2.0	1.96	2.37	2.67	2.96	3.27
2.5	2.18	2.31	2.56	3.18	3.49
2.75	2.29	2.42	2.66	3.28	3.60
3.0	2.39	2.53	2.77	3.01	3.70
3.5	2.61	2.74	2.98	3.23	3.48
4.0	2.83	2.95	3.20	3.44	3.70
4.5	3.05	3.16	3.41	3.66	3.93
4.75	3.16	3.26	3.52	3.76	4.02
5.00	3.27	3.36	3.62	3.88	4.12
5.25	3.38	3.47	3.73	3.98	4.23

(Contd)

Inside rad. (mm)	Sheet thickness (mm)/SWG				
	0.91/20G	1.02/19G	1.22/18G	1.42/17G	1.63/16G
5.5	3.49	3.58	3.84	4.09	4.34
6.0	3.71	3.78	4.06	4.31	4.57
6.5	3.93	4.00	4.27	4.54	4.79
7.0	4.15	4.21	4.48	4.76	5.02
7.5	4.37	4.42	4.7	4.99	5.24
8.0	4.59	4.63	4.93	5.21	5.47
9.5	5.25	5.26	5.15	5.88	6.15
11.0	5.91	5.89	5.83	6.55	6.82
12.5	6.57	6.52	6.51	7.22	7.50

Inside rad. (mm)	Sheet thickness (mm)/SWG				
	1.83/15G	2.03/14G	2.34/13G	2.64/12G	2.95/11G
1.5	3.36	—	—	—	—
2.0	3.57	3.87	—	—	—
2.5	3.78	4.08	4.28	—	—
2.75	3.89	4.19	4.65	5.09	—
3.25	4.11	4.40	4.86	5.31	5.76
3.5	4.21	4.51	4.97	5.41	5.87
4.0	3.94	4.72	5.18	5.63	6.09
4.25	4.05	4.29	5.29	5.73	6.19
4.75	4.26	4.50	4.88	5.95	6.41
5.25	4.48	4.72	5.09	6.16	6.62
5.75	4.69	4.94	5.31	6.38	6.83
6.0	4.80	5.05	5.42	6.49	6.94
6.5	5.02	5.26	5.63	6.71	7.15
7.0	5.23	5.48	5.85	6.93	7.37
7.5	5.45	5.69	6.06	7.15	7.58
8.0	5.66	5.91	6.28	7.37	7.80
9.50	6.31	6.56	6.93	8.03	8.44
11.0	6.96	7.2	7.57	8.69	9.09
12.5	7.60	7.85	8.22	9.35	9.74

Inside rad. (mm)	Sheet thickness (mm)/SWG				
	3.25/10G	3.66/9G	4.06/8G	4.47/7G	4.88/6G
3.5	6.32	6.92	7.52	8.12	8.73
4.0	6.53	7.14	7.73	8.33	8.95
4.5	6.74	7.34	7.94	8.54	9.17
5.0	6.96	7.57	8.16	8.75	9.38
5.5	7.17	7.78	8.39	8.97	9.58
6.0	7.38	7.99	8.61	9.18	9.79
6.5	6.74	8.20	8.81	9.40	10.00
7.0	6.96	8.42	9.01	9.62	10.22
7.5	7.18	7.66	9.22	9.84	10.45
8.0	7.40	7.88	9.44	10.05	10.67
9.5	8.06	8.52	10.04	9.50	11.33
11.0	8.72	9.16	10.66	10.15	10.65
12.5	9.38	9.81	11.30	11.79	11.29

M9.20 Developed Length for Other Angles

Developed length for an angular bend can be found from the following formula

$$L = \frac{\pi}{180} A (R + 0.5T) \text{ when } R \text{ is more than } 2T$$

$$L = \frac{\pi}{180} A (R + 0.33T) \text{ when } R \text{ is less than } 2T$$

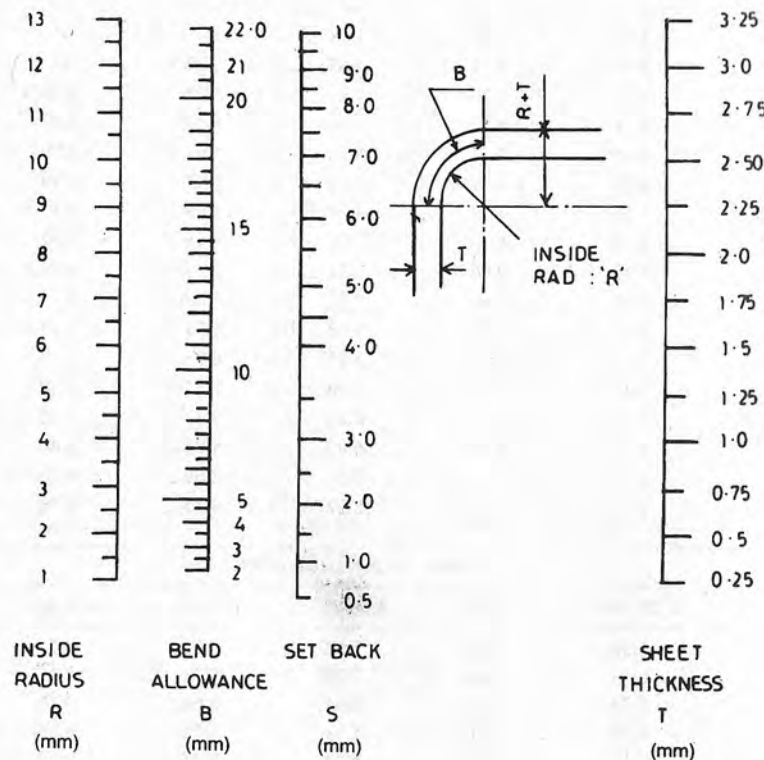
L = Developed length (mm)

A = Angle of bend (degrees)

R = Bend inside radius (mm)

T = Material thickness (mm)

Refer Examples C1 and C2 in Section C for applications. Developed length can be found approximately from the nomogram illustrated below (Fig. M6).



$$\text{SET BACK} = S = 2(R + T) - B$$

$$\text{BEND ALLOWANCE} = B = \frac{\pi}{2} (R + 0.5T)$$

NOTE: NOMOGRAM VALID ONLY FOR RADII 'R' ABOVE TWICE SHEET THICKNESS T ($R > 2T$)

Fig. M6 Nomogram for bend allowance and setback for 90° bends

M9.30 Spring Back for Various Materials

Spring back depends upon the tensile strength of the material and the bend radius. Spring back increases as the bend radius and the tensile strength increase. The following table gives the spring backs for 90° bends

Bend inside radius (mm)	Tensile strength	
	400 N/mm ²	600 N/mm ²
$R = T$ or lesser	4°	7°
R more than $5T$	6°	12°

M10.00 FLANGING LIMITATIONS

$$\text{Deformation} = D = \left[\frac{R_2}{R_1} - 1 \right] \times 100$$

R_1 = Radius of blank before flanging (mm)

R_2 = Radius of blank after flanging (mm)

Deformation possible in shrink forming (Refer Fig. M7) is much lesser than stretch forming.

M10.10 Drawings Speeds (meters/min)

Material	Press	
	Single action	Double action
Mild steel	18	10-15
Stainless steel	—	7-10
Aluminium	55	30
Aluminium alloys	—	10-15
Brass	65	60
Copper	45	25
Zinc	45	13

M10.20 Blank Size Computation

M10.21 Plain Cylindrical Cups

For a circular cup with negligible corner radius, the blank diameter can be found from the following formula

$$\text{Blank Dia} = D = \sqrt{d^2 + 4dh}$$

d = Mean (mid-thickness) dia of cup (mm)

h = Height of cup (mm)

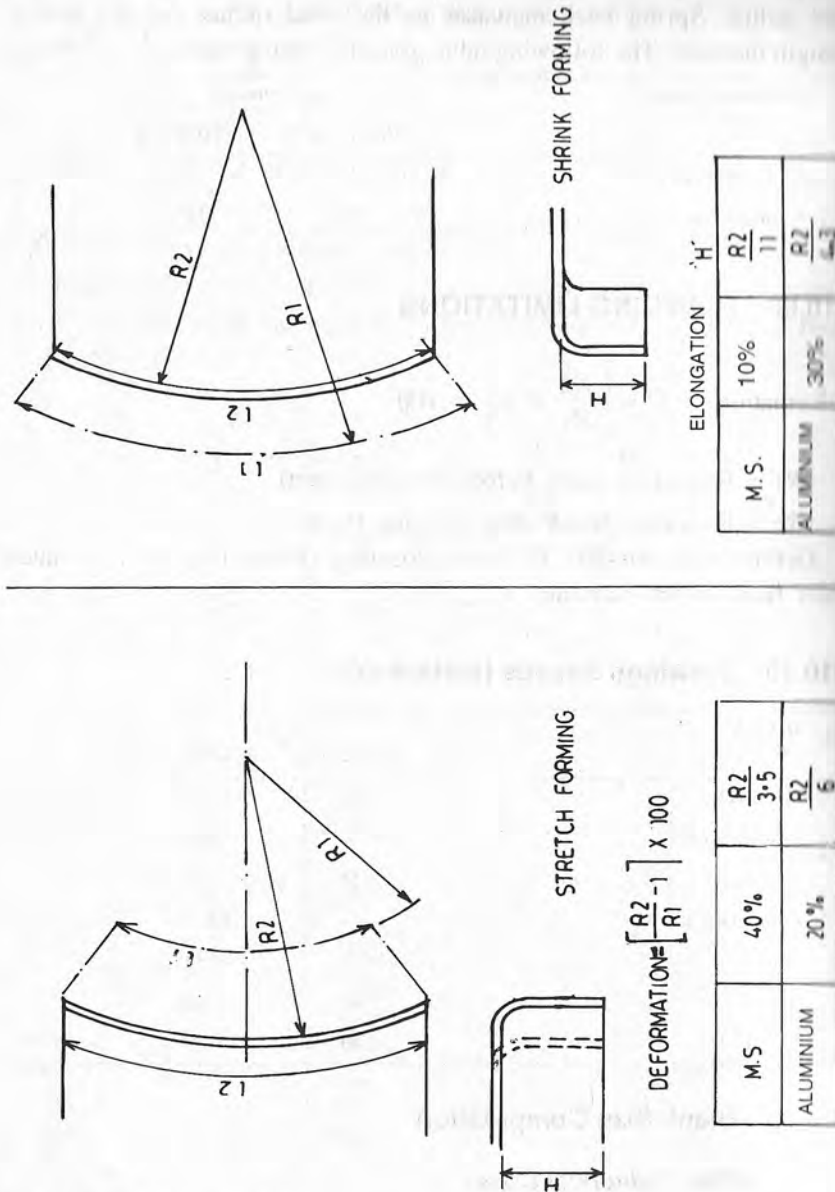


Fig. M7 Segmental flanges

M10.22

For circular cups with sophisticated shapes, the surface area of the entire cup should be found. This can be done by dividing the cup into various

simple shapes whose area can be found from the formulae stated in Fig. E4 in Section E. The areas are added to obtain the total surface area of the cup. The blank diameter can be found from the following formula

$$\text{Blank dia} = D = \sqrt{1.273 A}$$

A = Total surface area of the cup (mm^2)

M11.00 BLANK HOLDER PRESSURE FOR DRAWING VARIOUS MATERIALS

The blank holder pressure depends upon the material to be drawn. Excessive pressure can sever the bottom of the cup whereas lesser pressure leads to wrinkles in the cup walls. The following table gives commonly used blank holder pressures for various materials.

Material	Pressure in (N/mm^2) of blank holding area
Mild steel	2.0 to 3.0
Aluminium	0.8 to 1.2
Copper	1.00 to 1.5
Brass	1.5 to 2.0

M12.00 MAXIMUM REDUCTION IN DRAWING

$$\text{Reduction} = R = \frac{D - d}{D} \times 100$$

d = Diameter after drawing ; D = Diameter before drawing

Double action press permits higher reduction than a single action press. The first draw can accomplish much higher reduction than the following draws. For as the material gets work-hardened in draws possible reduction decreases drastically. The following table gives the reduction on single action and double action presses.

	Single action press	Double action press
Ist Draw	45%	65%
IInd Draw	20%	25%
IIIrd Draw	15%	20%
IVth Draw	12%	15%
Vth Draw	8%	12%
VIth Draw	—	10%

M13.00 DIE CLEARANCE FOR DRAWING

Die clearance depends upon the thickness of the material as well as the operation. The clearance is the least for 1st draw and more for the following draws. Sizing draws use the least clearance. The following table gives the die clearances for drawing for various operation for different material thicknesses 'T'.

Material thickness (mm)	1st draw	Following draws	Sizing draws
Up to 0.4	0.07-0.09T	0.08-0.11T	0.04-0.05T
0.5-1.25	0.08-0.10T	0.09-0.12T	0.05-0.06T
1.3-3.15	0.10-0.12T	0.12-0.14T	0.07-0.09T
Above 3.2	0.12-0.14T	0.15-0.20T	0.08-0.10T

Note The clearance should be added over and above the maximum material thickness in the variation range. Refer Example E3 in Section E for further details.

M14.00 TRIMMING ALLOWANCE

Trimming allowance depends on the material thickness and hardness. Harder materials require more trimming allowance than soft material. The following table gives the trimming allowances for various thickness and hardnesses.

Blank thickness (mm)	Material hardness RB		
	50-70	75-95	95-106
1.2	0.63	0.75	1.06
1.6	0.75	1.06	1.25
2.0	0.90	1.25	1.5 - 1.8
2.4	1.06	1.50	1.8 - 2.24
2.80	1.25	1.80	2.24 - 3.30
3.2	1.8	2.24	3.0 - 3.06

M15.00 FORCE CALCULATIONS

M15.10 Blanking/Piercing Force

$$V = S \times f_s$$

V = Cutting force reqd (N)

f_s = Shear strength of material cut from Sections M01-11 & 12 (N/mm²)

S = Shear area = CT (mm²)

C = Cut length (mm), i.e. πd for round holes and blanks

T = Material thickness (mm)

Refer Examples B1 and B2 in Section B for details.

M15.20 Bending Force

M15.21 For 'V' Bending

$$\text{Bending Force} = V_{bv} = \frac{1.33 LT^2 f_t}{W}$$

L = Transverse width of blank (mm)

T = Material thickness (mm)

f_t = Material tensile strength (N/mm²)

W = Top width of 'V' (mm)

Refer Examples C4 and C5 in Section C for further details.

M15.22 For Bending Channels

$$\text{Bending Force} = V_{bc} = \frac{2.66 LT^2 f_t}{W}$$

L = Transverse length of channel (mm)

T = Material thickness (mm)

f_t = Material tensile strength (N/mm²)

W = Width of channel (mm)

M15.30 Flanging Force

$$\text{Flanging force} = V_f = 1.5 \pi (D - d) T f_t$$

d = Hole size after flanging (mm)

D = Hole size before flanging (mm)

T = Material thickness (mm)

f_t = Material ultimate tensile strength (N/mm²)

M15.40 Circular Drawing Force

$$\text{Drawing Force} = V_{dc} = \pi d T \left(\frac{D}{d} - 0.6 \right) T f_y$$

D = Diameter before drawing (mm)

d = Diameter of cup after drawing (mm)

T = Material thickness (mm)

f_y = Material yield stress (N/mm²)

Refer Examples E1 and E2 in Section E for details.

M15.50 Rectangular Drawing Force

$$\text{Drawing Force} = V_{dr} = f_t \cdot T (2 RC_1 + 0.25 L)$$

f_t = Ultimate tensile strength of material (N/mm²)

T = Material thickness (mm)

R = Corner Radius between vertical sides (mm)

L = Length of box (mm)
 C = Constant depending upon $\frac{h}{R}$
 h = Height of box

$\frac{h}{R}$	C_1
2	0.5
6	2.0

Refer Example E8 in Section E for details.

M15.60 Ironing Force

$$\text{Ironing Force} = V_i = \pi d T_2 f_t \times 2.3 \log \frac{T_1}{T_2}$$

d = Mean dia of cup (mm)

T_1 = Thickness before ironing (mm)

T_2 = Thickness after ironing (mm)

f_t = Ultimate tensile strength of material (N/mm²)

M15.70 Extrusion Force

$$\text{Extrusion Force} = V_e = PA$$

P = Extrusion pressure

A = Extrusion area (square to stroke) (mm²)

Material	Cold Extrusion Pressure	
	Forward extrusion (N/mm ²)	Backward extrusion (N/mm ²)
Steel	1000–1800	2000–3000
Aluminium	400–700	800–1200
Brass	800–1500	1800–2500
Copper	600–1000	1500–2000

M16.00 DESIGN OF PRESS TOOL ELEMENTS

M16.10 Bolsters

M16.11 Bottom Bolster

Bottom bolster rests on press table with a fall thru hole. The bolster for cutting tools generally have a central hole for the gravitational fall of the blank [Fig. N2].

$$\text{Bolster thickness} = T = \sqrt{\frac{3V(1+p)D^2}{f[D^2-d^2]}} \log \frac{D}{d}$$

V = Vertical cutting force (N)

p = Poisson's Ratio = 0.30 for mild steel

= 0.23 for cast iron

f = Permissible hoop stress = 60 N/mm² for M.S.

D = Hole in press bed (mm)

d = Hole in bolster (mm)

Substituting values for M.S. and C.I. the formula can be simplified as follows

$$T_b = \sqrt{\frac{V}{4.83} - \frac{D^2}{D^2-d^2} \log \frac{D}{d}} \quad \text{for M.S. bolsters}$$

$$T_b = \sqrt{\frac{V}{2.55} - \frac{D^2}{D^2-d^2} \log \frac{D}{d}} \quad \text{for M.S. bolsters}$$

M16.12 Top Bolster

Thickness of top bolster is usually less than the bottom bolster. The thickness can be found from the following formula

$$T = \sqrt{\frac{3WD^2(1+p)}{32f}}$$

W = Pressure on press Ram (N/mm²)

$$= \frac{V}{\text{Ram area}}$$

V = Cutting force (N)

D = Diameter of shank hole (mm)

f = Permissible hoop stress (N/mm²)

p = Poisson's ratio

The thickness of the top bolster is often kept more than that obtained by the above formula to meet the functional and assembly requirements.

The thickness of the top bolster can be kept safely three-fourth of the thickness of bottom bolster. Compound tools and inverted press tools require thicker top bolsters to accommodate the knockout ejection mechanism.

M16.20 Guide Pillars

Guide pillars are subjected to bending due to the weight of the top tool. The deflection should be kept below 0.0025 mm.

M16.21 Rear Pillars

These can be treated as cantilevers. The bending force W on the pillars can be found from the following equation (Fig. M8)

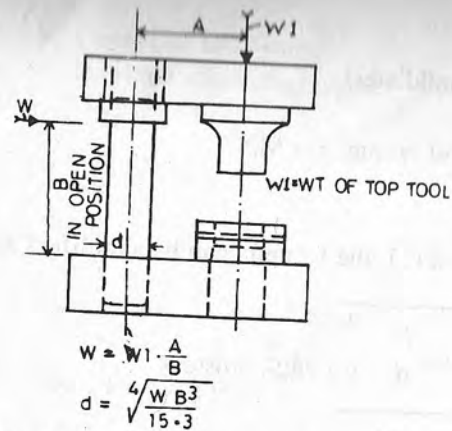


Fig. M8 Rear pillar design

$$W_1 \times A = W \times B$$

$$W = \frac{W_1 \times A}{B}$$

W_1 = Weight of Top Tool (kg)

A = Distance between pillar centre and centre of gravity of top tool (mm)

B = Distance between bottom bolster and guide bush bottom face when tool is in ram up position (mm)

If two rear pillars are used then, pillar dia = $D_p = \sqrt[4]{\frac{W B^3}{15.3}}$

It should be remembered that W_1 is the weight of the top tool and not the cutting force V .

M16.22 Diagonal Pillars

Top bolster on diagonal pillars is like a simply supported beam. Consequently the bending moment is about one-fourth the moment on rear pillars die set. The pillar size can hence be much smaller than the pillar size required for rear pillars

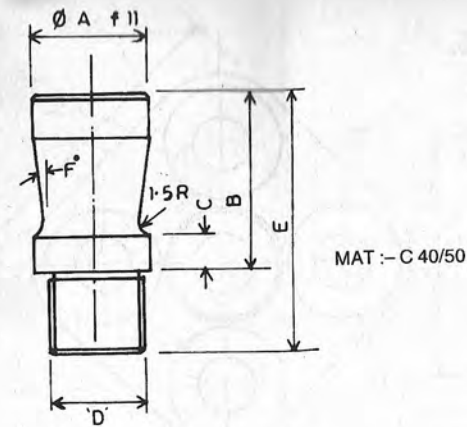
$$W = \frac{W_1 \times A}{4B}$$

where W_1 = Weight of top tool (kg)

A : span between pillars [mm]; B : pillar Length (mm)

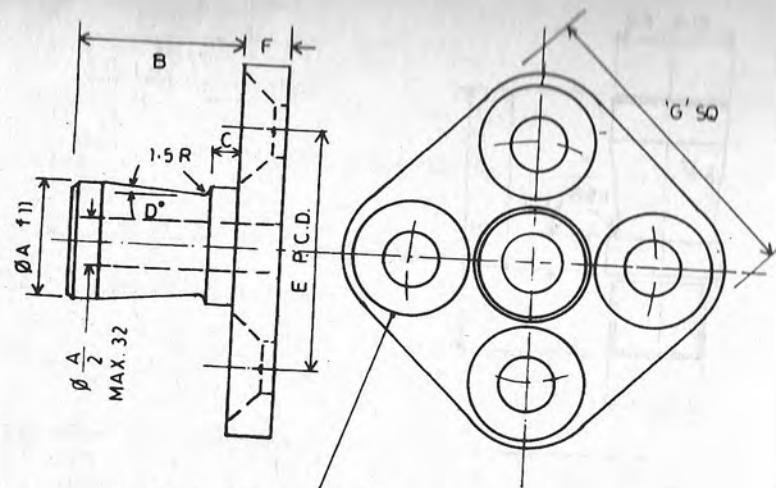
Pillar dia = $\sqrt[4]{\frac{W B^3}{61.2}}$ for 2 pillars

Pillar dia = $\sqrt[4]{\frac{W B^3}{122.4}}$ for 4 pillar Die Sets



Sr. no.	A f11	B	C	D	E	F	Press tonnage
1	20	35	7	M16	60	4°	10
2	25	45	12	M22	75	4°	25
3	32	57	12	M30	90	3°	40
4	40	67	12	M36	110	2°	60
5	50	77	14	M45	135	2°	100
6	63	82	19	M52	140	2°	125
7	80	107	25	M64	175	1 1/2°	200

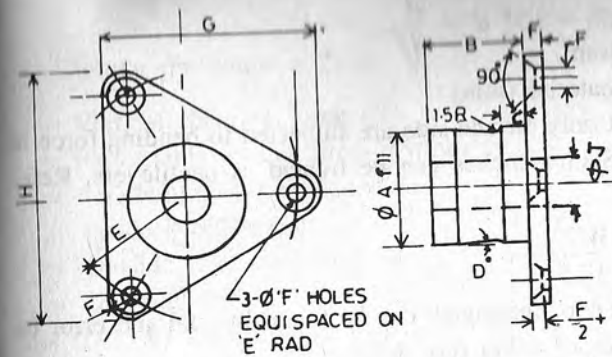
Fig. M9 Threaded shanks



4 EQUISPACED HOLES DRILL & C'SINK FOR
F' C'SK HD. SCREW. MAT. C 40 / 50

Sr. no.	A fll	B	C	D	E	F	G	Press tonnage
1	20	35	7	4°	40	M8	50	10
2	25	45	12	4°	53	M12	65	25
3	32	57	12	3°	68	M16	85	40
4	40	67	12	2°	78	M18	95	60
5	50	77	14	2°	98	M22	116	100
6	63	82	19	2°	115	M24	137	125
7	80	107	25	1 1/2°	144	M30	268	200

Fig. M10a Square flanged shanks



Sr. no.	Afl	B	C	D	E RAD	F	G	H	J
1	20	35	7	4°	21	11	54	60	10
2	25	45	12	4°	26	13	65	73	12
3	32	57	12	3°	34	17	95	95	16
4	40	67	12	2°	42	22	107	119	20
5	50	77	14	2°	54	29	140	155	25
6	63	82	19	2°	67	35	171	190	30
7	80	107	25	1°30'	84	44	214	238	32

Fig. M10b Triangular Flanged shanks

M16.30 Punch and Heel Design [Figs M11, M12] *notching*

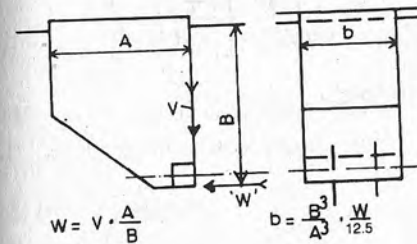


Fig. M11 Punch design

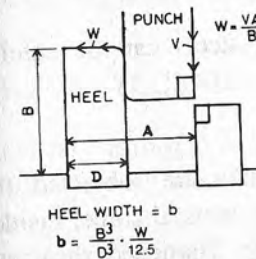


Fig. M12 Heel design

$$\text{Max. punch length} = 9.55 d \times \frac{d}{T}$$

d = Dia of punch (mm)

T = Thickness of material (mm)

Punches which cut only on one side are subjected to bending force in transverse direction. Such punches can be treated as cantilevers. Refer Fig. M.11

$$W = \frac{VA}{B}; bA^3 = \frac{WB^3}{12.5}$$

Dimensions b and A of the punch can be found by trial and error by assuming various values of either b or A .

Heels can also be treated in a similar manner. Fig. M12 shows the various dimensions to be considered. As above

$$bD^3 = \frac{WB^3}{12.5}$$

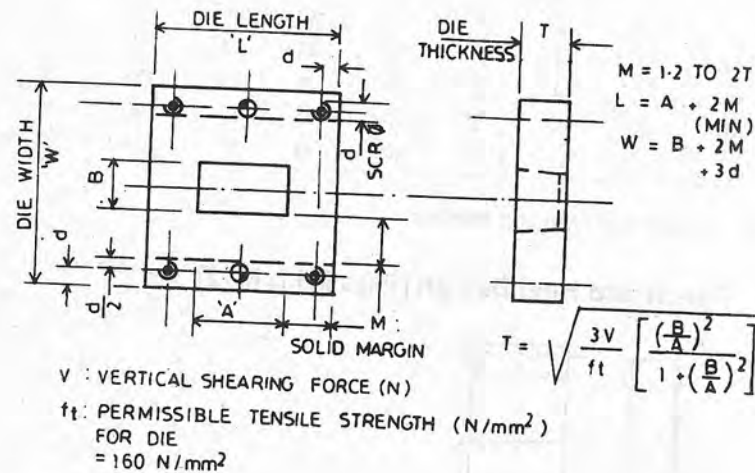


Fig. M13 Die design

M16.40 Dies

Die is subjected to bending. Heat treated tools steels can be safely stressed upto 160 N/mm² tensile stress.

M16.41 Computing Die Thickness and Margins

Circular dies used for shearing round holes/blanks are subjected to bending stress. The tensile stress depends upon the vertical force, inside and outside diameters and the thickness of the die. Hardened shearing dies can be safely stressed upto 160 N/mm².

$$\text{Circular die height} = T_c = \sqrt{\frac{1.5V}{f_t} \left[1 - \frac{D}{3d} \right]}$$

V = Vertical shearing force (N)

f_t = Permissible tensile stress (N/mm²)

= 160 N/mm² for hardened die

d = Inside ϕ of die (mm)

D = Outside ϕ of die (mm)

= $2d$ preferably

Note ($D - d$) should not be less than 6 mm.

Height T_c should be increased by 3 mm for resharping.

M16.42 Rectangular Dies

These are more convenient for rectangular piercing/blanking. Thickness of a rectangular die can be found from the following formula

$$T_r = \sqrt{\frac{3V}{f_t} \left[\frac{\left(\frac{W}{l} \right)^2}{1 + \left(\frac{W}{l} \right)^2} \right]}$$

T_r = Thickness of rectangular die (mm)

V = Vertical force (N)

f_t = Permissible tensile stress (N/mm²)

= 160 N/mm²

W = Width of slot/blank (mm)

l = Length of slot/blank (mm)

M16.43 Margin

It usually ranges from one to two times the die thickness. A solid cross-section around the die cutting edge, *Margin* should not have any weakening holes for fixing screws or dowels.

M17.00 TECHNICAL TABLES

M17.01 Strength of Threads

The following table states the permissible load on screw threads at 80 N/mm² stress on the core cross-section.

Screw size	Safe load (N)	Screw size	Safe load (N)
M5 × 0.8	1000	M27 × 3.0	33520
M6 × 1.0	1380	M30 × 3.5	40700
M8 × 1.25	2550	M33 × 3.5	50880
M10 × 1.5	4050	M39 × 4.0	71760
M12 × 1.75	5950	M42 × 4.5	82160
M16 × 2.0	11300	M45 × 4.5	96300
M18 × 2.5	13680	M48 × 5.0	108240
M20 × 2.5	17600	M52 × 5.0	130100
M32 × 2.5	22100	M64 × 6.0	198500
M24 × 3.0	25350	M80 × 4.0	351600

Notes 1. Safe loads for other sizes and pitches can be found by multiplying the core cross-sectional area (mm²) with the permissible stress 80 N/mm²

$$\text{Core area} = 0.7854 (D - 1.227 P)^2$$

D = Outside dia of thread (mm)

P = Pitch of thread (mm)

- The length of the thread engagement should not be less than half the nominal diameter D .
- Allen screws made from high tensile steel can safely bear one and half times the loads stated in the table.

M17.02 Dimensions for Allen Screws (Fig. M14)

Screw size	Head		Thread length b	Screw length range l
	Dia D	Length K		
M3	5.5	3	12	4–10
M4	7	4	14	6–50
M5	8.5	5	16	10–60
M6	10	6	18	12–60
M8	13	8	22	14–100
M10	16	10	26	14–120
M12	18	12	30	20–120
(M14)	21	14	34	30–120
M16	24	16	38	30–150
M18	27	18	42	40–150
M20	30	20	46	40–180
(M22)	33	22	50	50–200
M24	36	24	54	60–200

Notes

- Where overall length is less than thread length the screws are fully threaded.
- Second preference size of screws have been bracketed.
- Screw length excludes head length.

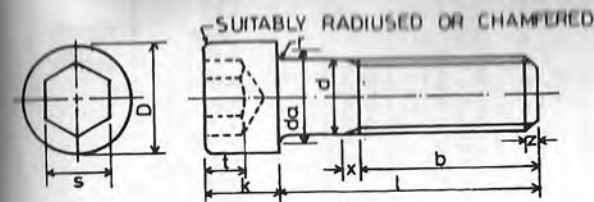


Fig. M14 Socket head cap allen screws

M17.03 Countersunk Head Screws (Fig. M15)

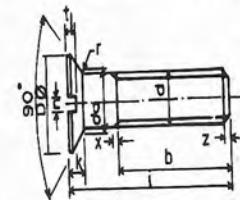


Fig. M15 Countersunk head screws

Screw size	Head		Projection	Thread length b	Overall length range l
	Dia D	Length K			
M3	6	1.5	0.75	19	6–30
M4	8	2	1	22	8–40
M5	10	2.5	1.25	25	10–50
M6	12	3	1.5	28	10–80
M8	16	4	2	34	12–90
M10	20	5	2.5	40	16–100
M12	24	6	3	46	20–105
(M14)	28	7	3.5	52	25–110
M16	32	8	4	58	25–110
(M18)	36	9	4.5	64	40–110
M20	40	10	5	70	45–110

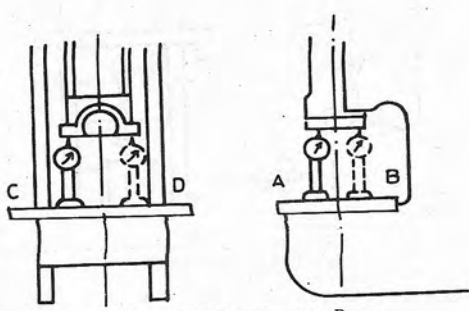
Notes

- Projection for raised head countersunk screws only.
- Where thread length exceeds overall length, screws are fully threaded.
- Overall length includes head length.*

N

Press Work Standards

Test Chart for Gap Frame Presses

Sl No.	Test item	Figure	Measuring instruments	Permissible error (mm)	Actual error	Instructions for testing
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Flatness of bed, bolster and slide face in plane through the centre of frame and in plane perpendicular to it	 Testing Parallelism between Press Table and Ram Face	Precision spirit level	0.02/300 mm	...	Spirit level placed on the bed surface in both the directions and readings noted.
2.	Bed surface parallel with slide face		Dial indicator having base of stand 200 to 250 mm long	In plane AB up to 40t capacity: 0.05/300 mm up to 250t capacity: 0.07/300 mm over 250t capacity: 0.10/300 mm In plane CD up to 40t capacity: 0.03/300mm up to 250t capacity: 0.05/300 mm over 250t capacity: 0.07/300 mm	...	Set maximum slide stroke down, and adjustment down. Dial indicator mounted on the bed, test point brought into contact with slide face as far out as possible in places AB and CD. Difference in dial indicator readings noted. Permissible deviation in plane shall be such that the slide to bed distance at A allowed smaller only. On presses with adjustable bed, measurements with the bed in its highest and lowest position taken.

(Contd.)

Sl. no.	Test item	Figure	Measuring instruments	Permissible error (mm)	Actual error	Instruction testing
(1)	(2)	(3)	(4)	(5)	(6)	(7)
3.	Slide motion square with bed surface	Testing Squareness of Ram Stroke with Table Surface	Dial indicator, engineers square (blade length of square to be commensurate with the press stroke)	In plane AB up to 40t capacity: 0.05/300 mm up to 250t capacity: 0.07/300 mm over 250t capacity: 0.10/300 mm In plane CD up to 40t capacity: 0.03/300 mm up to 250t capacity: 0.05/300 mm over 250t capacity: 0.07/300 mm	...	Set maximum slide stroke and adjustment down. Square placed on the bed and dial indicator attached to the slide, test point being in contact with the square in plane AB and CD. The slide moved and readings during one stroke taken. Permissible deviation in plane AB shall be such that slide motion allowed inclined towards frame only.
4.	*Hole receiving punch shank square with slide face	Testing Squareness of Shank Hole with Ram Face	Test mandrel with parallel shank for reception in slide. Box type precision spirit level	In planes AB and CD up to 40t capacity: 0.03/300 mm up to 250t capacity: 0.05/300 mm over 250t capacity: 0.07/300 mm	...	Test mandrel held inside the slide opening and spirit level placed against the test mandrel in plane AB as shown in figure and readings noted. Now spirit level placed on the slide face in the same plane and readings noted. Permissible deviation shall be the difference in two readings. Repeat the procedure in plane CD.

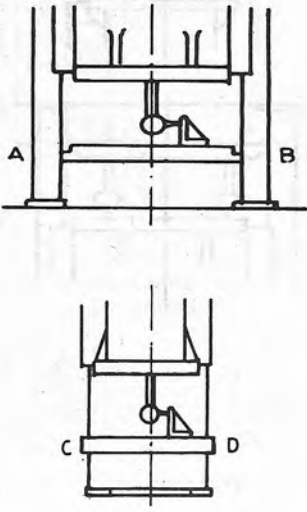
Fig. N1a Testing gap frame presses

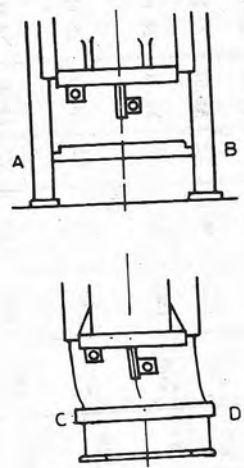
Note: Plane AB is the plane passing through the centre of frame.
Plane CD is the plane perpendicular to the plane AB.

Test Chart for Straight-sides Presses [Fig. N1b]

Sl. no.	Test item	Figure	Measuring instruments	Permissible error in (mm)	Actual error	Instructions for testing
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Flatness of bed, bolster and slide face in plane through the centre of the frame and in plane perpendicular		Precision spirit level	0.02/300 mm	...	Spirit level placed on the bed surface in both the directions and readings noted.
2.	Bed surface parallel with slide face		Dial Indicator having base of stand 200 to 250 mm long	In planes AB and CD up to 250t capacity: 0.03/300 mm over 250t capacity: 0.05/300 mm	...	Set maximum slide stroke down, and adjustment down. Dial indicator mounted on the bed, test point brought into contact with slide face as far as out as possible in planes AB and CD. Difference in dial indicator readings noted.

(Contd)

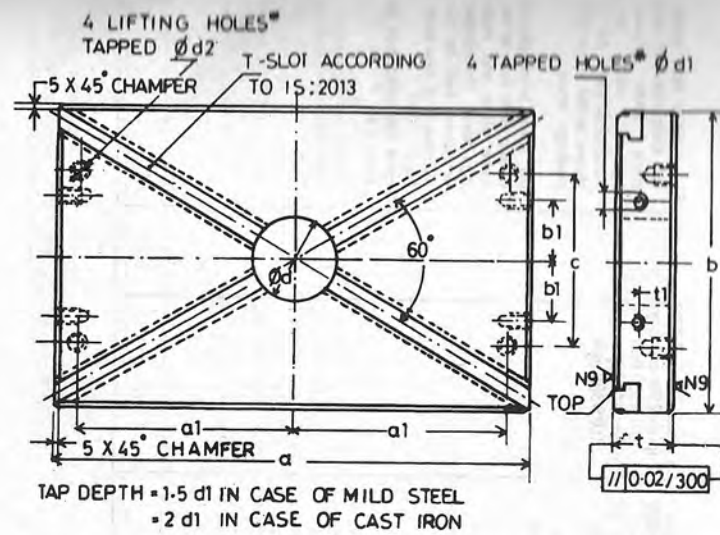
Sl. no.	Test item	Figure	Measuring instruments	Permissible error in (mm)	Actual error	Instructions for testing
(1)	(2)	(3)	(4)	(5)	(6)	(7)
3.	Slide motion square with bed surface		Dial indicator, engineers square (blade length of square to be commensurate with the press stroke)	In planes AB and CD up to 250t capacity: 0.03/300 mm over 250t capacity: 0.05/300 mm	...	Set maximum slide stroke and adjustment down. Square placed on the bed and dial indicator attached to the slide test point being in contact with the square in plane AB and CD. The slide moved and readings during one stroke taken.

Sl. no.	Test item	Figure	Measuring instruments	Permissible error (mm)	Actual error	Instruction testing
(1)	(2)	(3)	(4)	(5)	(6)	(7)
4.	*Hole receiving punch shank square with slide face		Test mandrel with parallel shank for reception in slide. Box type precision spirit level.	In planes AB and CD up to 250t capacity: 0.03/300 mm over 250t capacity: 0.05/300 mm	...	Test mandrel held inside the slide opening and spirit level placed against the test mandrel in plane AB as shown in the figure and readings noted. Now spirit level placed on the slide face in the same plane and readings noted. Permissible deviation shall be the difference in two readings. Repeat the procedure in plane CD.

Note Plane AB is the plane passing through the centre of frame.
Plane CD is the plane perpendicular to the plane passing through the centre of the plane.

*Measurement of acceptance test is not necessary where slide face does not have the punch shank receiving hole.

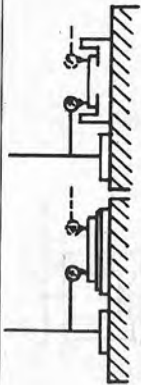
Fig. N1b Testing straight-sided presses



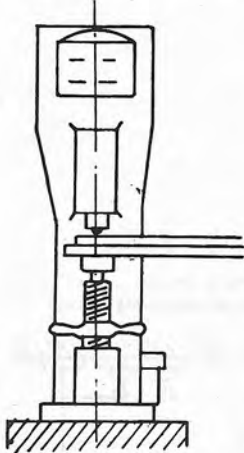
Capacity in tonnes	Nominal size $a \times b$	a_1	b_1	d	t	t_1	d_1	t Slot	d_2	
10	500 × 315	225	90	90	65	25	M 20	8 H 12	M 16	125
16	560 × 355	225	100	90	70	25	M 20	18 H 12	M 16	125
25	630 × 400	290	112	90	75	25	M 20	18 H12	M 16	160
40	710 × 450	325	125	112	75	25	M 24	22 H12	M 16	160
63	800 × 500	370	140	112	90	25	M 24	22 H12	M 16	200
(80) 100	100 × 630	460	200	140	90	32	M 30	28 H12	M 20	200
(125) 160	1120 × 710	520	240	140	112	32	M 30	28 H12	M 20	250
(200)	1250 × 900	585	240	140	120	32	M 30	28 H12	M 20	250

Fig. N2 Bolsters for presses

N3: Testing Pillar Die Sets

Sl. no.	Figure	Object	Meas- uring instru- ments	Permissible deviations				Actual error	Remarks
(1)	(2)	(3)	(4)	(5)				(6)	(7)
1.	 Testing Parallelism between Top and Bottom Bolsters	Parallelism between top and bottom surface of top and bottom tool holders	Surface plate, dial gauge and stand	Range	Standard	Preci- sion	High Pre- cision	Fine Ground	
				Up to 100	0.01/100	0.010	0.005		
			Over 100 Up to 200	0.014		0.007			
			Over 200 Up to 300	0.017		0.011			
			Over 300 Up to 400	0.020		0.014			
			Over 400 Up to 500	0.025	0.017				
			Up to 100	0.005	0.003				
			Over 100 Up to 200	0.006	0.004				
			Over 200 Up to 300	0.01/100	0.008	0.006			
			Over 300 Up to 400		0.010	0.008			
	Over 400 Up to 500	0.013	0.010						

(Contd)

Sl. no.	Figure	Object	Measuring instruments	Permissible deviations	Actual error	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
2.	 Checking Hardness of guide bushes and guide posts	Checking the hardness of guide bushes and guide posts	Rockwell hardness testing machine	Guide bushes hardness—61 to 63 HRC Guide posts hardness—58 to 62 HRC		Checking shall be done at two points on the surface

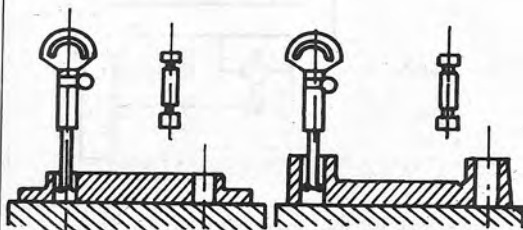
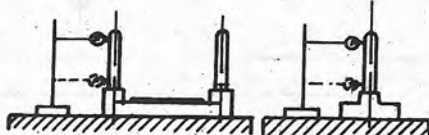
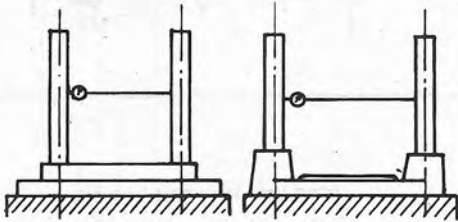
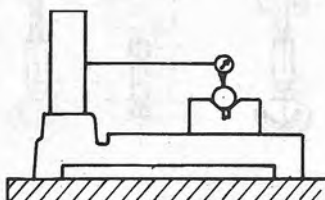
Sl. no.	Figure	Object	Measuring instruments	Permissible deviations				Actual error	Remarks	
(1)	(2)	(3)	(4)	(5)				(6)	(7)	
3.	 Checking Pillars and Bush Bores	Manufacturing accuracies of pillar and bush bore	Limit plug gauge and bore	Range	Precision		High Precision			Bottom tool holders: fine finish Top tool holder: fine ream to highly smooth finish
					Bottom tool holder P6	Top tool holder	Bottom tool holder P6	Top tool holder		
				Over 10 Up to 18	- 0.018 - 0.029	Choose the size to give a sliding fit similar to quality H3/h3	- 0.018 - 0.029	Choose the size to give a sliding fit similar to quality J3/h2		
				Over 18 Up to 30	- 0.022 - 0.035		- 0.022 - 0.035			
Over 30 Up to 50	- 0.026 - 0.042	- 0.026 - 0.042								
4.	 Checking Squareness of Bush Bores	Squareness of guide bush bores in top tool holder	Surface plate mandrels, dial gauges and stand	Range	Standard	Precision	High Precision		Checking shall be made at any point	
				Over a length of 100	0.02	0.01	0.005			

Fig. N3a Testing pillar die sets

(Gontd)

Sl. no.	Figure	Object	Measuring instruments	Permissible deviations				Actual error	Remarks		
(1)	(2)	(3)	(4)	(5)				(6)	(7)		
5.		Distance between bores	Dial gauges mandrel and adaptor	Range	Stand-ard	Preci-sion	High Precision		Checking shall be made at any point		
				Up to 200	—	± 0.01	± 0.005				
				Over 200 Up to 400	—	± 0.02	—				
				Over 400	—	± 0.02	—				
Checking Distance between Pillar and Bush Bores											
6.		Manufacturing accuracies of the guide posts	Surface plate, dial gauge, stand v-block	Range	Standard		Precision		High Precision		Lapped
					Dia-meter	Cyl form	Dia-meter	Cyl form	Dia-meter	Cyl form	
				Over 10 Up to 18	0 - 0.004	- 0.002	0 - 0.003	0.0015	0 - 0.002	0.001	
				Over 18 Up to 30	0 - 0.005	- 0.0025	0 - 0.004	0.002	0 - 0.002	0.0015	
				Over 30 Up to 50	0 - 0.005	- 0.0025	0 - 0.004	0.002	—	—	
Checking Guide Pillars Accuracy											

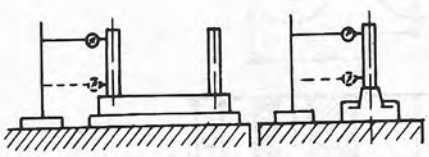
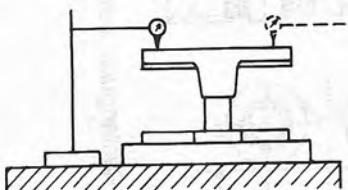
Sl. no.	Figure	Object	Measuring instruments	Permissible deviations				Actual error	Remarks
(1)	(2)	(3)	(4)	(5)				(6)	(7)
7.	 Checking Squareness of Assembled Pillars	Squareness of assembled guide posts	Surface plate, dial gauges and stand	Over a length of 100	Standard 0.02	Precision 0.01	High Precision 0.005		Checking shall be made at any point
8.	 Checking Parallelism between Top Bolster Top and Bottom Bolster Bottom Surfaces	Parallelism between bottom of bottom holder and top of top holder	Surface plate and dial gauge	Up to 100	0.02/100	0.020	0.010		
				Over 100 Up to 200		0.020	0.015		
				Over 200 Up to 300		0.025	0.020		
				Over 300 Up to 400		0.030	0.025		
				Over 400 Up to 500		0.040	0.030		

Fig. N3b Testing pillar die sets

(All dimensions in mm)

Working surface a & b	A	A1	B	C1	C2	C3	d	E	L	M	h1
80 × 50	125	105	78	50	70	35	20	75	150	22	55
100 × 50	150	130	78	50	70	35	20	100	150	22	55
120 × 50	176	152	92	50	70	35	24	120	160	22	65
150 × 50	206	182	92	50	75	40	24	150	160	22	65
150 × 80	206	186	112	50	75	40	24	150	160	25	65
200 × 80	256	236	112	50	75	40	24	200	160	25	65
150 × 100	206	190	132	55	80	45	25	150	170	25	75
180 × 100	250	220	166	60	85	50	30	180	180	25	75
200 × 100	256	240	132	55	85	50	25	200	170	25	75
250 × 100	306	290	132	55	85	50	25	250	170	25	55
200 × 130	278	240	200	55	85	50	38	200	200	30	75
230 × 130	300	270	166	60	85	50	38	230	200	30	80
280 × 130	350	320	166	60	85	50	38	280	200	30	80
250 × 160	328	290	200	65	85	50	38	250	200	30	80
300 × 160	378	340	200	65	85	50	38	300	200	30	80
375 × 160	453	415	200	65	85	50	38	375	200	30	80
400 × 160	480	435	250	65	85	50	38	400	200	30	80

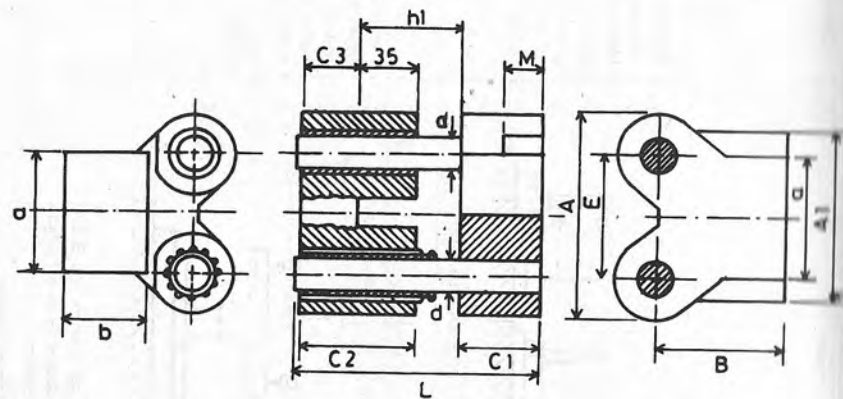


Fig. N4a Rectangular rear pillar die sets

(All dimensions in mm)

Diam working surface	A	B	C1	C2	C3	d	E1	L	M	r	h	Standard threads
63	95	40	45	65	35	20	85	150	25	25	70	M24 × 1.5
80	110	50	50	70	35	25	105	160	30	28	75	M24 × 1.5
100	135	56	50	80	40	25	120	170	30	28	80	M30 × 2
125	160	63	50	85	40	32	150	180	30	35	90	M30 × 2
160	200	80	50	90	50	40	200	200	30	39	100	M30 × 2
200	240	92	60	90	50	40	240	220	30	39	110	M40 × 2
250	290	110	60	90	50	40	290	220	30	40	110	M40 × 2

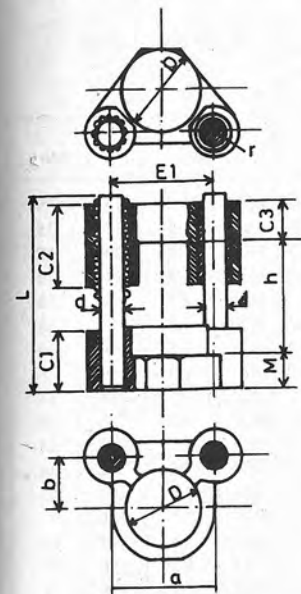
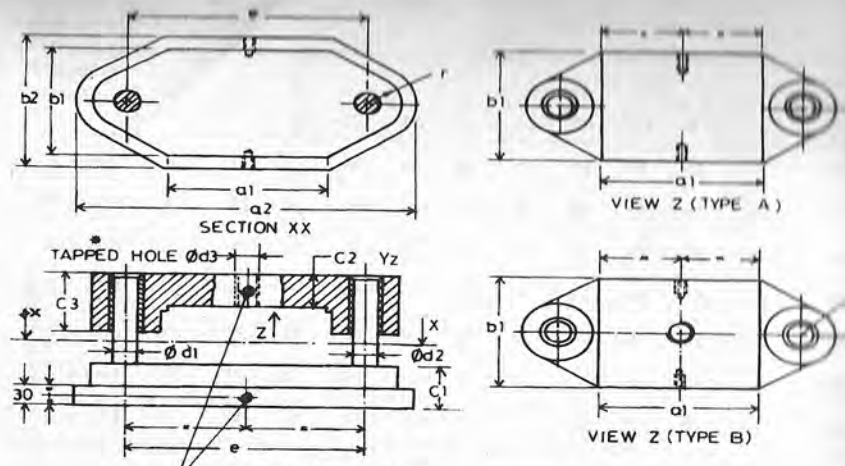


Fig. N4b Circular rear pillar die sets



LIFTING HOLES TAPPED SIZE:
M10 X 25 FOR DIE SETS UP TO 250 X 160 DIE SPACE
M16 X 40 FOR DIE SETS OF 315 X 125 DIE SPACE AND ABOVE

*TYPE A - WITHOUT TAPPED HOLE FOR SHANK AND
TYPE B - WITH TAPPED HOLE FOR SHANK

Die space $a_1 \times b_1$	a_1	b_1	C_1	C_2	C_3	d_1	d_2	d_3	e	r Min
80 x 63	266	103	45	30	70	19	20	M20 x 1.5	156	35
100 x 63	286	103	45	30	70	19	20	M20 x 1.5	176	35
125 x 63	311	103	45	30	70	19	20	M20 x 1.5	201	35
160 x 63	362	103	50	32	80	24	25	M20 x 1.5	246	38
200 x 63	402	103	50	32	80	24	25	M20 x 1.5	286	38
100 x 80	298	120	50	32	80	24	25	M20 x 1.5	182	38
125 x 80	323	120	50	32	80	24	25	M20 x 1.5	207	38
160 x 80	358	120	50	32	80	24	25	M20 x 1.5	242	38
200 x 80	402	120	50	32	80	24	25	M20 x 1.5	286	38
250 x 80	452	120	50	32	80	24	25	M20 x 1.5	336	38
125 x 100	323	140	56	40	80	24	25	M24 x 1.5	207	38
160 x 100	358	140	56	40	80	24	25	M24 x 1.5	242	38
200 x 100	422	140	56	40	90	30	32	M24 x 1.5	296	43
250 x 199	472	140	56	40	90	30	32	M24 x 1.5	346	43
315 x 100	537	140	56	40	90	30	32	M24 x 1.5	411	43
160 x 125	382	165	56	40	90	30	32	M24 x 1.5	256	43
200 x 125	422	165	56	40	90	30	32	M24 x 1.5	296	43
250 x 125	472	165	56	40	90	30	32	M24 x 1.5	346	43
315 x 125	537	165	56	40	90	30	32	M24 x 1.5	411	43
200 x 160	422	200	63	50	90	30	32	M30 x 2	296	43
250 x 160	472	200	63	50	90	30	32	M30 x 2	346	43
315 x 160	565	200	63	50	100	38	40	M30 x 2	425	50
400 x 160	650	200	63	50	100	38	40	M30 x 2	510	50
250 x 200	510	250	63	50	100	38	40	M30 x 2	360	50
315 x 200	575	250	63	50	100	38	40	M30 x 2	425	50
400 x 200	660	250	63	50	100	38	40	M30 x 2	510	50
500 x 200	760	250	63	50	100	38	40	M30 x 2	610	50
315 x 250	585	310	63	50	100	38	40	M30 x 2	425	50
400 x 250	670	310	63	50	100	38	40	M30 x 2	510	50
500 x 250	770	310	63	50	100	38	40	M30 x 2	610	50
400 x 315	698	375	75	63	110	48	50	M42 x 3	524	57
500 x 315	798	375	75	63	110	48	50	M42 x 3	624	57
500 x 400	798	460	75	63	110	48	50	M42 x 3	624	57

Fig. N5a Diagonal pillar die sets

Die space $a_1 \times b_1$	a_2	e_1	e_2	d_1	d_2	d_3	e	f
80 x 63	197	40	30	19	20	M 20 x 1.5	127	30
100 x 63	217	45	30	19	20	M 20 x 1.5	147	30
125 x 63	242	45	30	19	20	M 20 x 1.5	172	30
160 x 63	288	50	32	24	25	M 20 x 1.5	212	30
200 x 63	328	50	32	24	25	M 20 x 1.5	252	30
100 x 80	228	50	32	24	25	M 20 x 1.5	152	35
125 x 80	253	50	32	24	25	M 20 x 1.5	177	35
160 x 80	288	50	32	24	25	M 20 x 1.5	212	35
200 x 80	328	50	32	24	25	M 20 x 1.5	252	35
250 x 80	378	50	32	24	25	M 20 x 1.5	302	35
125 x 100	253	56	40	24	25	M 24 x 2	177	40
160 x 100	288	56	40	24	25	M 24 x 2	212	40
200 x 100	346	56	40	30	32	M 24 x 2	260	40
250 x 100	396	56	40	30	32	M 24 x 2	310	40
315 x 100	461	56	40	30	32	M 24 x 2	375	40
160 x 125	306	56	40	30	32	M 24 x 2	220	50
200 x 125	346	56	40	30	32	M 24 x 2	260	50
250 x 125	396	56	40	30	32	M 24 x 2	310	50
315 x 125	461	56	40	30	32	M 24 x 2	375	50
200 x 160	346	63	50	30	32	M 30 x 2	260	40
250 x 160	396	63	50	30	32	M 30 x 2	310	50
315 x 160	485	63	50	38	40	M 30 x 2	385	50
400 x 160	570	63	50	38	40	M 30 x 2	470	50
250 x 200	420	63	50	38	40	M 30 x 2	320	50
315 x 200	485	63	50	38	40	M 30 x 2	385	50
400 x 200	570	63	50	38	40	M 30 x 2	470	50
500 x 200	670	63	50	38	40	M 30 x 2	570	50
315 x 230	485	63	50	38	40	M 30 x 2	385	50
400 x 250	570	63	50	38	40	M 30 x 2	470	50
500 x 250	670	63	50	38	40	M 30 x 2	570	50
400 x 315	594	75	63	48	50	M 42 x 3	480	50
500 x 315	694	75	63	48	50	M 42 x 3	580	50
500 x 400	694	75	63	48	50	M 42 x 3	580	50

*Tapped Size — M8 x 20 for die sets up to 125 x 80 die space.

M10 x 25 for die sets from 160 x 80 to 250 x 160 die space, and

M12 x 35 for die sets of 315 x 160 die space and above.

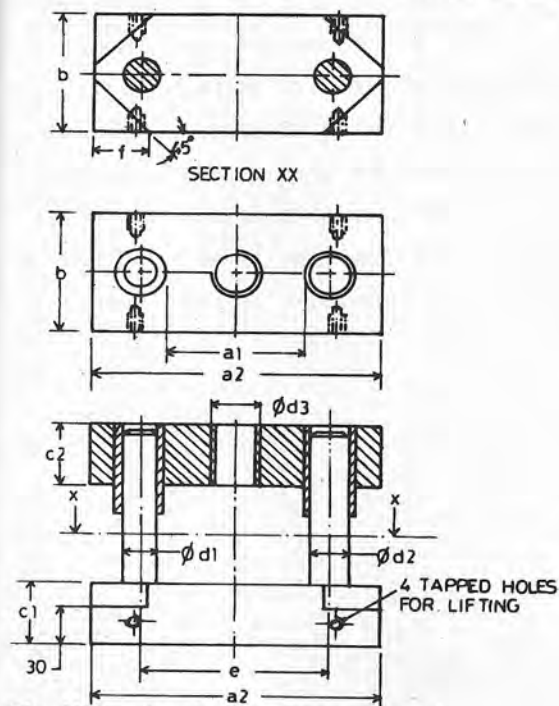


Fig. N5b Steel centre pillar die sets

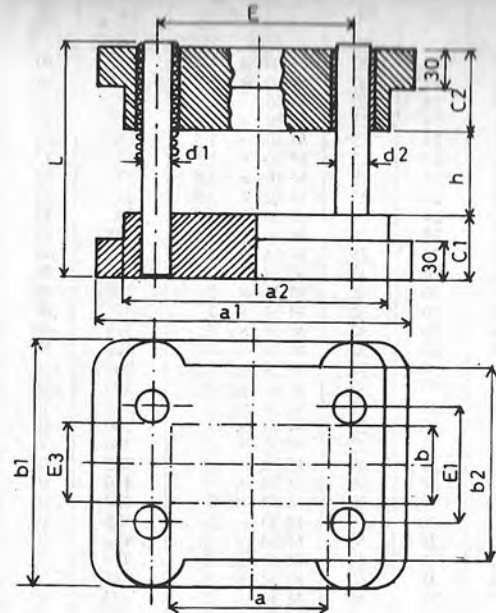


Fig. N6 Four pillar die sets

(All dimensions in mm)

Working surface	a1	a2	b1	b2	E	d1	d	E1	E3	C1	C2	h	L	Standard threads
125 × 63	250	210	190	150	155	24	25	90	61.5	50	65	56	180	M30 × 2
160 × 63	275	240	190	150	190	24	25	95	69.5	50	65	65	180	M30 × 2
200 × 100	340	300	240	200	230	24	24	130	104.5	50	65	65	200	M40 × 2
250 × 100	390	350	240	205	285	30	32	135	104	50	65	85	200	M50 × 2
315 × 160	450	440	340	290	350	30	32	200	169	50	65	85	200	M50 × 2
355 × 250	535	480	430	380	395	38	40	290	253	50	65	85	200	M50 × 2
400 × 250	545	495	430	380	395	38	40	290	253	50	65	85	200	M50 × 2

Basic Dimensions for Gap Frame Open-back Presses (Inclinable and Non-inclinable) (Fig. N7)

(All dimensions in millimetres)

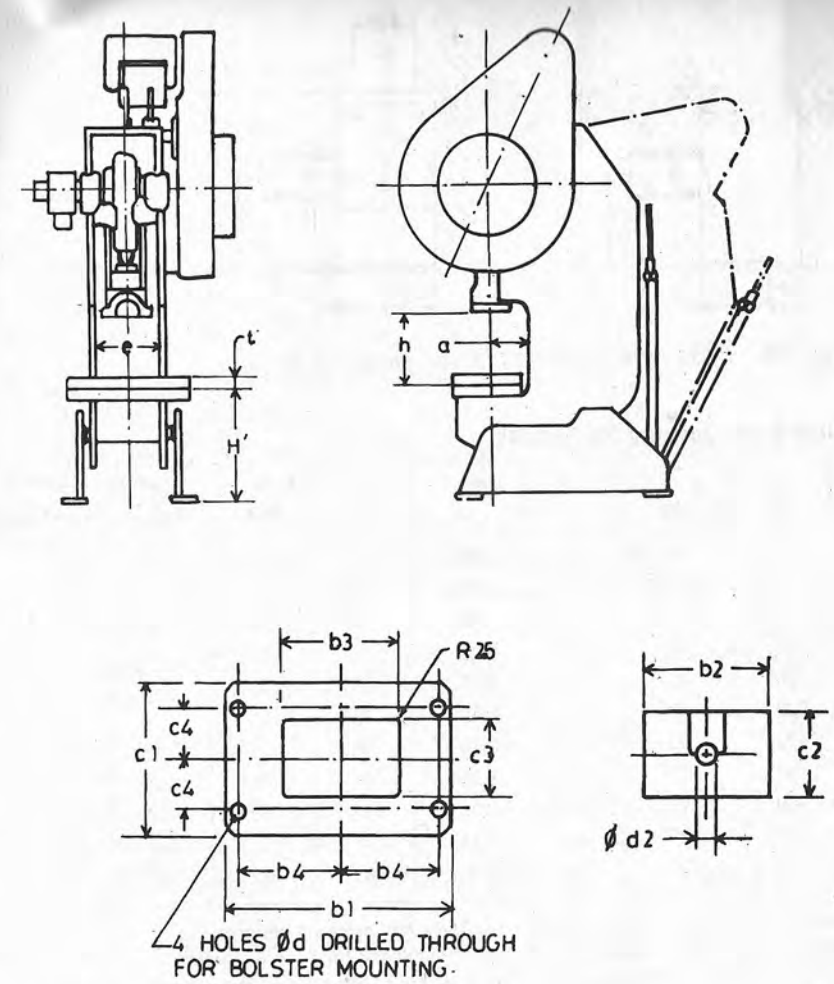
Capacity	Tonnes	10	16	25	40	63	(80)	(125)	(200)
Stroke standard	Adjustable	8 to 40	8 to 50	8 to 63	8 to 80	8 to 100	8 to 125	—	—
Distance up the stroke at which the capacity of the press shall be measured	Fixed	40	50	63	80	100	125	160	200
Throat, <i>a</i> , Min.	Gear	1.6	2	2.5	3.15	4	5	6.3	8
Shut height, <i>h</i>	Non-gear	1	1.25	1.6	2	2.5	3.15	—	—
Slide adjustment	Standard (see Note 4)	160	180	200	224	250	315	355	400
Slide face	Optional	224	250	280	315	355	450	500	560
Flanged*	Standard	315	355	400	450	500	630	710	800
	Optional	40	50	63	80	100	125	160	200
	Standard	280	315	355	400	450	560	630	710
	Optional	180	200	224	250	280	355	400	450
	Flanged*	400	450	500	560	630	710	800	900
		315	355	400	450	500	560	630	710

(Contd.)

Slide face opening	d_2	32	40	40	50	50	63	63	80
	Depth	60	75	75	85	85	85	85	85
Clear distance between up-rights, e		280	315	355	400	450	560	630	710
Height of table surface from floor, H		800	800	800	800	800	900	900	900
Table face	b_1	500	560	630	710	800	1000	1120	1250
	c_1	315	355	400	450	500	630	710	800
Opening in table, M_{in}	b_3	250	280	315	355	400	500	560	630
	c_3	180	200	224	250	280	355	400	450
Bolster thickness, t		65	70	75	75	90	90	112	120
b_4		225	255	290	325	370	460	520	585
c_4		90	100	130	125	140	200	240	240
d		23	23	23	30	30	40	40	40

- Note 1** — Values given in parentheses are non-preferred.
- Note 2** — It is recommended that these presses should always be used with bolster plates.
- Note 3** — The manufacturer shall provide the tonnage-stroke relationship curve.
- Note 4** — *Nominal Throat* The throat dimensions shall be half of front to back dimensions of the table (c_1). The actual dimensions of the throat shall be equal to nominal throat plus clearance as per manufacturer's practice.
- Note 5** — The slide face should always remain below the guides with slide in stroke up and adjustment up conditions.
- Note 6** — The flywheel energy and the motor should be sufficient to provide the rated capacity at continuous operation of the press.

Fig. N7 Dimensions of gap frame open back presses



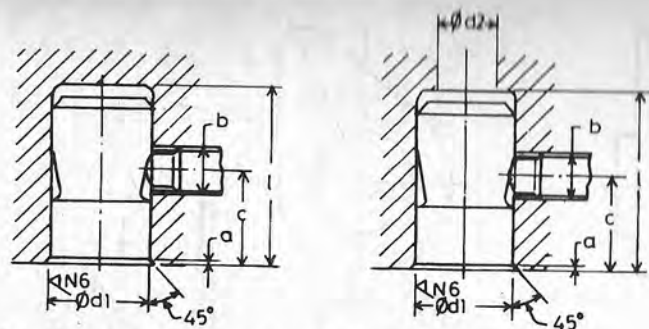


Fig. N8 Slide face openings for locating shanks

Slide Face Opening for Shanks

d ₁ H7	l Min	a	b	c	d ₂ Min	Capacity in tonnes	
						Above	Up to 8 incl.
8	25	1	M8	12	—	—	—
10	28	1	M8	12	—	—	—
12	32	1	M8	12	—	—	—
16	36	1	M10	20	—	—	—
20	45	1.6	M12	20	20	—	4
25	50	1.6	M12	25	25	4	10
32	60	1.6	M16	28	25	10	25
40	75	2.0	M20	40	25	25	63
50	85	2.0	M20	40	32	63	160
63	105	2.0	M24	45	32	160	400
80	130	2.5	M30	60	32	400	1000

Note 1 — In the case of large faced rams, fixing bolt holes are optional.

Note 2 — Type A slide face opening shall be applicable for d₁ up to 16 mm.

Note 3 — Square or hexagonal head dog point bolts with radiused end should be used.

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