

FORGING HANDBOOK

FORGING PLANT

by

A Thomas

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SHEPHERD STREET, SHEFFIELD S3 7BA**

FOREWORD

THE DIE design section of the DFRA Forging Handbook, published just over two years ago, was very well received. Many copies were sold, and are still being sold, not only in the UK but throughout the world, and the indications are that the book is being widely used and much appreciated.

It was with some trepidation that we chose die design to launch the series as this is not by any means the easiest of subjects to deal with, but the success of the first issue has encouraged us in producing the second section, which is on the rather more straightforward subject of forging plant.

Again the material has been written by Dr Alwyne Thomas, partly from his own knowledge of the subject and partly from information supplied by machinery builders, users and outside forging experts.

The aim throughout has been to provide not just a description of the different types of forging plant available but to explain the fundamental technical concepts and principles on which their designs are based. By this means the reader should be helped both in making the best selection for his purpose and in utilising the equipment at maximum efficiency.

It will be realised that a book of this standard is now very expensive to produce, and to defray some of the cost we have accepted advertisements. These have however been kept as unobtrusive as possible so as to preserve the image of a working manual rather than a technical journal.

We consider there is no better way of transferring technology to industry than through publications of this type, and it is our hope that this handbook will be as well received as its predecessor and will be as extensively used.

S E ROGERS
Director, DFRA
December 1982

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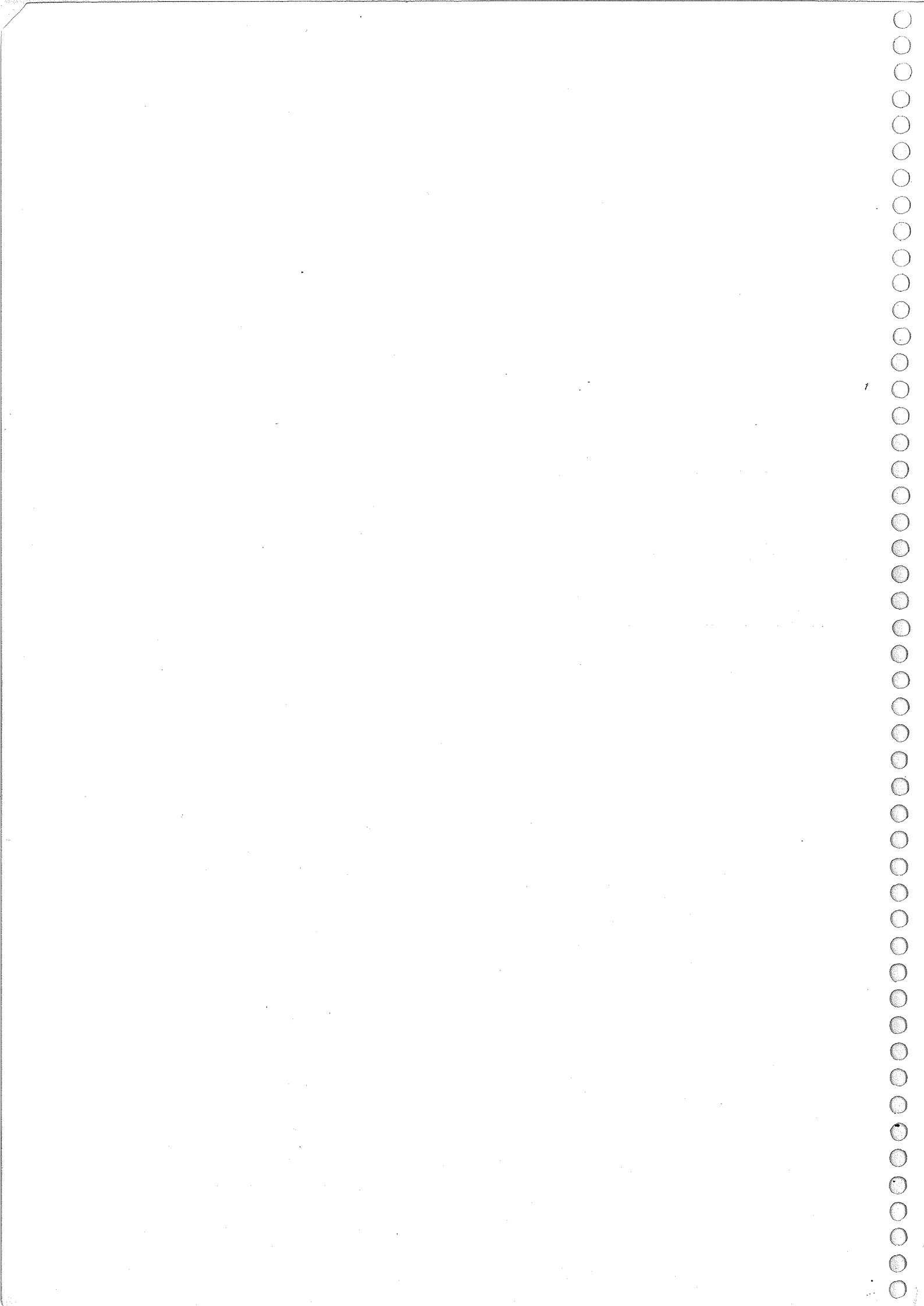
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DFRA FORGING HANDBOOK

FORGING PLANT

1 CHARACTERISTICS OF METAL FORMING PROCESSES

Any metal forming operation may be characterised by a load-displacement curve. Such a curve will indicate the load requirement throughout the process and will also show the maximum load (L_{max}), the total displacement (D) and the energy required (E), the latter being given by the area under the load-displacement curve.

Figure 1.1 indicates the general shape of load-displacement curves for a number of metal forming processes. The figure shows that some processes such as hot extrusion may only require a moderate load but because the displacement is large the energy requirement is high. At the opposite end of the scale cold coining demands a very high load but only little energy because the displacement is very small.

To meet these varying demands a wide range of metal forming machines has been developed and their individual characteristics are described later.

Some machines perform the required deformation in a single blow or "squeeze". Examples of such machines are crank presses and hydraulic presses. Others may supply the energy requirement and build up the load by means of several repeated blows. Screw presses are commonly used for forging in two blows whilst in hammers many more blows may be struck.

Table 1.1 shows the general way in which useful energy varies with type of machine for a given maximum operating load.

Table 1.1

Typical ratios of useful energy to maximum load for different forming machines with the same maximum load capacity

Plant type	Load rating L —tonnef	Available energy per blow E —mkg	Ratio E/L
Hydraulic press	1250	250 000	200
Crank press	1250	20 000	16
Friction screw press	1250	8 000	6.4
Drop hammer	1250	1 600	1.3

It is apparent from table 1.1 and figure 1.1 that the load and energy requirements for a given forming process will influence the type of plant used. This theme is developed in more detail in subsequent sections.

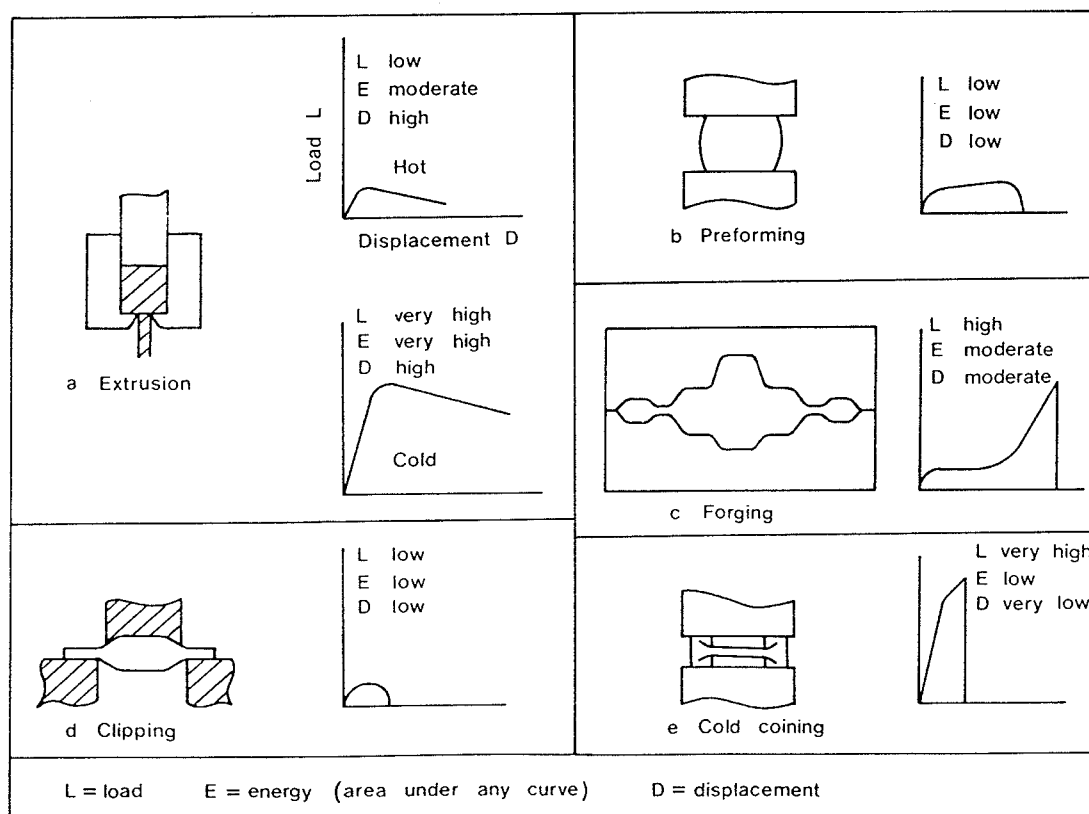


FIG. 1.1

Typical load-displacement curves for metal forming processes.

2 CLASSIFICATION AND GENERAL APPLICATION OF FORGING MACHINES

2.1 Classification of forging machines

Whilst there are many ways in which forging machines can be classified one of the most widely used and helpful methods in understanding their operation is the division into energy restricted, stroke restricted or load restricted machines.

2.1.1 Energy restricted machines

In energy or work restricted machines the deformation energy is derived from the kinetic energy of a moving body or bodies. During a forging blow deformation of the work piece continues until all the available energy is used. Further deformation can only be accomplished by striking further blows.

The capacity of energy restricted machines is usually denoted by quoting the maximum kinetic energy available at each blow. As will be explained later such machines do also have a limiting load capacity.

2.1.2 Stroke restricted machines

Stroke restricted forging machines derive their initial drive from a rotating eccentric mechanism which imparts linear movement to a ram by means of a connecting device.

During deformation the load builds up until the ram passes through a bottom dead centre position. In such machines forging in a given impression must be completed in a single blow.

2.1.3 Load restricted machines

The hydraulic press is a load restricted machine since the maximum load can be developed at any position within the available stroke. The maximum load which can be sustained depends on the oil pressure in the cylinder whilst the speed of ram travel is dependent on the rate at which oil can be supplied to the hydraulic cylinder.

Table 2.1 below shows the forging machines which belong to each of the classifications. The detailed characteristics of each group are discussed later.

Table 2.1
Classification of forging machines

Energy restricted machines	Stroke restricted machines	Load restricted machines
1 Hammers (all types)	1 Crank and eccentric presses	1 Hydraulic presses
2 Friction screw presses	2 Knuckle-joint presses	2 Orbital presses
3 HERF machines	3 Wedge presses	
	4 Horizontal upsetters	

2.2.2 Asymmetric elongate forgings

Elongate forgings with varying cross-section along their length require several preforming blows to redistribute metal and are therefore usually made on hammers. For such forgings the modern trend is to use double acting hammers because of their high stroking rate.

For large order quantities press forging may be developed but preforming must be done on ancillary plant such as forging rolls.

Very long forgings such as axle beams and large crankshafts require a larger die block area than is available on a suitably rated press and such forgings are therefore made on large gravity drop hammers or counterblow hammers. Recently however even these forgings have been made on crank and friction screw presses.

2.2.3 Large axisymmetric forgings

Very large circular forgings such as turbine discs made in heat resisting steels and super alloys require very high forging loads and are therefore made on hammers.

2.2.4 Close to form forgings

Close-to-form forgings requiring close thickness tolerances such as turbine blades are normally made on friction screw presses. Thickness control is not so good on crank presses due to frame spring and the guidance on hammers is inadequate for close control of offset. The good ram guidance and ability to forge die to die on screw presses allows good control of both offset and thickness.

2.2.5 Light alloy forgings

Conventional light alloy forgings may be made on all types of forging plant but thin plate type forgings with edge ribs, draftless precision forgings and very large forgings are usually made on hydraulic presses. The use of hydraulic presses with light alloys is permissible because dies can be preheated close to the forging temperature thus compensating for heat losses. Table 2.2 below shows the commercially available ranges of forging plant.

Table 2.2
Forging plant

Type of plant	Normal energy (E-mkg) or load (L-tonnef) range	Maximum energy (E) or load (L)
Friction drop hammers	E = 500— 5 000	E = 40 000
Double acting hammers	E = 2000—10 000	E = 20 000
Counterblow hammers	E = 6000—40 000	E = 80 000
Crank presses	L = 500— 2 500	L = 14 000
Friction screw presses	L = 100— 3 000	L = 16 000

2.2 General applications of forging plant

Although there are wide variations in the products made on individual pieces of forging plant forgings can be broadly grouped into categories for which a particular forging machine is likely to be most suitable.

2.2.1. Axisymmetric and ring type forgings

Because axisymmetric forgings generally do not require extensive preforming operations to redistribute metal they are frequently made on crank presses by upsetting cut pieces.

When the dimensions of axisymmetric forgings demand a load in excess of available presses they are usually made on hammers.

2.2.6 A note on load and energy estimation in forging

In later sections of this handbook methods are presented for calculating forging loads and energies and estimating the plant size needed to produce a given forging.

Usually the drop forger will not have to resort to theoretical calculations for plant selection since previous experience in the manufacture of similar forgings will indicate the equipment to be used.

Inevitably however occasions arise when a decision has to be made on whether a particular forging can be made safely and economically on a given piece of plant. On such occasions it is essential to make an estimate of the load and energy requirements.

In this section some of the factors which influence the forging load and energy are discussed. Curve 1 in figure 2.1 shows how the load would vary during the upsetting of a mild steel cylinder initially 50 mm diameter $\times$ 100 mm long at 1250°C under frictionless conditions. In drawing this curve it has been assumed that there is no heat loss from the billet and the deformation rate is very slow so that the yield strength has been taken as 6 kg/mm².

Under such frictionless conditions the load at any time is simply the instantaneous area of the billet multiplied by the material yield strength.

In practice however friction does occur and so extra load is required to overcome the frictional forces and cause the deforming billet to slide across the die faces. Curve 2 in figure 2.1 shows this increased load assuming a friction factor of 0.5.

Thus even in the simple case of slow upsetting the load, and hence energy, will depend on the size of the upset piece, the friction conditions, the material and forging temperature.

In practice there will also be some heat loss from the billet to the die so that the material yield strength will change during forging.

The yield strength of a material when it is hot forged also depends on how fast the deformation is accomplished. The faster the rate of deformation the higher is the yield strength. This phenomenon is called strain rate sensitivity.

In the case of simple upsetting the strain rate at any time is given by the velocity of the tup V divided by the instantaneous height h of the upset piece. Since V has the units of mm/sec and h is in mm the units of strain rate are 1/sec or sec⁻¹.

Curve 3 in figure 2.1 shows how significantly the load increases if deformation is performed rapidly instead of slowly. In drawing this curve a strain rate of 60 sec⁻¹ has been assumed so that the yield strength has increased to a value of 12 kg/mm² compared with 6 kg/mm² with slow deformation.

In the case of a forging made with flash the situation is complicated even further by the fact that additional load must be built up to extrude material out through the narrow flash gap into the flash gutter.

This additional load depends on the width to thickness ratio of the flash land and the load rises very quickly during the last stages of forging when the flash becomes thin.

Yet another complication is that the design of the flash land must be varied according to the complexity of the forging. Complex forgings with tall narrow ribs demand wide thin flashes to ensure die filling. Also in a real forging the strain rate will vary throughout the forging.

It is clear from the foregoing statements that any theoretical method which is used to estimate forging load should ideally take account of

- (1) material
- (2) forging temperature
- (3) strain rate
- (4) forging complexity
- (5) flash gap dimensions
- (6) friction conditions.

In addition the method should be mathematically simple for use by the practical forger. Many plant suppliers publish graphs relating forging load to the plan area of a forging as shown in figure 2.2. Whilst such charts are undoubtedly simple to use they are of little value if an accurate indication of forging load is required.

The method of load estimation presented in this handbook was developed at DFRA and represents a compromise between accuracy and complexity of calculation.

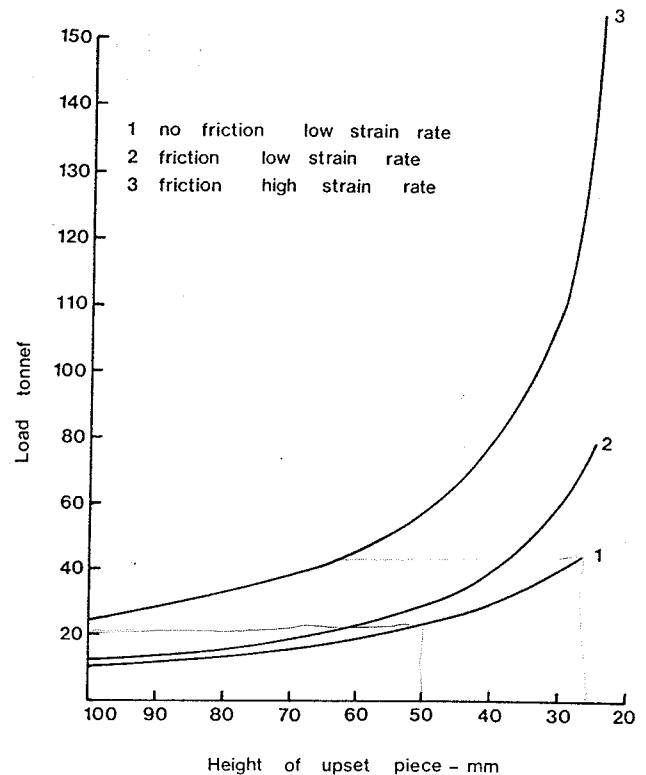


FIG. 2.1

Forging load when upsetting a cylinder under different conditions.

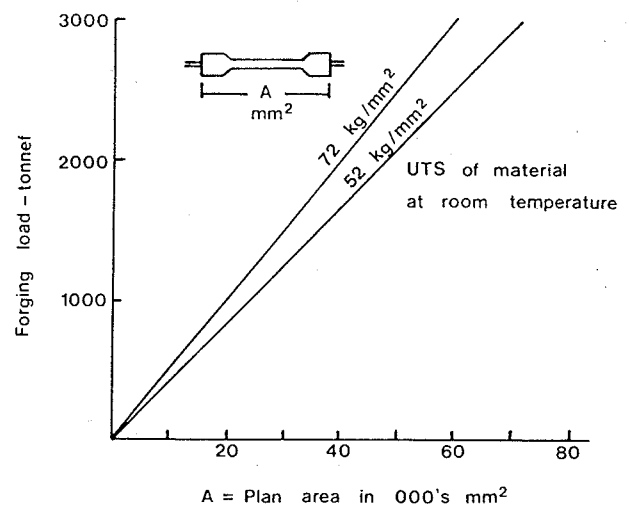


FIG. 2.2

Typical plant manufacturer's load estimation graph.

It is only recommended for use in estimating forging loads on crank presses and friction screw presses since the yield strength assumed is appropriate only to typical strain rates encountered on these machines.

It does however take into account most of the requirements previously listed since flash gap dimensions, forging complexity, forging material and forging temperature are all considered.

The method is described in detail later and examples of its application are given. It must be stressed that where calculated loads are close to the capacity of the forging machine the load should be monitored during forging trials. The cost of installing load measuring equipment is negligible compared with the cost of the plant which it protects.

The estimation of forging energy is even more difficult than the estimation of the final forging load since the shape of the load-displacement curve up to the maximum load is required.

The manner in which load-displacement curves vary according to the particular forming operation has already been indicated in figure 1.1.

If the maximum forging load and the die displacement under load are known the approximate forging energy required may be calculated as follows.

Consider the load-displacement diagram shown in figure 2.3. Suppose the maximum forging load is 1000 tonnef and the displacement under load is 50 mm.

Then the area under the rectangle shown by the chain dashed lines is

$$E = 50 \times 1000 = 50\,000 \text{ mm-tonnef}$$

or 50 000 mkg.

The actual forging energy may be estimated by multiplying this value by a fractional correction factor which represents the ratio of the true area of the load-displacement curve (ie, the area under the solid line curve) to the area of the rectangle.

The value of this correction factor will depend on the type of forming process. Suggested values for the correction factor are shown in figure 2.4.

The forming process depicted in figure 2.3 is a forging operation so that the energy multiplication factor is 0.25. Thus the estimated forging energy is given by

$$E = 50\,000 \times 0.25 = 12\,500 \text{ mkg}$$

3 HAMMERS

According to their mode of operation hammers may be divided into three types:

- (1) Gravity drop hammers
- (2) Double acting hammers
- (3) Counterblow hammers

3.1 Gravity drop hammers

In gravity drop hammers the tup is lifted by some arrangement and then allowed to fall freely under gravity to strike a forging blow. Depending on the lifting mechanism used it may be possible to vary the drop height of each blow (variable stroke hammers) or alternatively the drop height may be constant (fixed stroke hammers).

Fixed stroke hammers strike their full energy at every blow and if used for fullering and rolling operations the gap between the dies must be carefully selected since gradual deformation cannot be achieved by the stamper controlling the "weight" of each blow which is possible with variable stroke hammers.

The board hammer (figure 3.1a) is a fixed stroke hammer in which the tup is fixed to a number of hard wood boards which are gripped between rotating cylinders to lift the tup. At the top of the stroke the boards are released and the tup is allowed to fall.

Belt lift hammers (figure 3.1b) have the tup attached to a belt which passes over a rotating shaft. When the belt is engaged on the shaft the tup is lifted and falls as soon as the belt is disengaged. In hand driven hammers the drop height can be varied at will whilst with treadle operated hammers it is usually possible to select a short (light) or long (heavy) blow depending on the treadle position.

A third type of gravity drop hammer is the piston type (figure 3.1c). In this the tup is attached to a piston and is lifted by the application of fluid pressure below the piston. Air oil or steam may be used although steam hammers are gradually disappearing.

3.2 Double acting hammers

In double acting hammers (figure 3.2) the tup is again attached to a piston and is lifted by fluid pressure. During the forging stroke the weight of the tup is augmented by the application of fluid pressure to the top of the piston thus increasing the energy of the blow compared with a gravity drop hammer of the same tup weight.

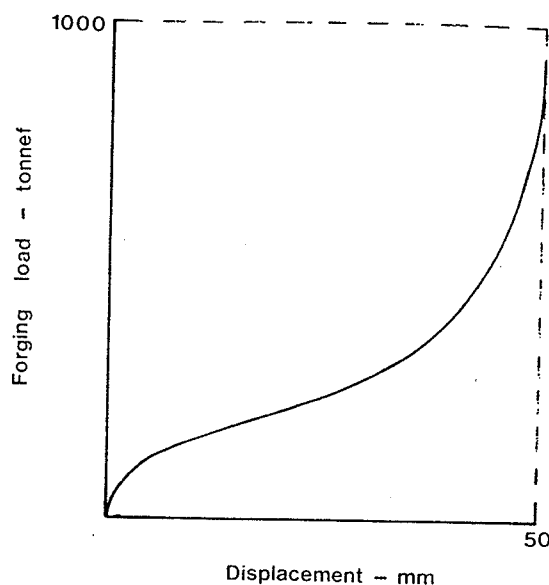


FIG. 2.3
Typical forging load-displacement curve.

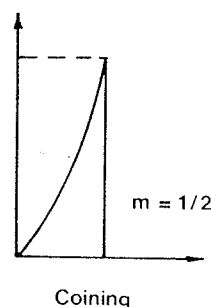
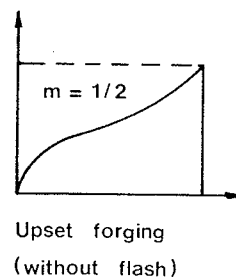
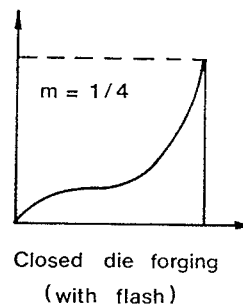
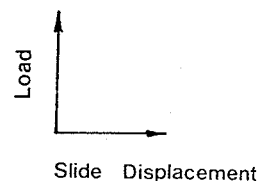


FIG. 2.4
Energy estimation factors.

Another advantage of the double-acting hammer is its greater striking rate compared with a gravity drop hammer of the same energy rating.

Double acting hammers may be of the ram type or the piston rod type (figure 3.3). A larger pressure cylinder is used with the ram type thus providing a greater blow energy than with the piston rod type. This enables the stroke on ram type machines to be reduced for a given blow energy thus resulting in a faster striking rate than is obtained with a piston rod hammer of equivalent energy capacity.

The additional weight of the ram also allows a shorter tup to be used and this together with the reduced stroke length gives the ram type hammer greater rigidity and stability than the piston rod hammer.

The original double acting hammers were steam operated but these gradually gave way to air operated hammers. From about 1960 however several manufacturers have developed hydraulically actuated double acting hammers.

A degree of controversy exists over the relative economics of air and hydraulically operated hammers.

Manufacturers of the air driven units point out their lower initial capital cost and their higher striking rate which it is claimed leads to higher production rates.

Makers of hydraulic hammers on the other hand point to their lower running costs and claim that there is in fact little difference in production rates since the very high striking rates of air operated hammers can rarely be achieved in actual production forging due to the need for handling work in the dies.

In deciding the overall economics the forger must therefore consider carefully the type of work for which the hammer is to be used.

The case for air hammers is presented in "A study of the economics of die forging" by H J Marcziński and H Hampe, published in *Metallurgia and Metal Forming*, August 1977.

The counter claims for hydraulic hammers are contained in a Lasco publicity leaflet entitled "Energy Conservation".

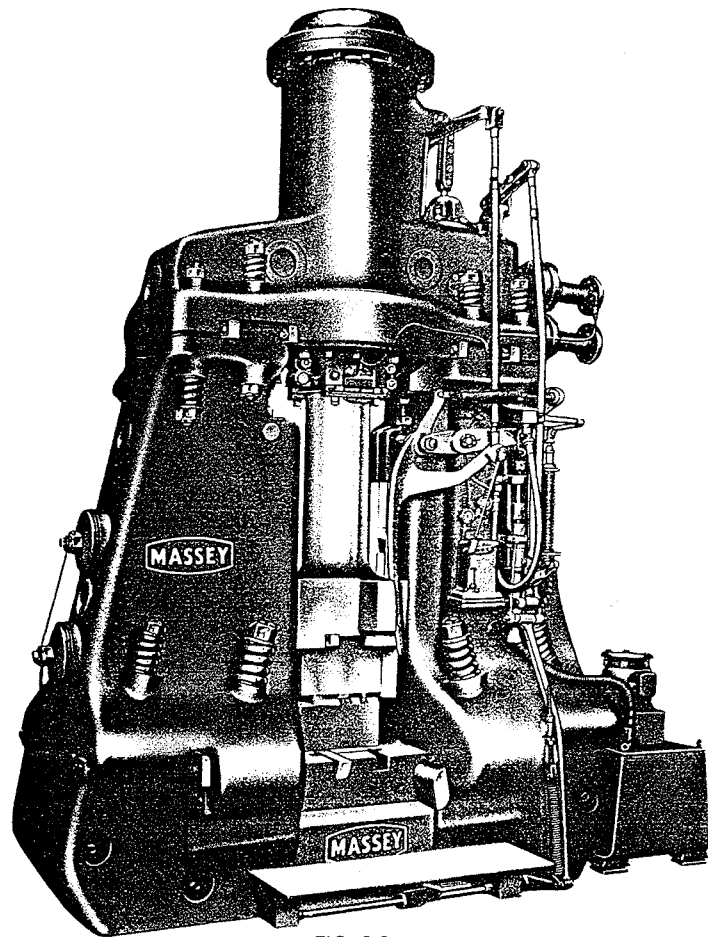


FIG. 3.3a
Ram type double acting hammer.

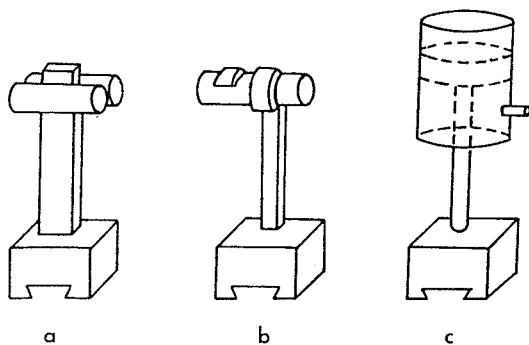


FIG. 3.1

Types of drop hammer:

(a) Board hammer (b) Belt lift hammer (c) Air lift hammer.

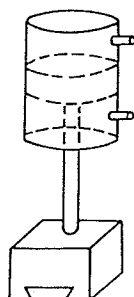


FIG. 3.2

Double acting drop hammer.

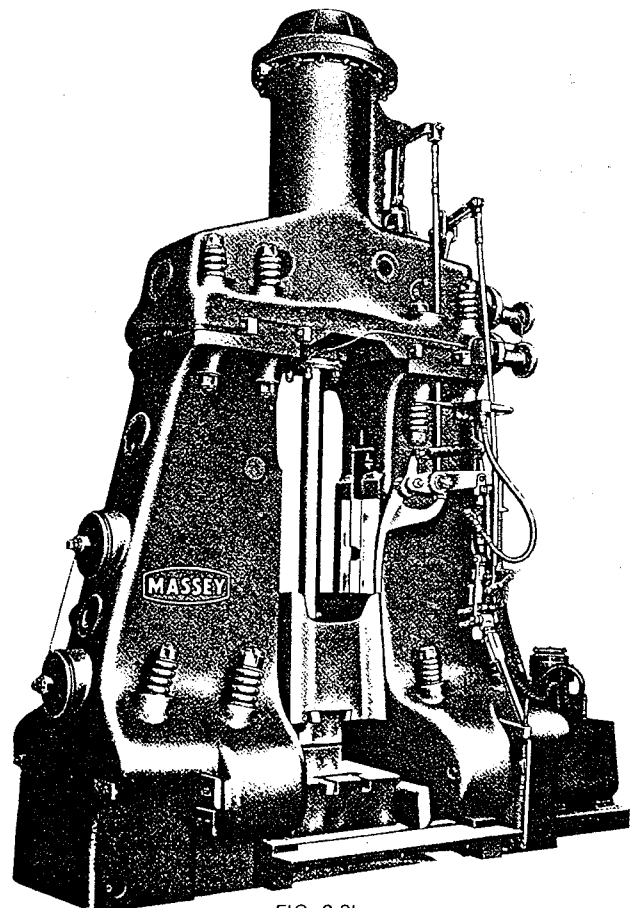


FIG. 3.3b
Piston rod type double acting hammer.

3.3 Vertical counterblow hammers

In the vertical counterblow hammer as shown in figure 3.4 and 3.5 two large tups of nearly equal weight are driven towards each other during a forging blow.

Fluid pressure is applied above the top ram assembly to drive it downwards and a steel band or hydraulic arrangement links the two tups so that the bottom one is simultaneously driven upwards.

This upwards movement of the bottom tup by an appreciable distance prevents preforming work off-the-bar on counterblow hammers. They are used therefore for cut piece work often forged in a single die impression.

Vertical counterblow hammers compete mainly with the larger sizes of gravity drop hammers and are favoured in situations where ground conditions are unsuited to bear the heavy anvil and foundation weights used with gravity drop hammers.

The striking velocity of the tups in a counterblow hammer is only about half that of a gravity hammer and thus to maintain energy ratings very heavy tups are used.

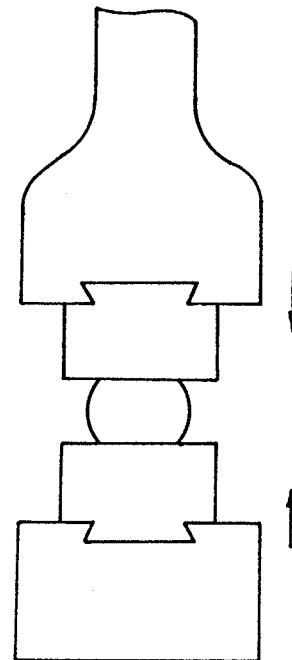


FIG. 3.4
Counterblow hammer.

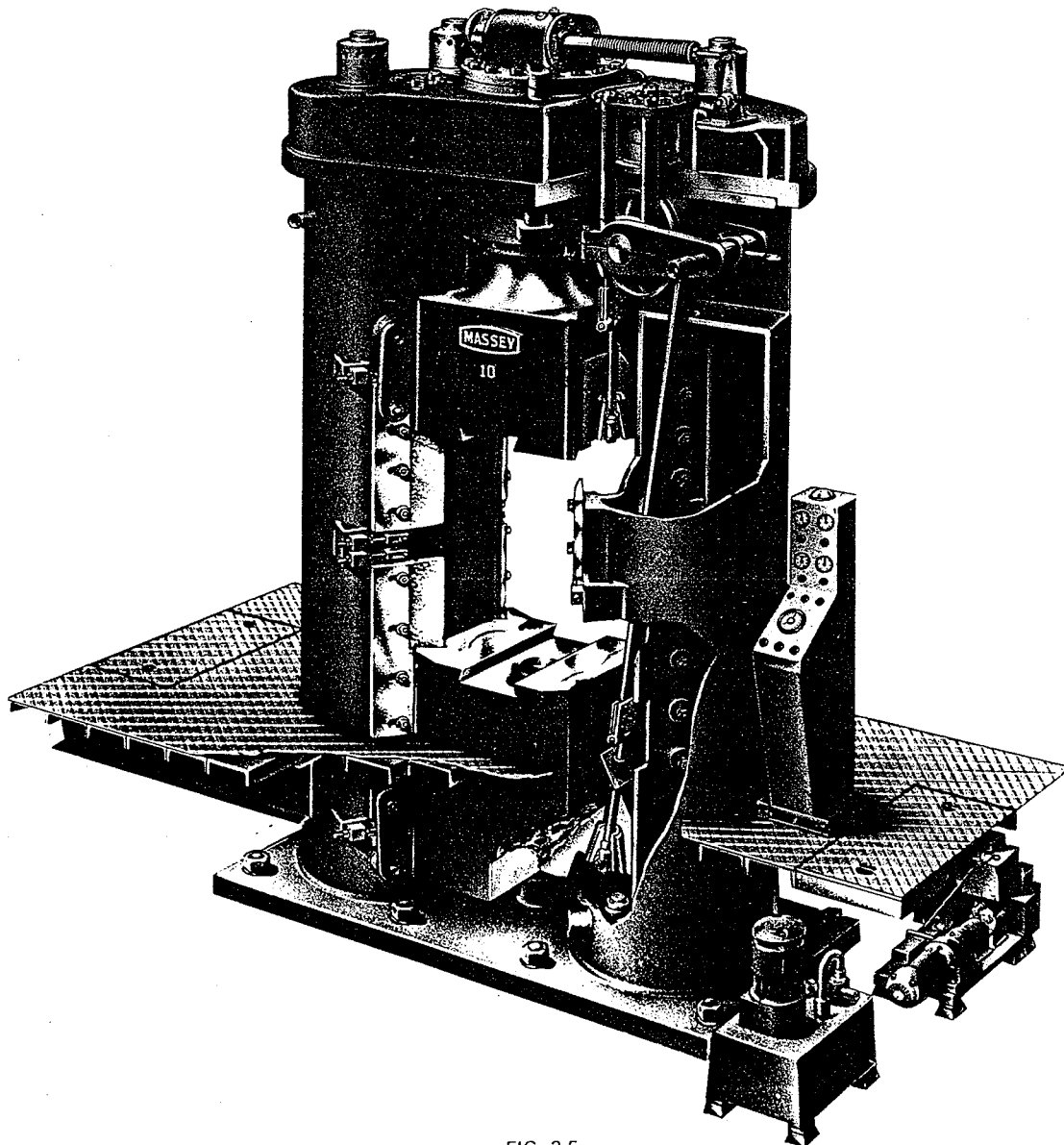
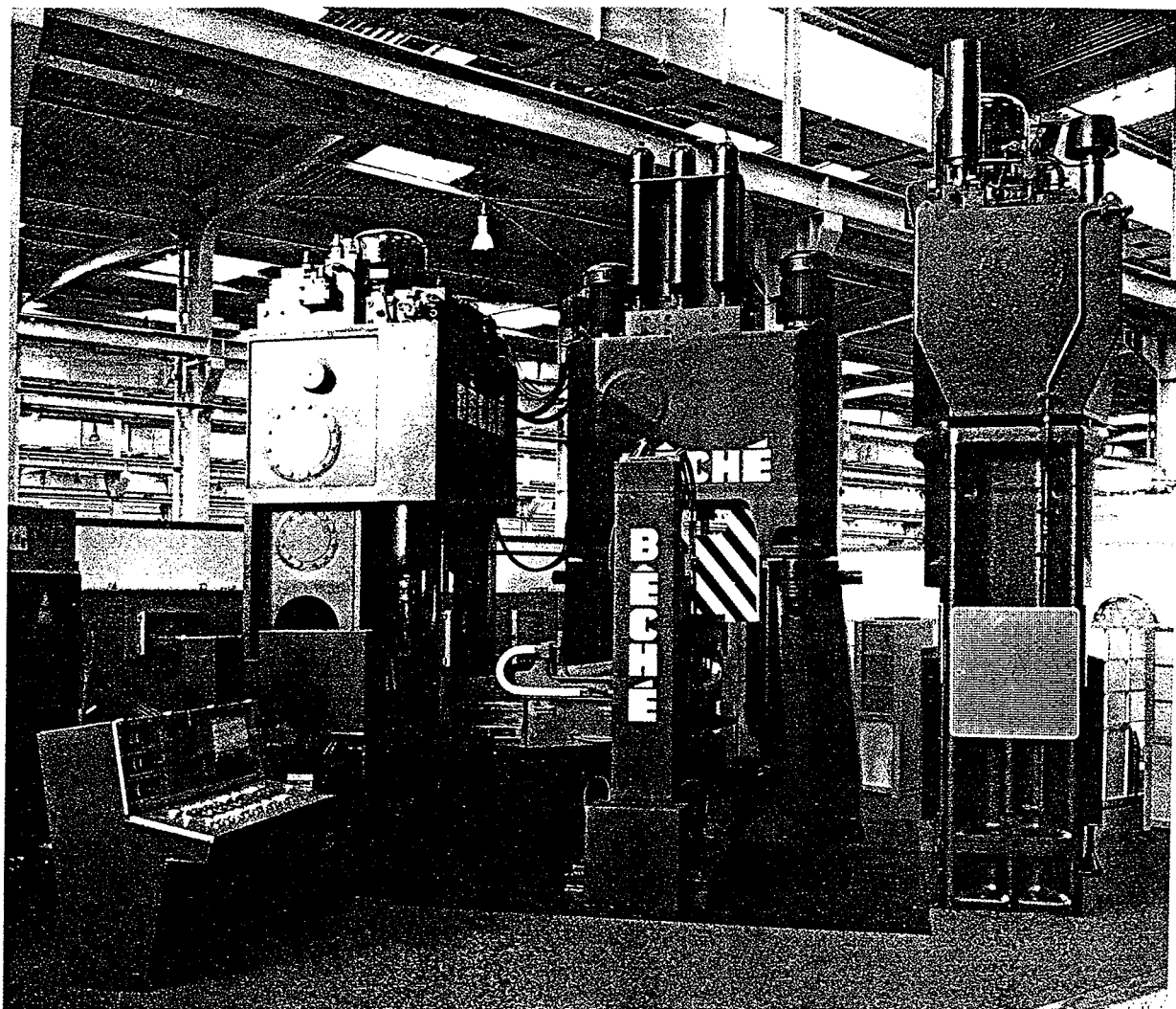


FIG. 3.5
Counterblow hammer.

BÊCHÉ



Automated Forging Line with:

Electrically-oilhydraulic BÊCHÉ-PRE-FORMING PRESS
type PH 4S with hydro-shock installation
pressure power 4 MN
with an automatic tool for chamfering and upsetting
operations

**Electrical-oilhydraulic BÊCHÉ-SHORT-STROKE DIE
FORGING HAMMER**

type KGH 5 B with top pressure blow capacity 50 kJ
with hydraulic ejector in anvil insert

**Electrical-oilhydraulic BÊCHÉ-CALIBRATING AND
TRIMMING PRESS**

type PH 8 K
pressure power 8 MN

**BÊCHÉ-DOUBLE-ARMED AUTOMATIC
MANIPULATOR**

with hydraulic drive

FORGING:

In one impression with approx. six blows, lifting by
ejector.

TRIMMING AND CALIBRATING:

In one stroke in combined tool; three surfaces of
20 mm Ø will be calibrated.

The complete production process is automated, i.e.
the production line is interlinked with a BÊCHÉ-
Double-Armed Automatic Manipulator. One person is
required for operation.

The cycle of the Forging Line is approx. 15 sec.

BÊCHÉ & GROHS GMBH

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The West German company Langenstein and Schemen AG (Lasco) has developed a form of counterblow hammer which differs in several important features from conventional ones.

The design of the hammer is shown schematically in figure 3.6. When a blow is initiated pressure is applied to the hydraulic cylinder (a) which drives the top tup downwards. Simultaneously the oil pressure in the hydraulic cylinders (b) above the frame is released allowing the machine frame and bottom die to be driven upwards by the air cylinders (c).

On completion of a blow the top tup is lifted to its upper position and the application of oil pressure above the cylinders (b) drives the frame downwards recompressing the air cylinders (c).

This arrangement results in a much shorter travel of the bottom die than in conventional counterblow hammers. Depending on the size of the hammer the bottom die travel is only 120-150 mm and this, together with the low impact speed of the bottom die is claimed to prevent shallow forgings bouncing from the die impression.

Another feature of the machine design is that the upper ram is guided in the machine frame rather than having top and bottom separately guided.

This results in a reduced number of slides to be adjusted and allows reduced gib clearance compared with normal counterblow hammers.

3.4 Horizontal counterblow hammers

A horizontal counterblow hammer often referred to as an Impacter has been developed by the Chambersburg Engineering Company of America. The principle of operation is illustrated in figure 3.7.

Two tups of equal weight are driven towards each other in a horizontal plane by high pressure air. After the forging blow is struck the tups are returned by low pressure air.

The energy of each blow may be preselected within wide limits by controlling the time interval during which high pressure driving air is admitted to the system.

Forgings are made from cut bar lengths which are transported through the die stations in a vertical position by an automatic transfer unit as shown in figure 3.8.

Multiple blows may be struck at each forging station and the transfer mechanism allows the bar to be rotated through 90° either between die stations or in any one station.

Since each forging is made from a cut piece with a tong hold small forgings are made in multiple platters as shown in figure 3.9 to minimise bar end losses.

The energy range of impacters is much lower than that for vertical counterblow hammers, machines with energy ratings from 400 to 10 000 mkg being available.

The horizontal counterblow hammer therefore competes with double acting hammers and is used for the rapid automatic production of forgings where the conventional sequence of fullering, rolling, moulding and finish forging is employed.

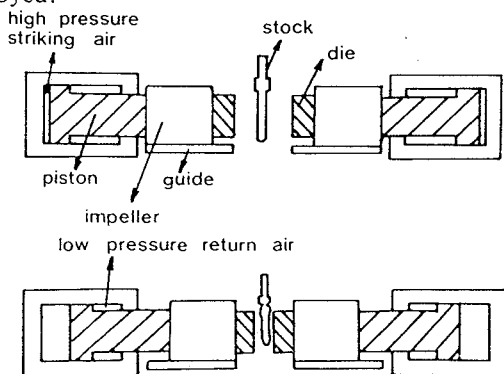
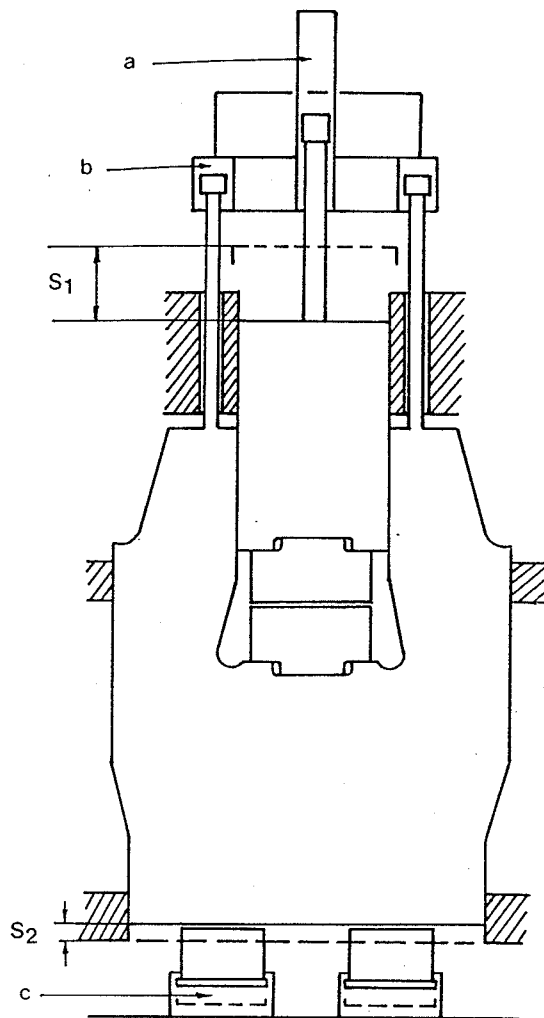


FIG. 3.7



a & b = Hydraulic cylinders

c = Air cylinder

S_1 = Stroke of upper tup

S_2 = Stroke of lower tup

FIG. 3.6

Lasco counterblow hammer.

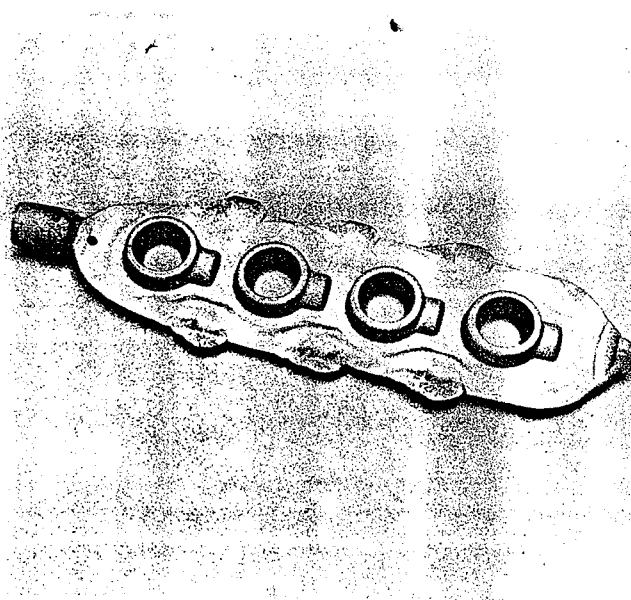


FIG. 3.9

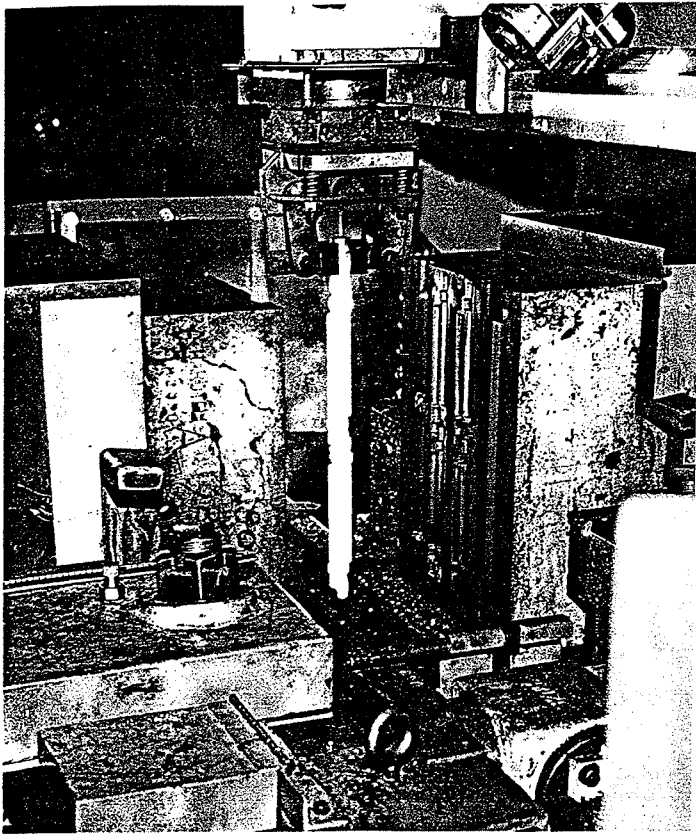


FIG. 3.8
Transfer unit for Chambersburg Impacter.

3.5 Hammer characteristics

Figure 3.10 illustrates a load-deformation diagram when producing a forging under a hammer. At each blow load builds up and deformation proceeds until the energy of the tup is used up. Not all of the tup energy however is used in deforming the forging.

On striking the forging the tup and top die assembly have a certain kinetic energy E_k . Neglecting minor energy losses this applied energy is dissipated in three ways as illustrated in figure 3.11.

Some of the energy is used in plastically deforming the forging and this is the useful energy of deformation E_d . Some of the energy is used in accelerating the anvil and foundations downwards and is lost energy performing no useful deformation. This anvil loss energy E_a depends on the ratio of anvil to tup weight and also on the maximum load generated during the blow.

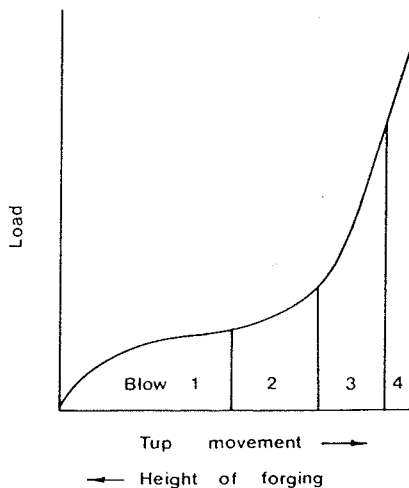


FIG. 3.10
Load-deformation diagram for hammer forging.

The second energy loss is that part of the applied energy which is used in elastically deforming tup, dies and anvil. This elastic energy loss E_e again depends on the maximum load developed and also on the dimensions of the deformed members.

The efficiency of a hammer blow may be defined as the ratio of useful deformation energy to the total blow energy.

$$\text{ie Efficiency } e = E_d / E_k$$

Since the energy losses E_a and E_e increase with maximum load it follows that the efficiency of hammer blows decreases with succeeding blows. This is illustrated by the diagram in figure 3.12, which shows that a stage is eventually reached where very little energy is being used for deformation and the striking of further blows is thus ineffective. Figure 3.12 also shows that there is a maximum load which any hammer can generate and this occurs when a full energy blow is struck die to die.

Thus although the hammer is defined as an energy restricted forging machine it does also have a maximum load capacity.

The situation when forging on counterblow hammers is slightly different since no anvil energy loss occurs. Elastic deformation energy losses E_e however still occur and counterblow hammers still have a limiting load capacity.

For a given energy input counterblow hammers are more efficient than anvil hammers and perform more deformation per blow due to the absence of anvil energy losses. The increase in efficiency is relatively small however and will not exceed a maximum of 10% even on hard blows.

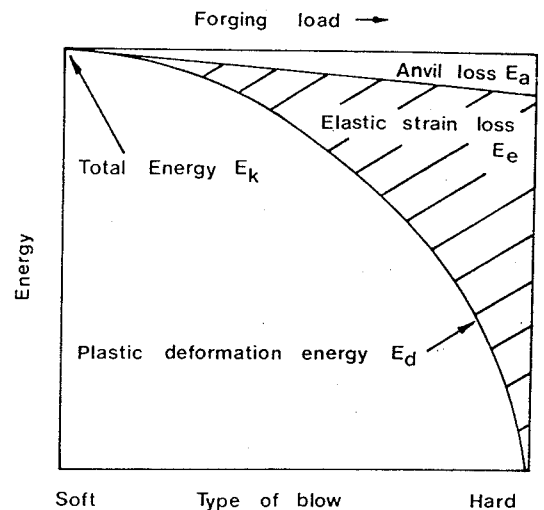


FIG. 3.11
Energy dissipation in hammer forging.

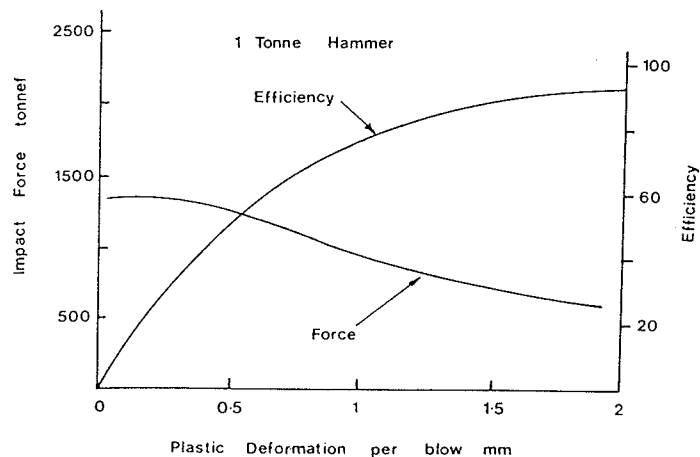


FIG. 3.12
Influence of deformation per blow on hammer efficiency.

3.6 Hammer foundations

Figure 3.13 shows a schematic arrangement of a hammer foundation. The heavy anvil sits on a reinforced concrete foundation block. Originally oak timbers were placed between the anvil and the inertia block to distribute the load on the concrete. In modern installations however a special resilient rubberised fabric mat has replaced the timber. When a hammer blow is struck the anvil and foundation are accelerated downwards and thus the ground below the foundation is loaded and deflects elastically in the manner of a spring. The frequency and amplitude of the vibrations set up in the ground depend on the design of the foundation and the type of ground structure.

The design and construction of hammer foundations requires detailed civil engineering knowledge and experts in this field should be consulted to deal with individual cases.

Figure 3.14 shows the order of magnitude of the size of solid foundations as a function of hammer energy rating and is based on manufacturers' published recommendations. It is not meant in any way to serve as a design guide.

The ground vibrations set up when using solid foundations can be quite severe and over the last twenty years or so it has become increasingly common to use sprung foundations as illustrated schematically in figure 3.15.

The principle of these anti-vibration mountings is to interpose a spring between the concrete inertia block and the ground. During forging the energy of the moving anvil and inertia block is largely absorbed by deflection of the springs with consequent reduction in ground deflection and vibrations.

Because the springs used must be relatively soft to be effective dampers are usually required to damp out the oscillation of the hammer-anvil-inertia block assembly.

A more recently developed method of anti-vibration mounting utilises a sophisticated spring and damping system interposed between the anvil block and a concrete well as illustrated in figure 3.16. This system effectively removes the need for the concrete inertia block and in spite of the higher cost of the special spring-damping system can prove cheaper to install than a conventional anti-vibration system.

This system is supplied by the German company GERB Gesellschaft für Isolierung GmbH & Co KG. A double acting hammer mounted on a GERB sprung foundation is shown in figure 3.17.

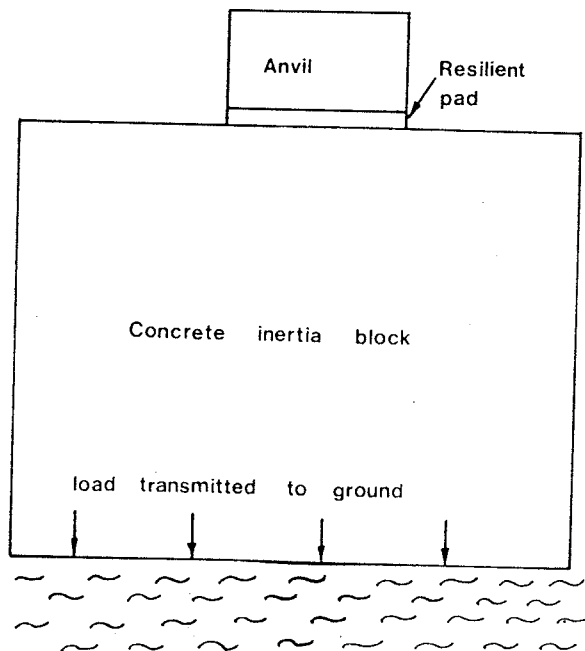


FIG. 3.13

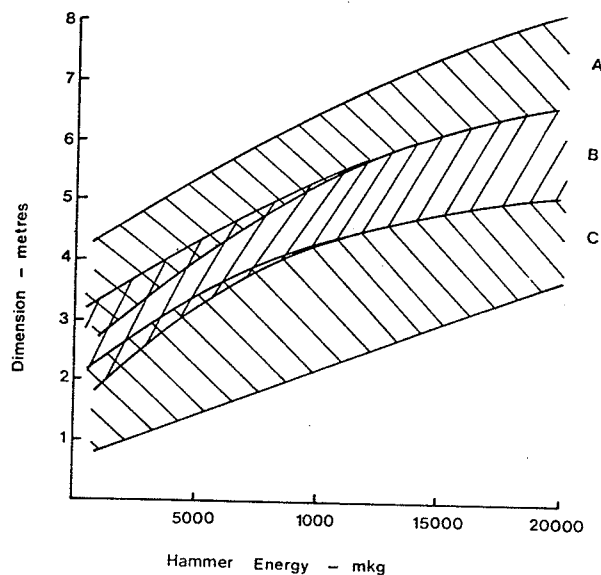
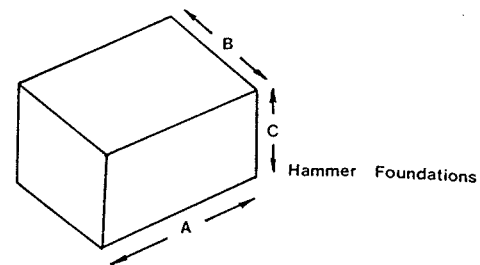


FIG. 3.14

Dimensions of hammer foundations.

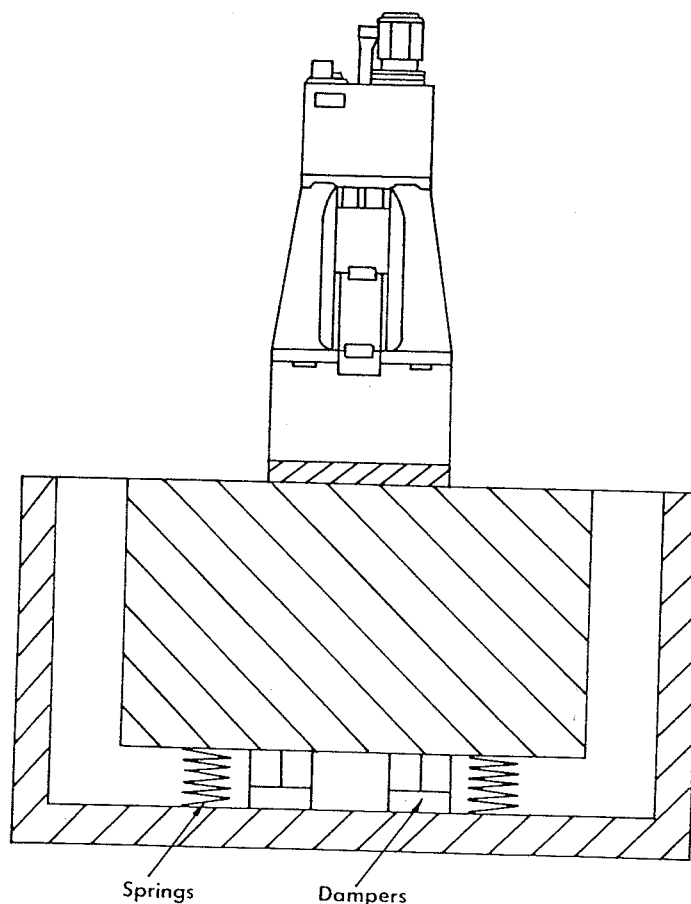


FIG. 3.15

Conventional sprung foundation with springs and dampers below large inertia block.

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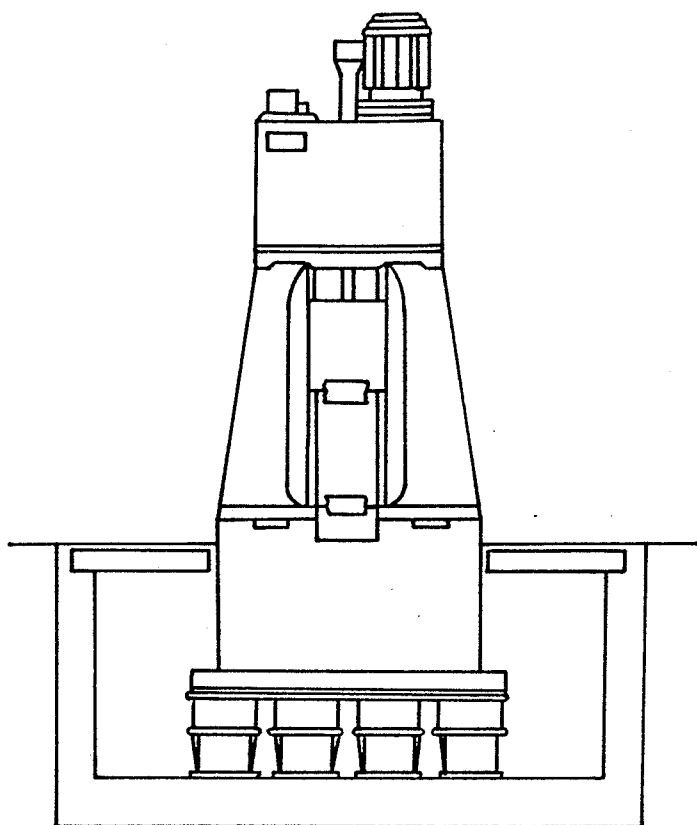


FIG. 3.16

Special gerb sprung foundation obviating need for inertia block.

3.7 Hammer selection

In deciding what size of hammer to make a given forging on, the load and energy requirements to produce the forging are the most important considerations.

If the hammer used is too small it may not be possible to get the forging down to the correct thickness due to inadequate load capacity and even if this is achieved an excessively large number of blows will be required due to inadequate energy capacity.

Conversely if too large a hammer is used the plant overheads borne by the forging are excessively high and damage to the dies and hammer may ensue due to the excessive energy used.

Thus the concept of an optimum sized hammer for a given forging is easily envisaged but that optimum size is less easily defined.

Table 3.1 below gives an approximate relationship between hammer size and weight of forging.

Table 3.1

Selection of hammer size as a function of forging weight

Weight of forging kg	Hammer blow energy energy mkg	Blow energy per kg weight mkg/kg
up to 1.0	1370	1370
2.25	2060	916
4.5	2740	609
7.0	4100	586
9.0	5460	607
13.5	6830	506
23.0	8200	357
32.0	10900	341
above 34.0	>10900	320 or less

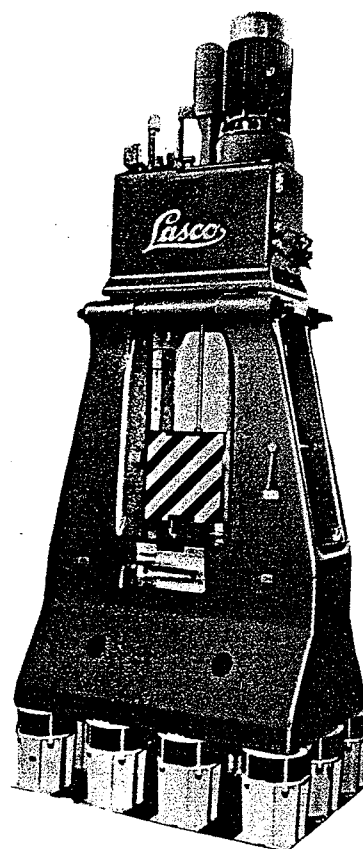


FIG. 3.17

As the forging size increases the blow energy per unit weight decreases due to reduced heat losses from larger forgings so that more blows can be struck before the forging becomes excessively cooled.

Table 3.2 relates forging energy required to the plan area of the forging including flash.

Table 3.2

Selection of hammer size as a function of plan area of forging plus flash

Material	Energy factor mkg/mm ²
Aluminium alloys	0.048—0.070
Carbon steels	0.054—0.075
Alloys steels	0.075—0.107
Stainless steels	0.086—0.150
Titanium alloys	0.128—0.193
Heat resisting alloys	0.150—0.257

Neither of these methods can be expected to give more than a rough guide to hammer selection since they do not take into consideration the complexity of the forging.

A more reliable method of hammer selection has been described and its use is illustrated below. The information required in this method is

- (1) the volume or weight of the forging plus any forged webs and the material in the flash land but not in the flash gutter — V_t or W_t .
- (2) the plan area of the forging including the flash land and any webs — A_t . The mean thickness of the forging t_m is then found from $t_m = V_t/A_t$.

Knowing the mean thickness and the plan area figure 3.18a or 3.18b may be used to determine the required hammer size in terms of energy rating.

$$t = \frac{\text{volume of forging + webs + flash land}}{\text{area of forging + webs + flash land}}$$

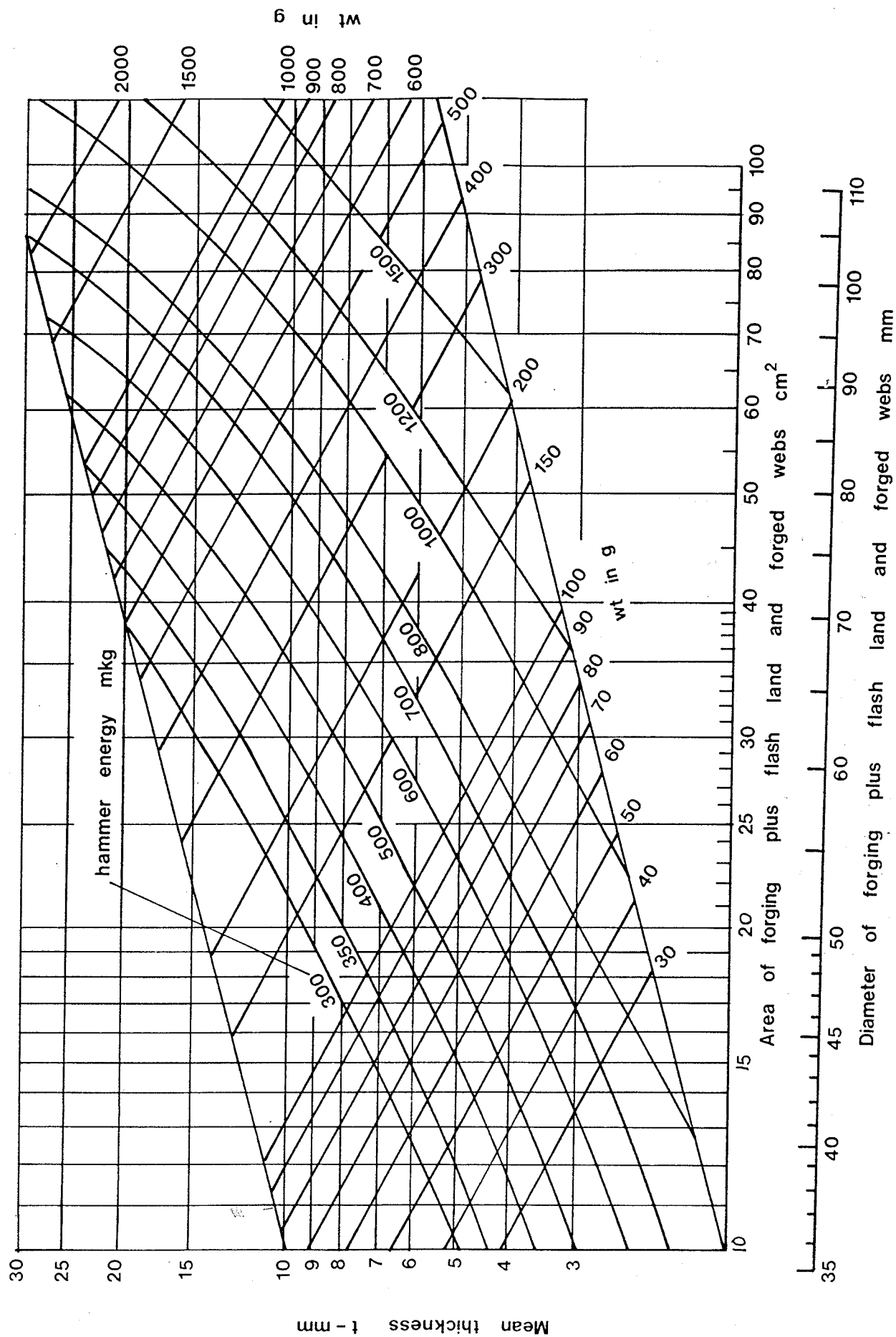


FIG. 3.18a

$$t = \frac{\text{volume of forging + webs + flash land}}{\text{area of forging + webs + flash land}}$$

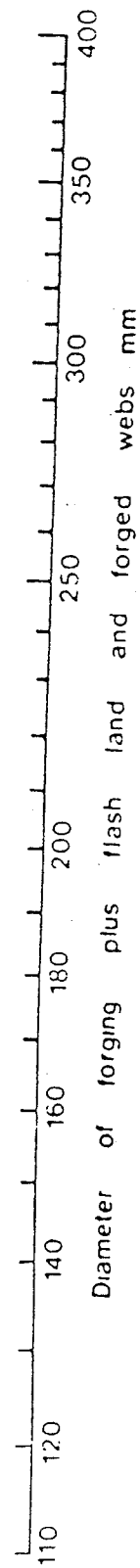
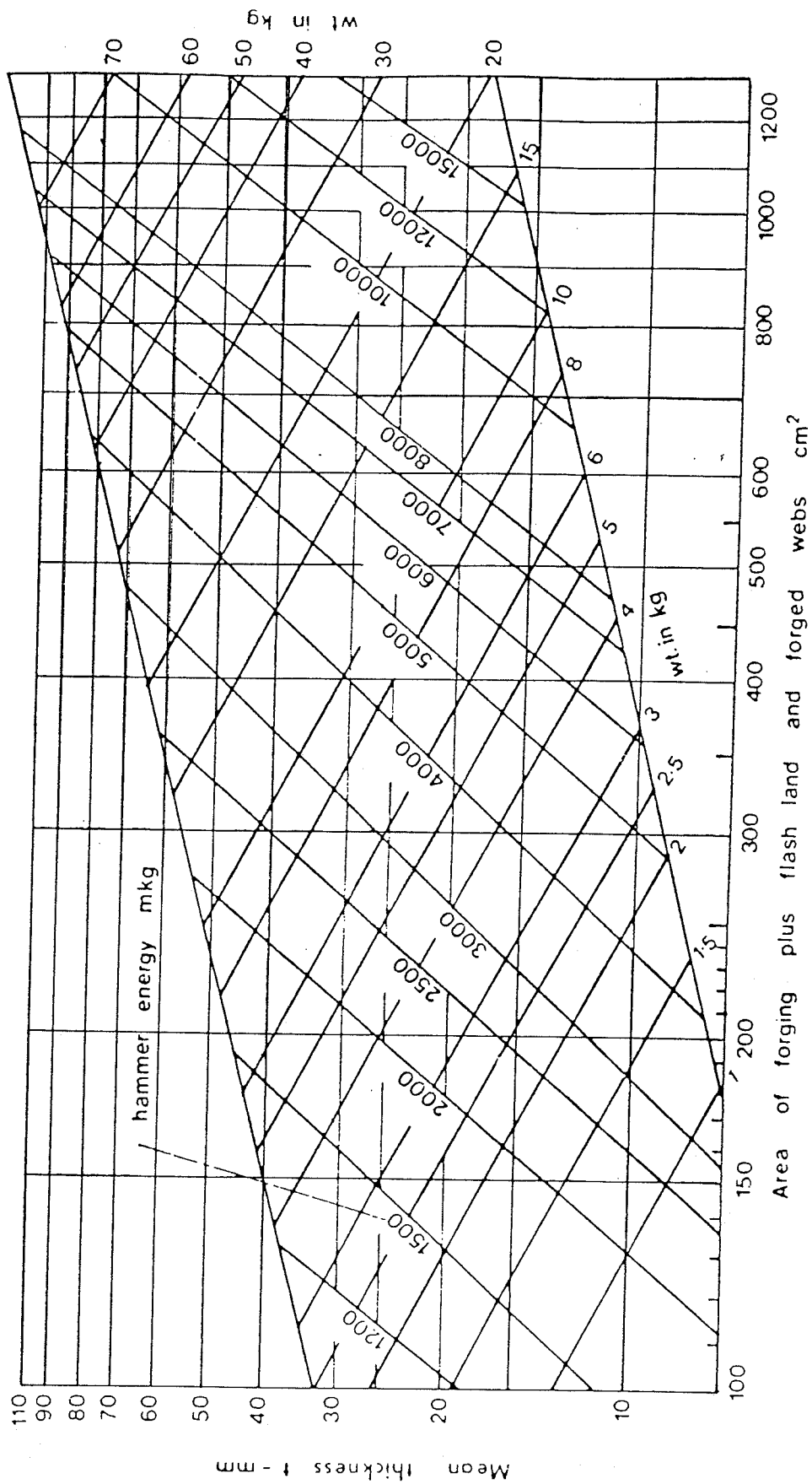


FIG. 3.18b

Example

For the forging shown in figure 3.19 the following data apply:

	Weight—g	Volume—cm ³	Plan area—cm ²
Forging proper	2400	305	113
Web	180	23	38
Flash land	110	14	80
total Wt=2690		Vt=342	At= 231

The mean thickness of the forging $t = Vt/At = 342/231 = 1.5 \text{ cm} = 15 \text{ mm}$. Referring to figure 3.18b the intersection of $t = 15 \text{ mm}$ and $At = 231 \text{ cm}^2$ indicates a hammer energy requirement of 3000 mkg.

Alternatively the same hammer size can be determined from the intersection of $Wt = 2.69 \text{ kg}$ and $At = 231 \text{ cm}^2$.

In practice a hammer size within $\pm 15\%$ of the rated one may be used without serious loss of efficiency. Thus for the forging considered any hammer in the range 2500-3500 mkg could be used.

The hammer energy estimated by this method is applicable to carbon and low alloy steels. Where other alloys are being forged the required hammer energy can be estimated by applying the approximate alloy correction factors shown in table 3.4.

Table 3.4

Hammer energy alloy correction factors

Alloy	Correction factor
Aluminium alloy	0.9
Alloy steels	1.3
Stainless steels	1.8
Titanium alloys	2.5
Heat resisting alloys	3.1

Thus if the forging considered in the example had been made in stainless steel the approximate hammer energy required would have been

$$300 \times 1.8 = 5400 \text{ mkg}$$

Frequently due to the lack of a hammer of optimum size or the need to balance plant loading forgings are made on non-ideal hammers. The foregoing however is a useful guide to selecting the hammer for a given forging.

The approximate number of forging blows required in the moulding and/or finishing impressions may be determined from figure 3.20. Thus for the forging considered the flash weight was 510g thus

$$\% \text{ flash} = (510/2690) \times 100 = 19\%$$

The intersection of 19% flash and a forging weight of 2.69 kg in figure 3.20 indicates that 8 forging blows are required. This however refers to the use of the "optimum" hammer determined from figure 3.18. If a hammer of a different energy rating is used the number of blows required must be corrected by multiplying by the factor F where

$$F = \frac{\text{ideal hammer energy rating}}{\text{actual hammer energy rating}}$$

For example if a 3500 mkg hammer was used for the forging considered instead of the optimum 3000 mkg $F = 3000/3500 = 0.86$ and the number of blows required would be $8 \times 0.86 = 6.9$ say 7.

It must be emphasised that this number of blows is the number required for forging in the mould and finish impressions and does not include any fullering, rolling or bending blows.

In cases where the amount of flash is not known precisely figure 3.21 may be used to obtain a rough estimate of the percentage flash for use with figure 3.20.

This method of hammer selection is based on a paper presented by A Chamouard at the 8th International Drop Forging Convention 1974.

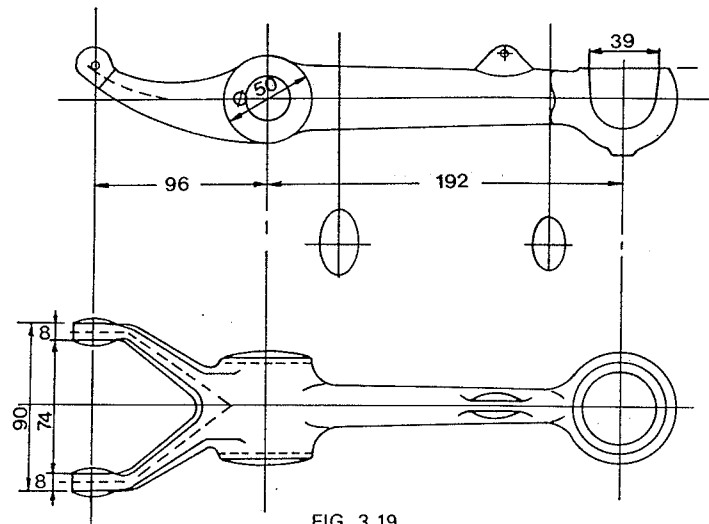


FIG. 3.19

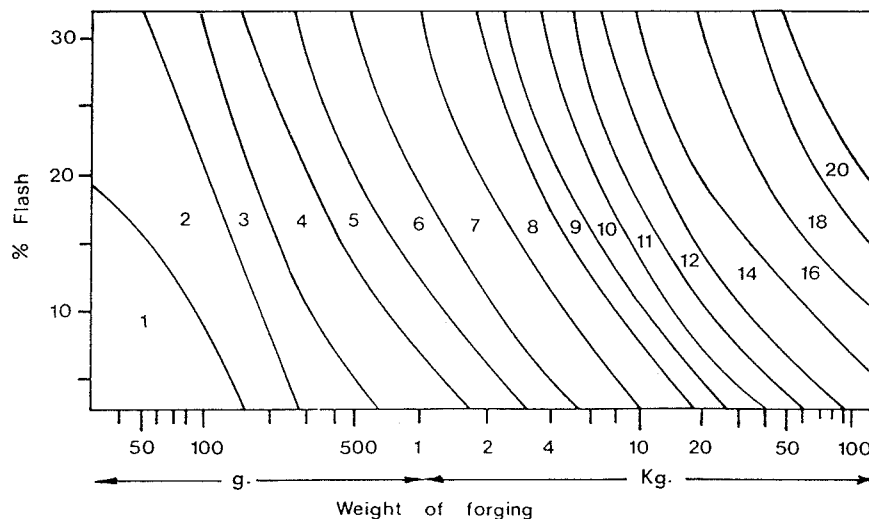


FIG. 3.20

Chart for determining approximate number of finishing blows.

% Flash to be used in conjunction with Figure 3.20 when estimating number of finishing blows

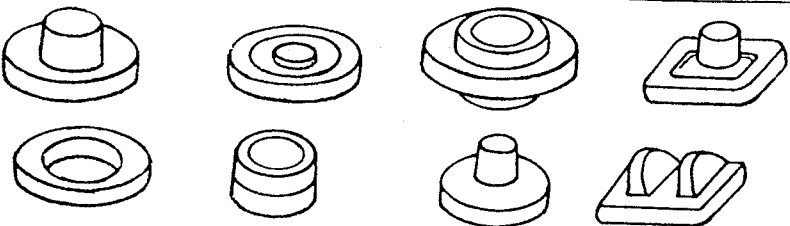
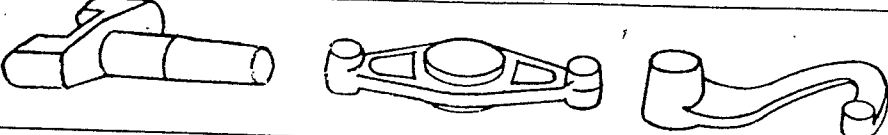
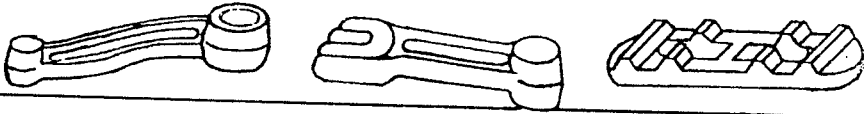
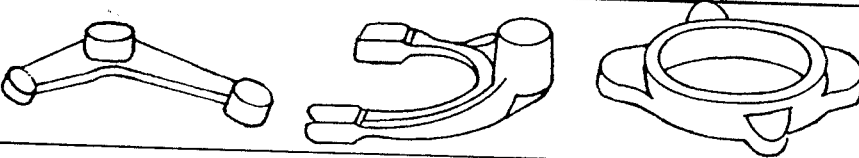
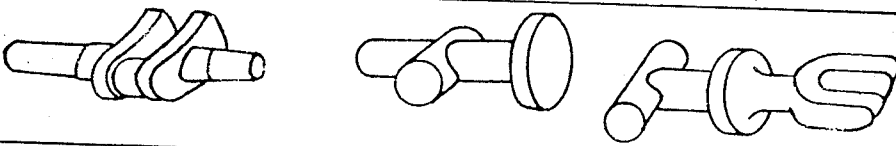
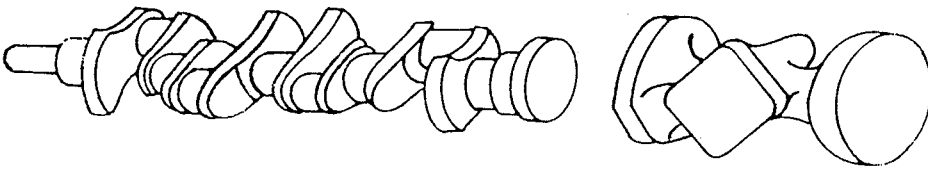
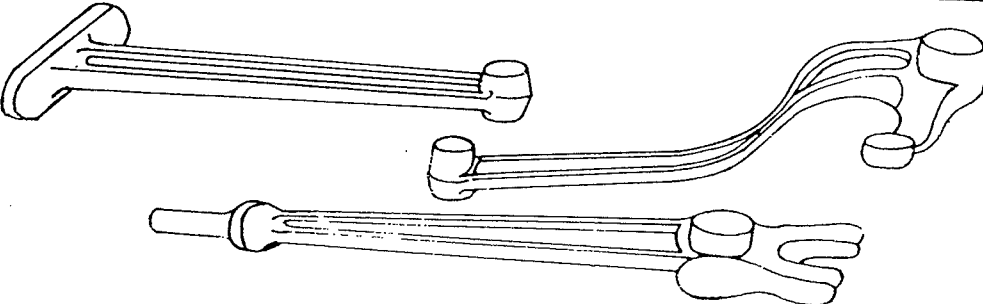
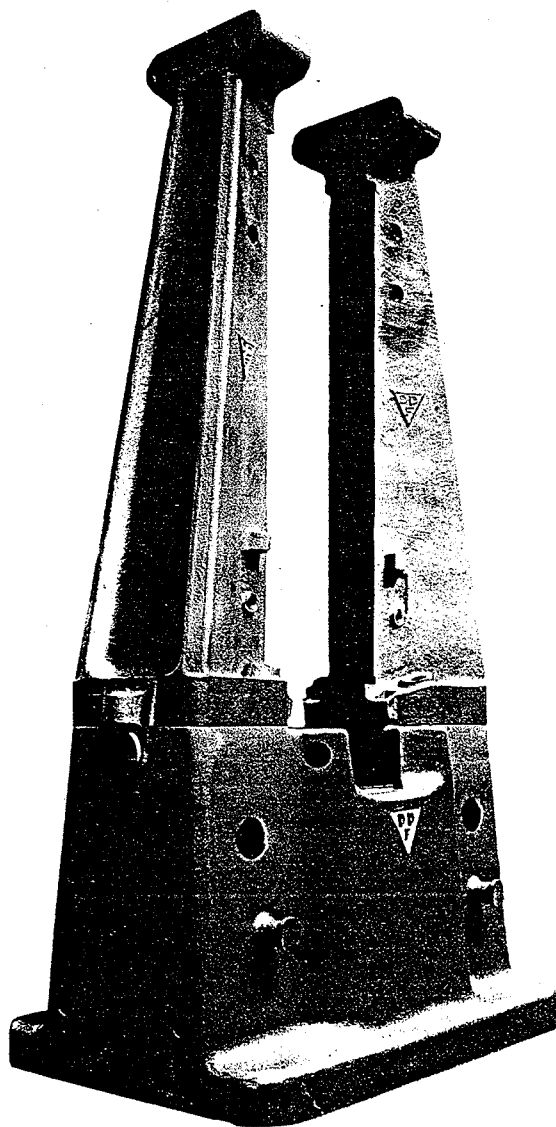
	5 to 8 %
	8 to 11 %
	12 to 15 %
	15 to 18 %
	19 to 22 %
	22 to 25 %
	26 to 29 %
	29 to 32 %
	32 to 35 %

FIG. 3.21

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3.8 Hammer manning and plant layout

Plant layout and the manning system used on hammer forging have a significant effect on plant utilisation and production rate.

In this section some of the more common layouts and manning systems are described together with the factors which influence hammer utilisation.

3.8.1 Off-the-bar forging with rotating stampers for small to medium size forgings

Figure 3.22 shows some typical plant arrangements for small and medium sized hammers utilising the basic "rotating stamper" method when forging off-the-bar.

In this method a stamper takes a bar from the furnace then moves to the hammer to make the forging. He then moves to the clipping press, clips the flash, cuts the forging from the bar and returns to the furnace and replaces the bar before removing another bar to begin the cycle again. This method of forging may be operated with one, two or three stampers working on the same hammer (figure 3.22a).

An alternative to this method is the introduction of a shear on which the stamper cuts the unclipped forging from the bar, the piece then being clipped by an additional operator (figure 3.22b).

Another alternative is for the stamper to cut the forging from the bar at the hammer for clipping by another operator (figure 3.22c and 3.22d).

In understanding how layout and manning affect productivity it is necessary to consider certain basic time elements involved in the forging cycle. These are defined below.

B = basic cycle time. This is the time taken for one stamper to complete all the operations involved in making one stamping including returning the bar to the furnace.

This basic cycle time **B** is comprised of the following time elements:

H = stamping time. This is the actual stroking time of the hammer in making one forging.

C = change over time. This is the time which the hammer is at rest to allow removal of the forging from the hammer and the positioning of the next bar prior to striking the first blow. Typically this time is about two seconds.

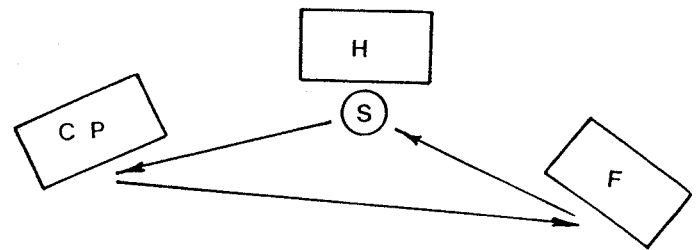
T is the total hammer time per forging and is the sum of **H** and **C**, ie $T = H + C$.

R is the plant layout time given by the basic cycle time less the total hammer time, ie $R = B - T$.

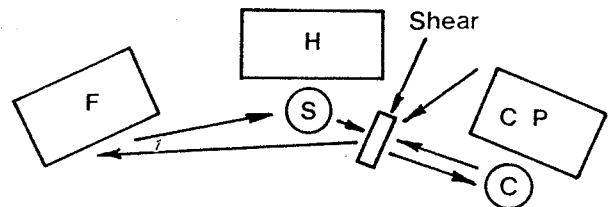
U is the hammer utilisation given by the total time the hammer is in use by all stampers divided by the basic cycle time **B**.

$U = nH/B$ where **n** is the number of stampers.

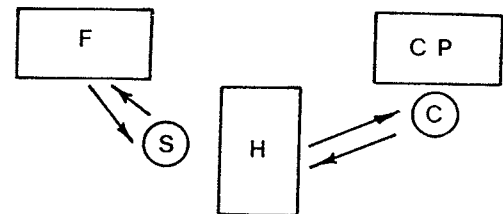
The above terms will be more clearly understood by reference to figure 3.23 which shows multiple activity charts for a forging made by one, two or three stampers.



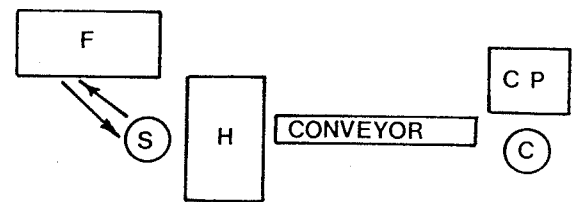
a



b



c



d

F = furnace
H = hammer
C P = clipping press
S = stamper
C = Clipping press operator

FIG. 3.22

Forging plant layout arrangements for small and medium size forgings.

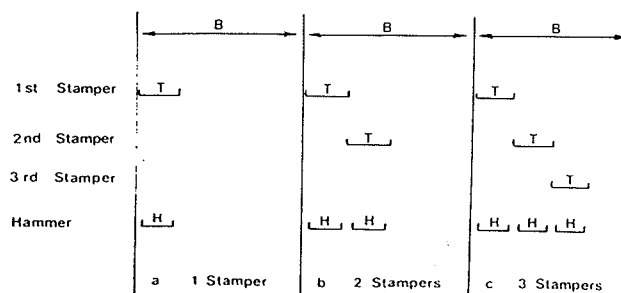


FIG. 3.23

Activity charts for hammer forging.

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With one stamper it is easily shown that hammer utilisation is given by

$$U = H/B \text{ or } U = H/T + R$$

Since R can never be zero maximum utilisation of the hammer can never be achieved.

For two stampers

$$U = 2H/B \text{ or } U = 2H/T + R$$

In this case utilisation increases as the hammer time H increases up to a maximum value of $H = R - C$. For forgings which require a hammer time H greater than this the second stamper is waiting at the hammer whilst the first completes his forging operation.

In the case of three stampers hammer utilisation increases as H increases up to a value of $H = \frac{1}{2}R - C$. Beyond this value of H queuing of stampers at the hammer occurs.

These theoretical concepts are summarised by the graph of figure 3.24 which shows how hammer utilisation U is affected by stamping time H for different manning levels.

It is clear from figure 3.24 that to effectively use three stampers requires short hammer times, ie relatively few blows can be struck unless queueing at the hammer is to occur. Forgings requiring a longer hammer time may be more effectively made using only two stampers.

Whilst the exact number of forging blows which determines manning level depends on many factors a general guide is that forgings requiring only eight blows or less in total will support three stamper manning. Two stampers are usually effective for forgings up to about 16 total blows.

A good indication of optimum manning levels required for a hammer can be obtained by plotting a histogram for the forgings made on the hammer as shown in figure 3.25. In this particular illustration it is clear that hardly any of the forgings made are suitable for three stamper operation (ie eight blows or less) but a large proportion of forgings can be efficiently made using two stampers (ie 16 blows or less). Thus for the hammer under consideration two stampers should be employed whenever possible.

3.8.2 Cut piece forging with a single stamper

Off-the-bar forging with rotating stampers appears to have been introduced into Britain immediately after the second world war and is still the most widely used method in mass production forges using multiple impression dies.

The method however is not universal and several reports of visits to foreign forges have shown that other production methods are used there. It is therefore worthwhile describing techniques for forging from cut pieces using a single stamper.

One objection to using cut pieces has been the need for a tonghold which if used with every forging represents a significant wastage of material.

Two techniques have been developed to overcome this problem. In the first several forgings are made from one cut piece in one heat. The first forging is stamped and cut from the bar in the hammer and then a second and sometimes a third are similarly made. In this way the tong hold wastage is distributed over two or three forgings.

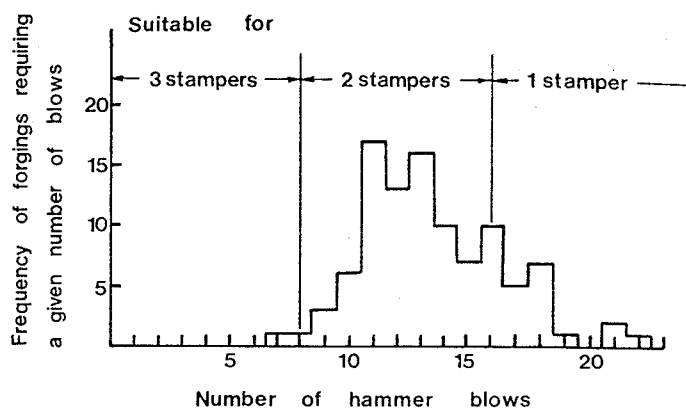


FIG. 3.25
Frequency distribution of total number of forging blows for a drop hammer.

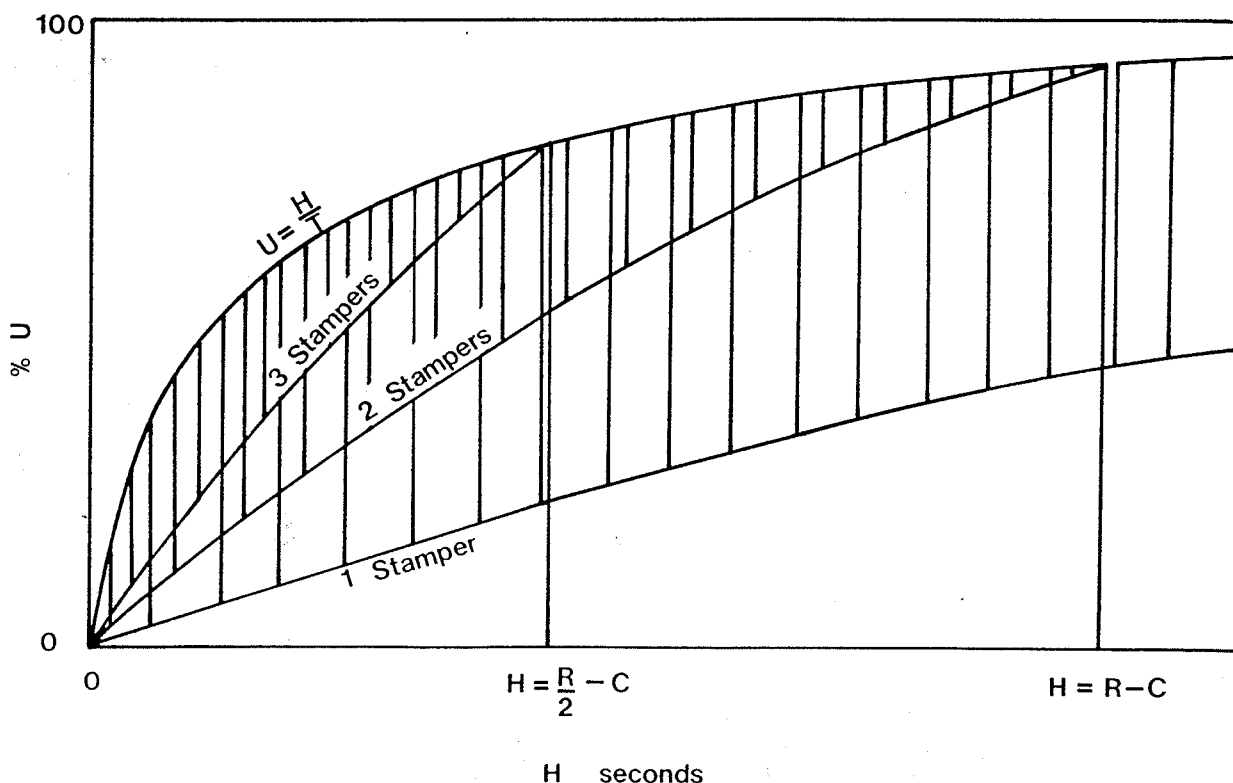


FIG. 2.24

Obviously this method is most suited to forgings which do not require excessive preforming and which can be made in a few hammer blows. The number of blows which can be struck in one heat and the number of blows per forging will determine how many forgings per heat can be made. Alternatively forgings may be made in multiples which increases the required hammer size and the cost of dies and clipping tools.

Another method of making forgings from cut pieces which has been developed, especially in Japan, is to use a piece long enough to make two forgings. The first forging is stamped in a conventional manner and the bar is then turned round so that the first forging is used as the tong-hold to produce the second forging. Sometimes specially adapted tongs are used to produce the second forging. Forgings requiring up to 12 blows each have been made by this method.

Whichever of the two cut piece methods is used it is usual to have a furnaceman feeding the single stamper with cut pieces and a separate clipping press operator.

Cut piece working has several potential advantages over off-the-bar forging. Firstly the operator only handles the weight of steel necessary to make the forging. In off-the-bar working it may be necessary to carry a 15 kg bar to make the first 2 kg forging for instance. It is not unusual with this method of working for a stamper to handle 5-7 times the weight of forgings produced.

In cut piece working high production rates can be achieved with only one skilled stamper. Similar production rates in off-the-bar forging would require two or three skilled men.

Another advantage of cut piece working is the possibility of using improved heating methods. With off-the-bar forging slot furnaces are almost mandatory but with cut pieces rapid heating or even induction or resistance heating can be contemplated. Cut piece working also offers considerable scope for the introduction of mechanical handling.

The disadvantages are of course the need to shear or saw the cut pieces and a possible increased material wastage.

It is of course impossible here to define where each method would be most economical since this involves cost exercises for each individual forging.

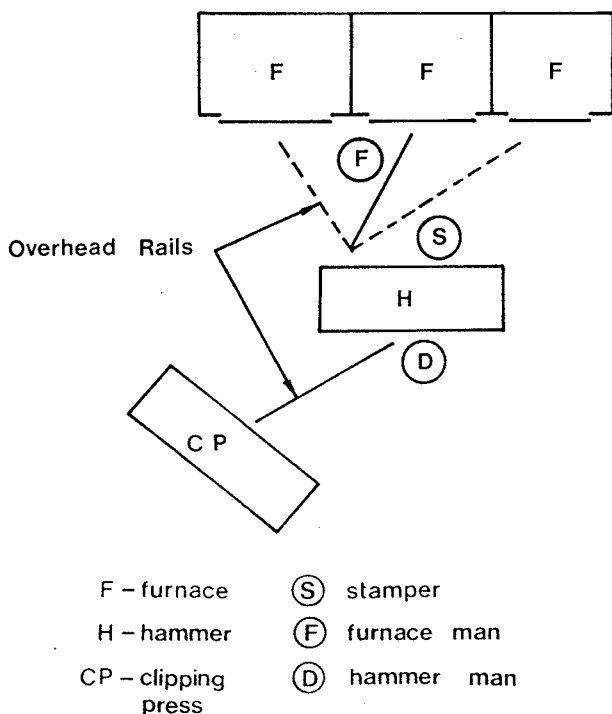
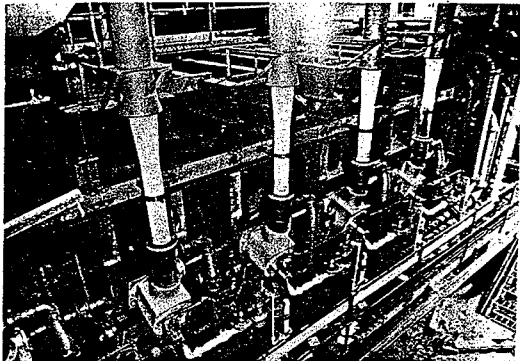


FIG. 3.26

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3.8.3 Plant layout for larger forgings

When the forging weight becomes too large to be handled in bar lengths, forgings are made from cut pieces and plant layouts often incorporate some form of mechanical assistance for handling the heavy weights involved.

Two typical layouts and manning arrangements are shown in figures 3.26 and 3.27. Medium sized forgings can be handled by tongs carried on chains slung from overhead rails. Very large pieces are usually handled by manipulators.

New heavy hammer installations usually incorporate more sophisticated mechanical handling techniques. Furnaces are automatically loaded and unloaded and transport between the various work stations is achieved by handling devices.

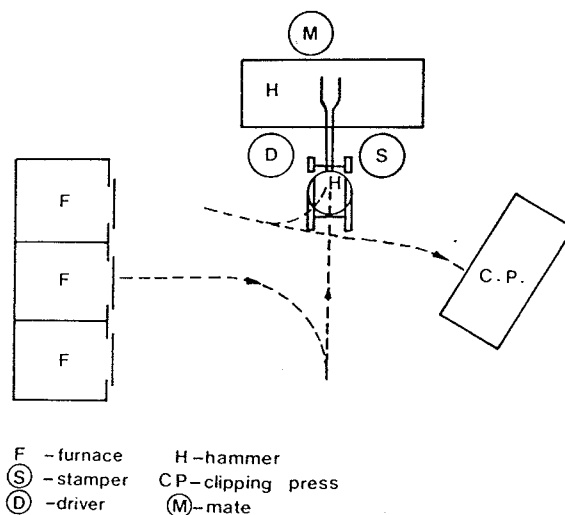


FIG. 3.27

4 FORGING PRESSES

4.1 Press drive mechanisms

All presses whether designed for forging or other operations depend for their action on a rotating eccentric mechanism which drives the ram of the press by means of a direct or indirect connecting mechanism.

The main types of eccentric drive which are shown in figure 4.1 are

- (1) The eccentric shaft
- (2) The crankshaft
- (3) The eccentric gear

For heavy-duty forging presses an eccentric shaft is normally used since this design is more rigid than the crankshaft and it also allows an improved crown construction which reduces press spring.

Eccentric gears are frequently used on wide ram trimming and preforming presses.

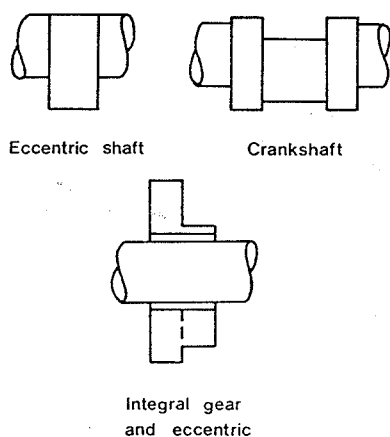


FIG. 4.1
Drive arrangements for presses.

The eccentric drive may be a direct one with the flywheel connected to the eccentric mechanism or a geared drive. The use of a geared drive allows a high shaft speed to be used with a corresponding reduction in flywheel size for a given energy capacity.

The various geared drive arrangements which may be used are illustrated in figure 4.2.

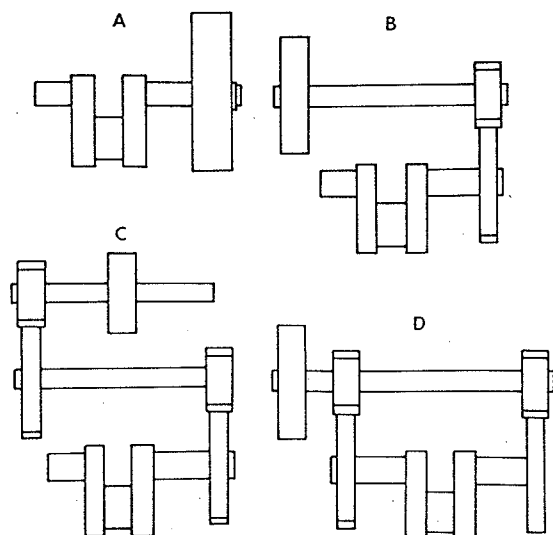


FIG. 4.2
Drive arrangements for presses.
A Direct drive B Single geared drive
C Double geared drive D Single geared twin drive

The various ways in which the rotational movement of the eccentric is converted to linear movement of the ram are shown in figures 4.3a to 4.3e.

The most common connection is the pitman or connecting rod illustrated in figure 4.3a.

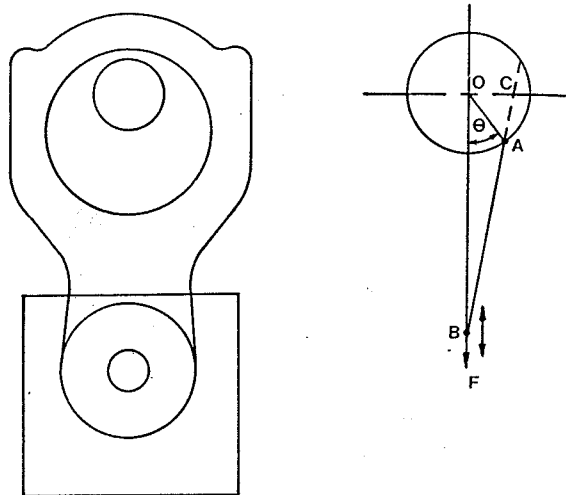
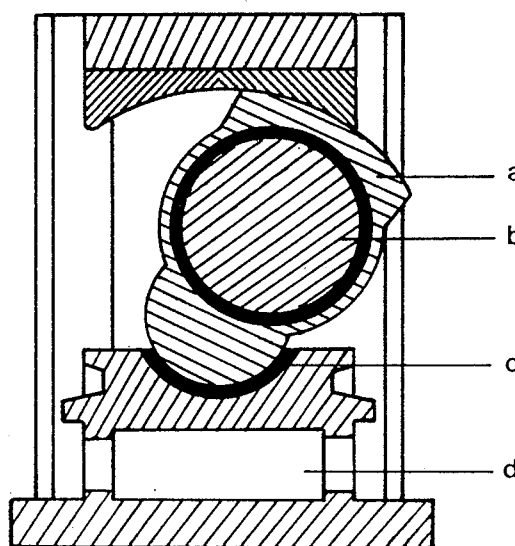


FIG. 4.3a
Crank press mechanism.

The German company Maschinenfabrik Hasenclever has recently introduced a variation of this which they refer to as a "pressure ring" press. The main feature is a very short connecting rod as shown in figure 4.3b which acts directly on the ram via a thrust socket rather than via the conventional wrist pin.

The reduction in length of the connecting rod is claimed to reduce press spring and because it is lighter than the conventional connecting rod it is easier to accelerate and brake thus leading to higher stroking rates and reduced die contact times.



a = Thrust-ring
b = Eccentric shaft
c = Thrust bearing
d = Ram

FIG. 4.3b
Hasenclever pressure ring mechanism.

Forging Convenience

1 Power Clamping

Low-pressure hydraulic circuits rigidly clamp the wedge assembly together. Simply holding a push-button adjusts wedge.

2 Push-Button adjustment

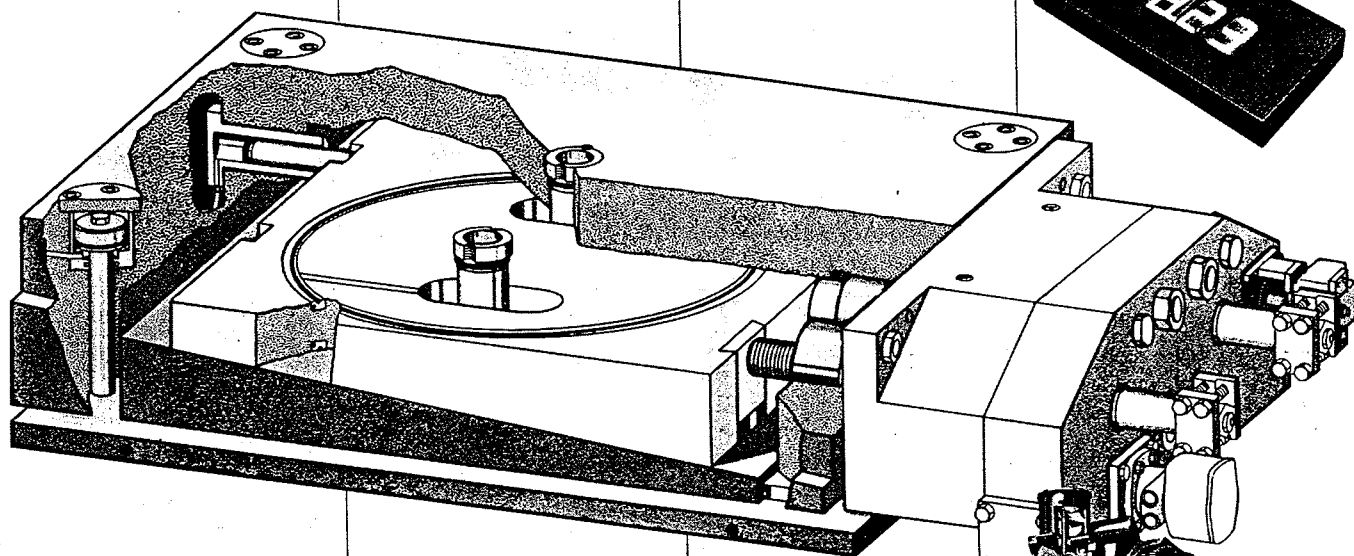
To adjust lower dies, simply press "WEDGE UP" or "WEDGE DOWN" push-button. A hydraulic motor raises or lowers the bottom die set.

3 Stall release

A simple procedure admits high-pressure hydraulic fluid to both sides of the center wedge. Seals contain the fluid and permit large areas between the wedges to become pressurized, forcing the surfaces apart, letting the center wedge move to relieve the stall.

4 Digital readout

An electronic digital display shows wedge position in hundredths of a millimeter from 0 to 12 mm.



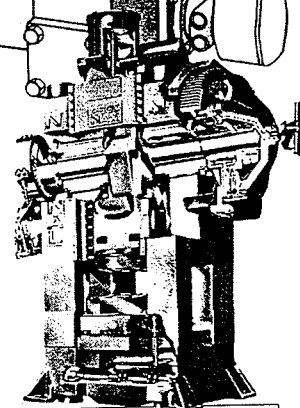
A multi-purpose hydraulic wedge for our MAXI (new mechanical forging Maxipres) offers four operational, time-saving conveniences:

1. Power clamping
2. Push-button die adjustment
3. Stall release
4. Digital readout

Getting press dies set for in-tolerance forging thickness can be a tedious job of shimming. Then, with all set and production under way, heat expands everything and you lose thickness tolerance. Stop, reshim and start over. Lost production.

Now, with a hydraulic wedge, you can adjust forging thickness in seconds, with the touch of a button. More production. Quality, close-tolerance forgings. And, if you stall the press during a forging blow, powered stall release gets you going quickly without burning out dies or other costly operations.

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Another German manufacturer, Eumuco Aktiengesellschaft für Maschinenbau, has introduced a design in which the eccentric and connecting rod activate a wedge which drives the ram as illustrated in figure 4.3c. The advantages of this design are reduced ram tilting and a greater ability to perform off-centre loading as discussed later.

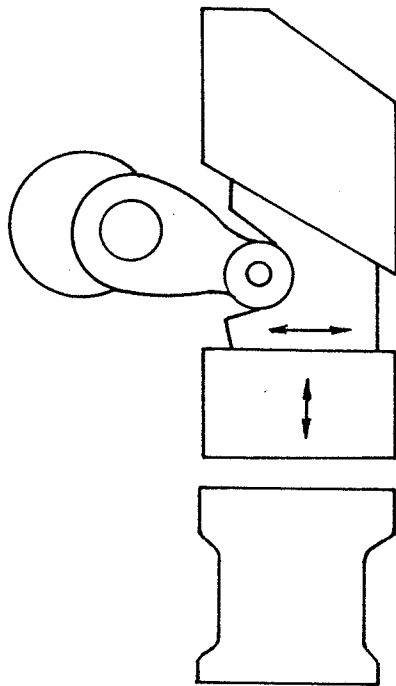


FIG. 4.3c
Wedge press mechanism.

The American company, Erie Press Systems, uses a Scotch-yoke mechanism as shown in figure 4.3d, to drive the ram.

As the illustration shows the press ram contains a split eccentric block. As the eccentric shaft rotates the block moves from side to side and up and down causing the ram movement.

The advantages claimed for this design are improved press stiffness due to a reduction on overall height of the machine compared with conventional connecting-rod presses and good off-centre loading capabilities.

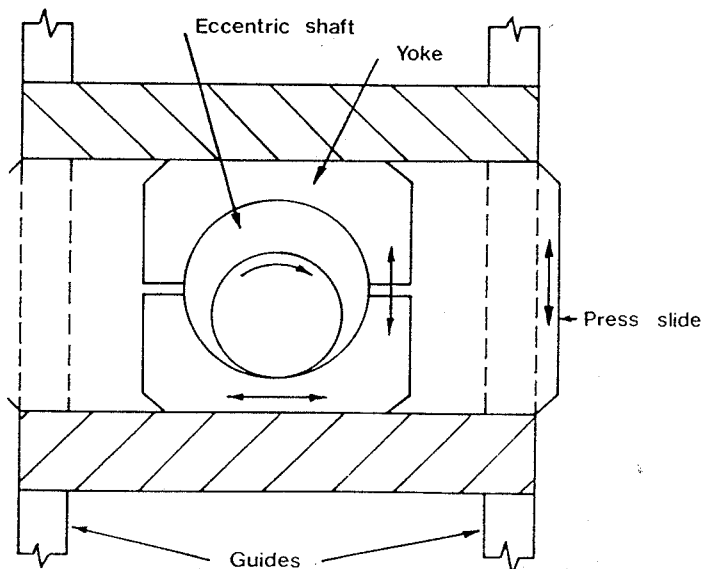


FIG. 4.3d
Scotch yoke system.

In the knuckle-joint press illustrated in figure 4.3e, the connecting rod driven by the eccentric actuates a knuckle-joint system.

As will be explained later these presses are characterised by a short stroke length and high load capacity and are not normally used for forging operations.

Where a connecting rod system is used to drive the press ram one, two or four rods may be used as illustrated in figure 4.4. The number used influences the load distribution which can be used on the press bed, the stiffness of the press and the extent of ram tilting as will be explained later.

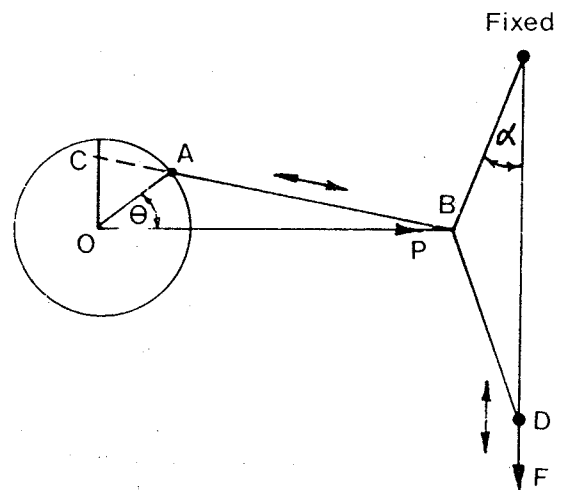
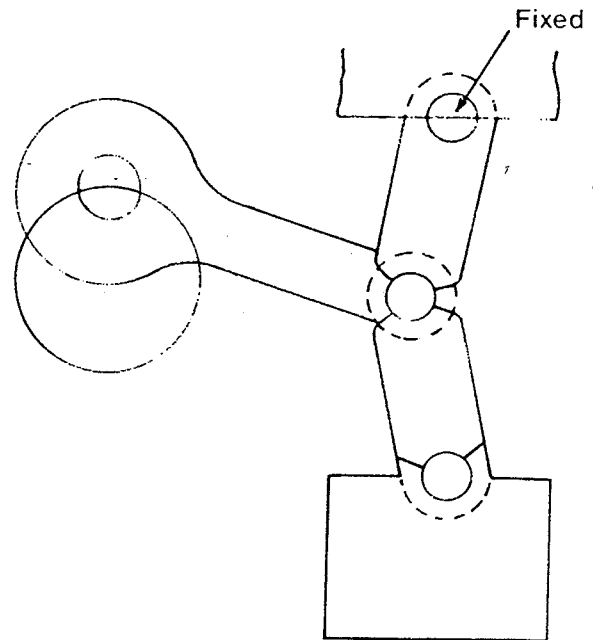
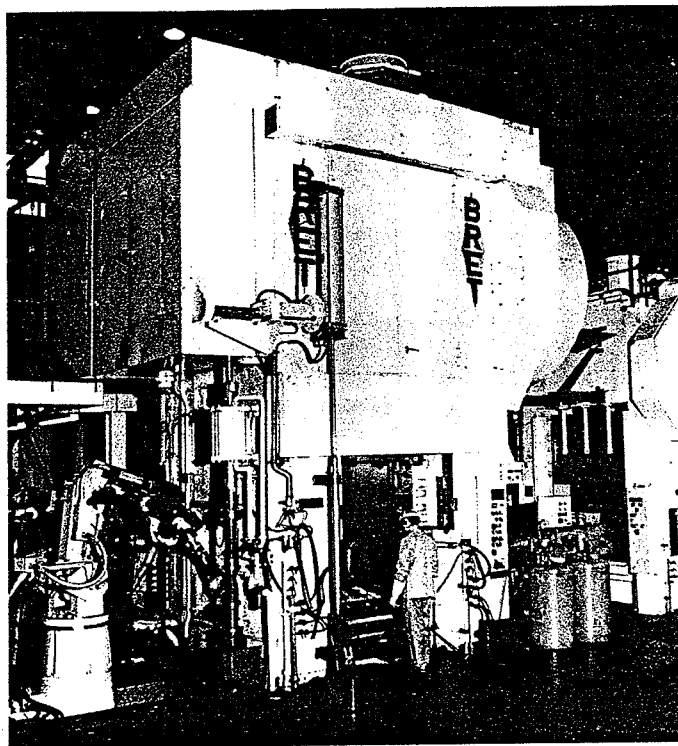
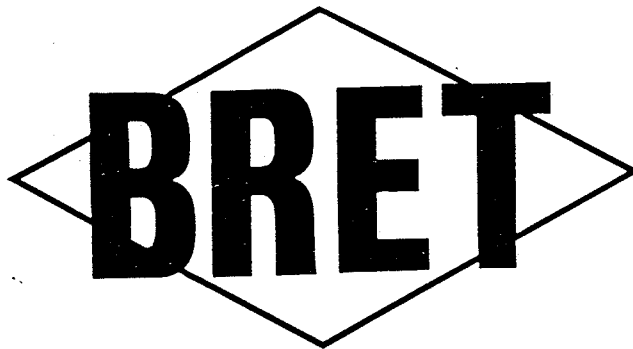


FIG. 4.3e
Knuckle joint press mechanism.



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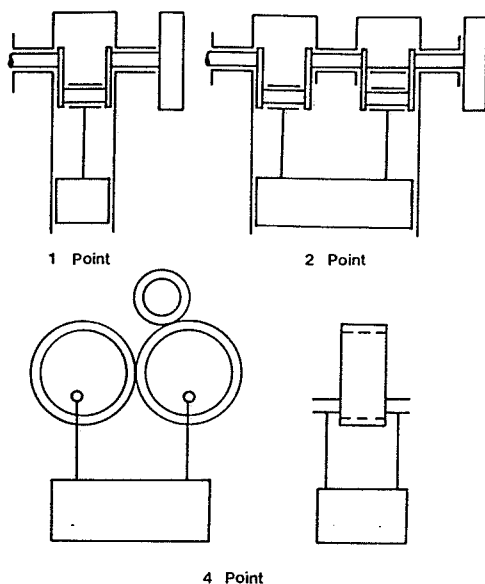


FIG. 4.4
1, 2 and 4 point presses.

4.2 Press load-stroke characteristics

In forging presses, unlike hydraulic presses, the maximum rated load is not available over the whole of the ram travel or stroke. Figure 4.3 shows schematically the linkage arrangements in an eccentric and a knuckle-joint press.

In the eccentric drive if the maximum torque available is T the load rating F at any crank angle θ is given by $P = T/OC$ (see figure 4.3a).

In the knuckle-joint press the force P acting on the linkage is similarly given by $P = T/OC$ (see figure 4.3e) but the toggle-system increases the available forging load F to a value given by $F = P/2 \tan \alpha$. Thus for the knuckle-joint press the available load at any part of the cycle is given by

$$F = T/2 OC \tan \alpha$$

These relationships lead to load-stroke characteristics as shown in figure 4.5. The knuckle-joint press develops high load ratings only close to bottom dead-centre (BDC) and such presses are characterised by a high load capacity but only a short useful stroke length. This makes them usually unsuitable for general forging work but ideal for such operations as coining and embossing. Their suitability for such work is evident by comparing the shape of the load-stroke curve shown in figure 4.5 with that required for coining (see figure 1.1e).

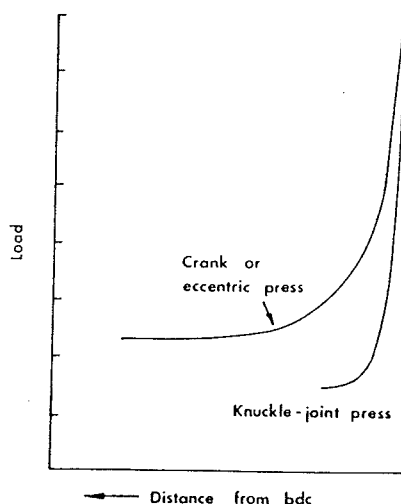
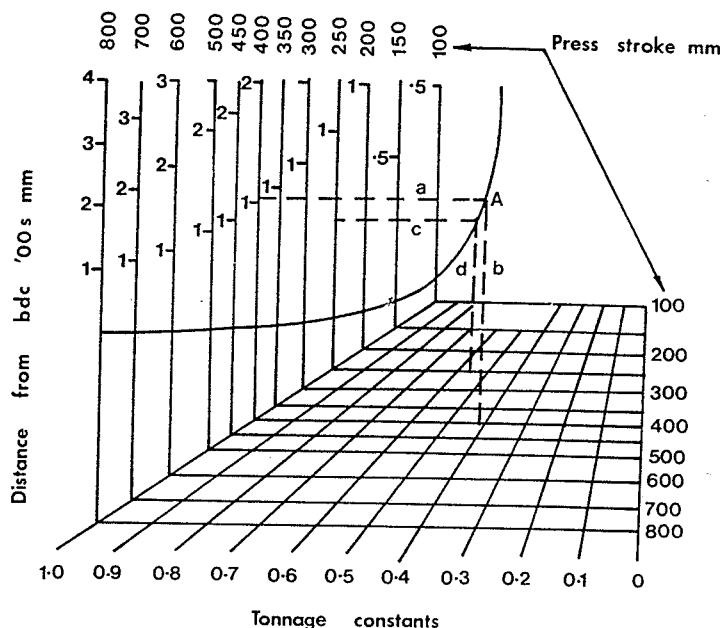


FIG. 4.5

The load-stroke curve for the eccentric press however is ideally suited for hot forging as can be seen by comparing figures 4.5 and 1.1c.

When rating presses the tonnages at a specified distance from BDC is quoted. If this figure is known the tonnage rating at any point on the press stroke may be inferred from the nomogram and table in figure 4.6.



Rated Tonnage Point Distance from BDC—mm	6.4	12.7	19.0	25.4	31.8	50.8	76.2
Modification Factor for Tonnage Constant	0.71	1.00	1.24	1.41	1.72	2	2.4

FIG. 4.6

The basic nomogram is for presses rated at 12.5 mm from BDC. For presses rated at other distances the table must be used in conjunction with the nomogram. Examples of use of the nomogram are given below.

(1) Consider a press of 600 tonnef at 12.5 mm from BDC with a stroke of 400 mm. What is the rating 100 mm from BDC?

Construct a horizontal line a from the 100 mm from BDC point on the 400 mm stroke line to meet the master curve at A . Drop a perpendicular b from A to meet the 400 mm stroke line in the bottom half of the nomogram. This indicates a tonnage constant of 0.42 and thus the rating 100 mm from BDC is given by $600 \times 0.42 = 252$ tonnef.

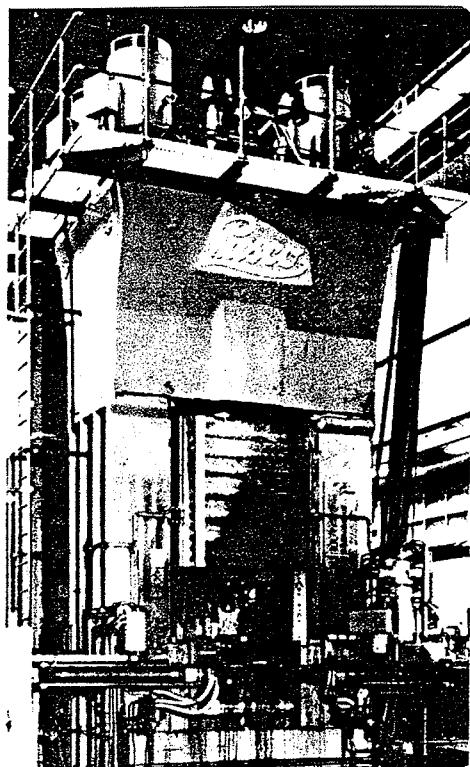
(2) Consider a press rated at 1000 tonnef at 6 mm from BDC with a stroke length of 250 mm. What is the tonnage rating 50 mm from BDC?

The construction lines c and d shown indicate a tonnage constant of 0.55 but as the table shows a correction factor of 0.71 must be applied. The press rating at 50 mm from BDC is therefore $1000 \times 0.55 \times 0.71 = 390$ tonnef.

The load-stroke characteristics of the crank press are ideally suited for forging as shown in figure 4.7a. During forging the load requirement must be below the characteristic curve at all times otherwise stalling of the press will occur as shown in figure 4.7b.

Care must therefore be taken when using a crank press for an operation such as extrusion where the maximum load although well below the nominal press rating builds up early in the stroke and may thus lead to load requirements in excess of the characteristic curve as shown in figure 4.7c by the full curve.

HOT FLOW PRESSES



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Extrusion could be accomplished lower down the press stroke as shown by the dashed curve in figure 4.7c.

Thus in using crank presses for extrusion care must be taken to begin the work at the correct ram position and of course this places a restriction on the amount of ram travel that can be used for extrusion.

Another factor which must be considered in press forging is the forging energy requirement in relation to the production rate. During a forging blow energy is taken from the flywheel which consequently slows down. The flywheel must regain its maximum speed before a further blow otherwise it will gradually slow down to such an extent that there is insufficient energy to carry on forging.

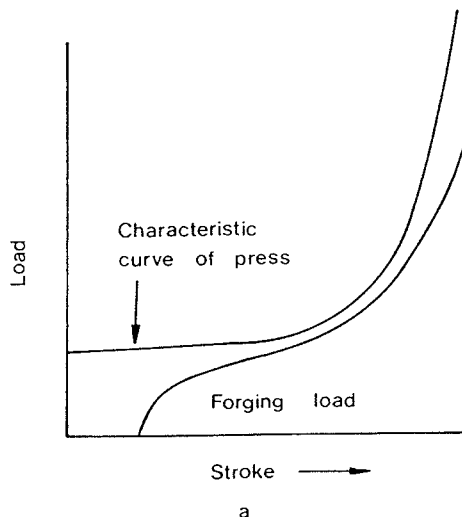
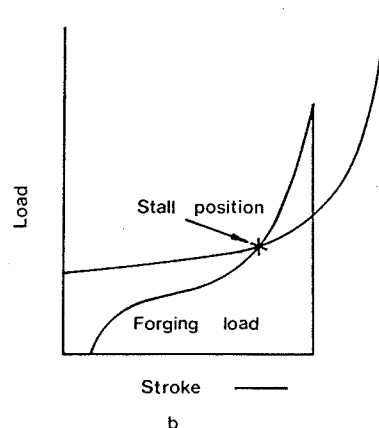


FIG. 4.7

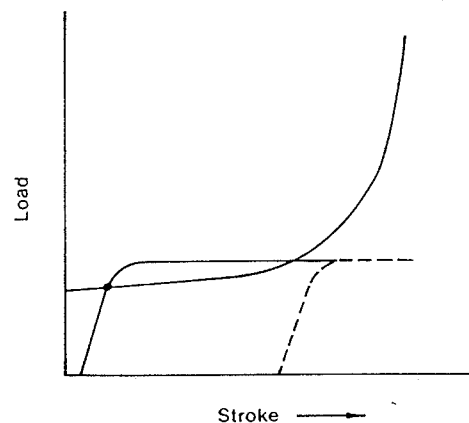


FIG. 4.7

4.3 Press deflection and ram tilting

During forging on hammers and friction screw presses the dies are provided with clash faces and are allowed to come together on the last blow thus effectively controlling the thickness of the forging.

In press forging however the dies are not usually allowed to meet since this could cause gross overloading of the press. When press dies are set up a small clearance is left between top and bottom die and the flash thickness developed during forging is determined by how much the press deflects which in turn depends on the press stiffness and the forging load.

Figure 4.8 shows schematically how the distance between the press bed and the ram varies with increasing load. The slope of the straight part of the line after play has been taken up gives the press stiffness measured in tonne/mm.

Typically a 1000 tonf forging press would have a stiffness of about 700 tonf/mm. Such a press used at its rated load of a 1000 tonf would therefore deflect by $1000 \times 1/700 \text{ mm} = 1.43 \text{ mm}$.

If off-centre forging is carried out on a press the vertical forces are not uniformly distributed between the press columns and tilting of the ram will occur. Ram tilt is usually quoted in mm/m and typical curves are shown in figure 4.9.

The extent of press deflection and ram tilting depend on the press design. Two point presses with their double pitman deflect and tilt less than single point presses. The recently introduced wedge press is claimed to be even more rigid than the two point press.

The press stiffness influences the area of the bed which can be used at a given percentage of the load rating as shown schematically in figure 4.10.

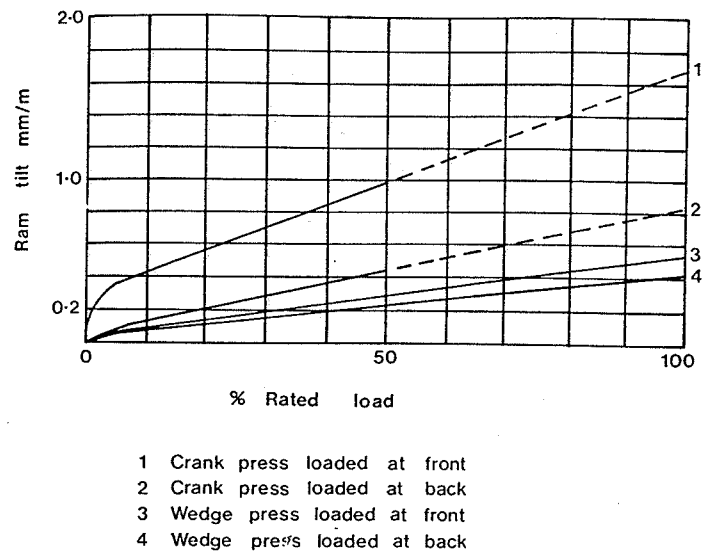


FIG. 4.9

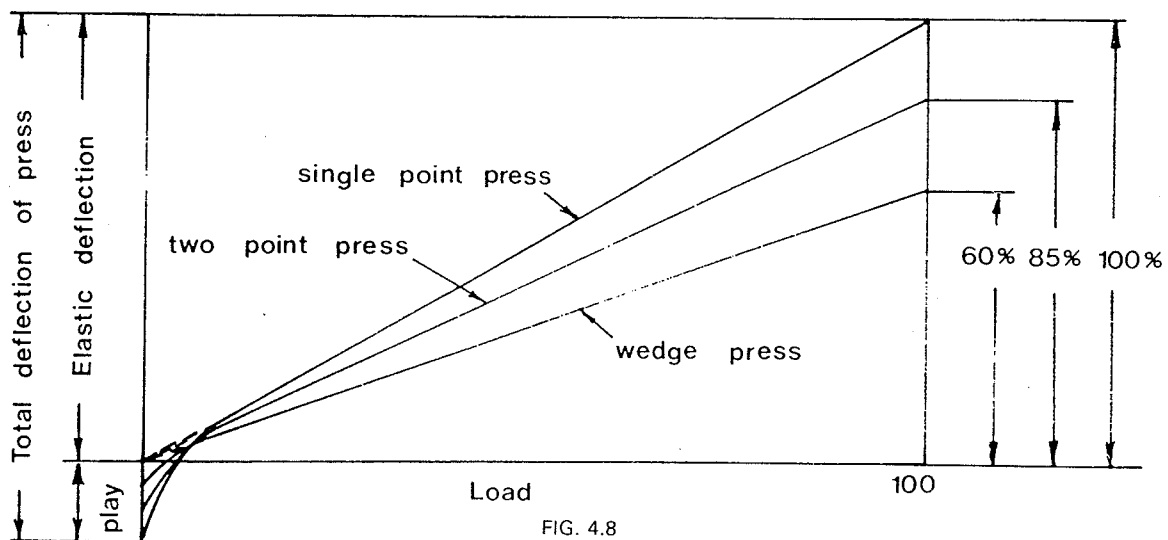


FIG. 4.8

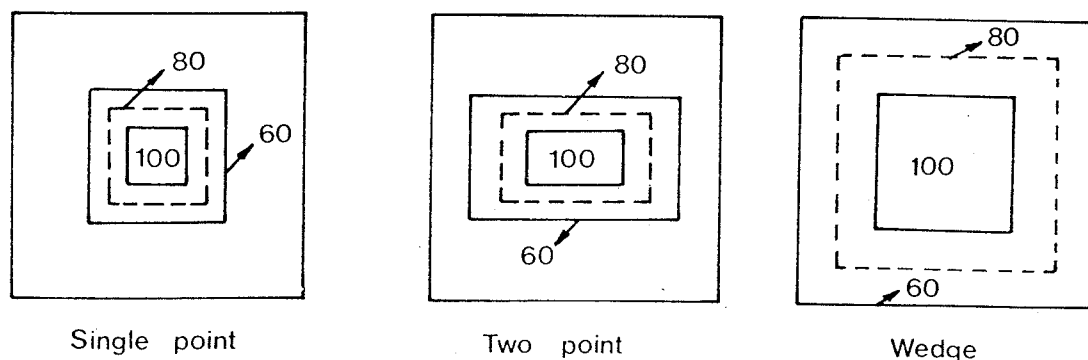


FIG. 4.10

Bed area loading diagrams. The areas shown can be loaded at the percentage rating indicated.

4.4 Press selection

The main requirement in selecting a press to produce a given forging is an estimate of the forging load. This will depend on the material, forging temperature, forging complexity and the flash land dimensions as already discussed in section 2.2.6.

Many methods of estimating forging loads have been presented in the literature but the one described below has been used extensively at DFRA and has been found to give close agreement with measured forging loads.

The information required to calculate the forging load is:

- (1) the volume of the forging excluding flash $V_{fo} \text{ mm}^3$
- (2) the length of the forging excluding flash $L_{fo} \text{ mm}$
- (3) the plan area of the forging excluding flash $A_{fo} \text{ mm}^2$
- (4) the volume of the flash in the flash land $V_{fl} \text{ mm}^3$
- (5) the length of the forging including flash land $L_{fl} \text{ mm}$
- (6) the plan area of the flash land $A_{fl} \text{ mm}^2$
- (7) the flash land width/thickness ratio r

The forging load is then determined as follows:

The load on the flash land L_{fl} is given by

$$L_{fl} = 6.3 A_{fl}^2 \sqrt{1/(L_{fl} V_{fl})} \text{ kg}$$

The load on the forging L_{fo} is given by

$$L_{fo} = 6.3 A_{fo}^2 (1+r) \sqrt{1/(L_{fo} V_{fo})} \text{ kg}$$

The total forging load LT is then given by

$$LT = L_{fo} + L_{fl}$$

This is the load for a mild steel forging at 1250°C .

For other forging materials and other forging temperatures the total load LT must be multiplied by a factor derived from table 4.1.

Three examples of estimating press forging loads are given below.

Example 1:

The following data apply to the axisymmetric forging shown in figure 4.11 forged in mild steel at 1275°C .

Volume of forging excluding flash	$V_{fo} = 188\,451 \text{ mm}^3$
Area of forging excluding flash	$A_{fo} = 9852 \text{ mm}^2$
Length of forging excluding flash	$L_{fo} = 112 \text{ mm}$
Volume of flash (ie metal in flash land)	$V_{fl} = 10\,200 \text{ mm}^3$
Area of flash land	$A_{fl} = 4\,250 \text{ mm}^2$
Length of flash	$L_{fl} = 134 \text{ mm}$
Flash land ratio	$r = 3.6$

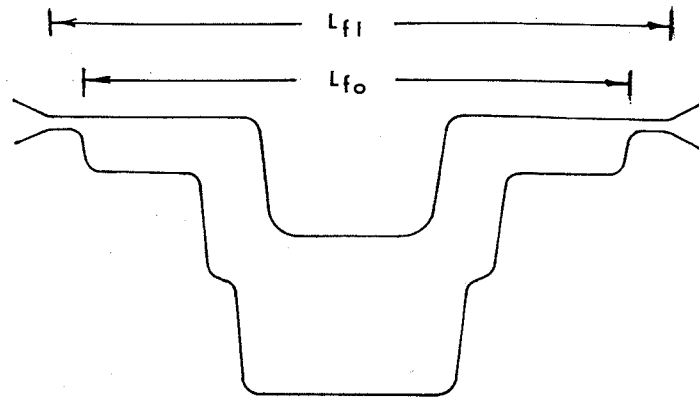


FIG. 4.11

The load may now be calculated as follows:

$$L_{fl} = 6.3 A_{fl}^2 \sqrt{1/V_{fl} L_{fl}}$$

$$L_{fl} = 6.3 \times 4250^2 \sqrt{1/(10200 \times 134)} = 97334 \text{ kg} = 97 \text{ tonnef}$$

$$L_{fo} = 6.3 A_{fo}^2 (1+r) \sqrt{1/V_{fo} L_{fo}}$$

$$L_{fo} = 6.3 \times 9852^2 \times 4.6 \sqrt{1/(188451 \times 112)} = 612262 \text{ kg} = 612 \text{ tonnef}$$

$$LT = L_{fo} + L_{fl} = 612 + 97 = 709 \text{ tonnef}$$

Correction factor for forging temperature of 1275°C instead of $1250^\circ\text{C} = 0.95$ interpolated from table 4.1.

Revised forging load $= 709 \times 0.95 = 674 \text{ tonnef}$.

The measured load for this forging was 650 tonnef.

Example 2:

Figure 4.12 shows a forging with both internal and external flash lands. In this case the procedure is similar to before except that the internal flash land is included in calculating the flash volume and area.

For the forging shown the following data apply:

Volume of forging excluding flash	$V_{fo} = 600\,258 \text{ mm}^3$
Area of forging excluding flash	$A_{fo} = 33084 \text{ mm}^2$
Length of forging excluding flash	$L_{fo} = 205 \text{ mm}$
Volume of flash (ie metal in flash land)	$V_{fl} = 29115 \text{ mm}^3$
Area of flash land	$A_{fl} = 6771 \text{ mm}^2$
Length of flash	$L_{fl} = 221 \text{ mm}$
Flash land ratio	$r = 1.9$

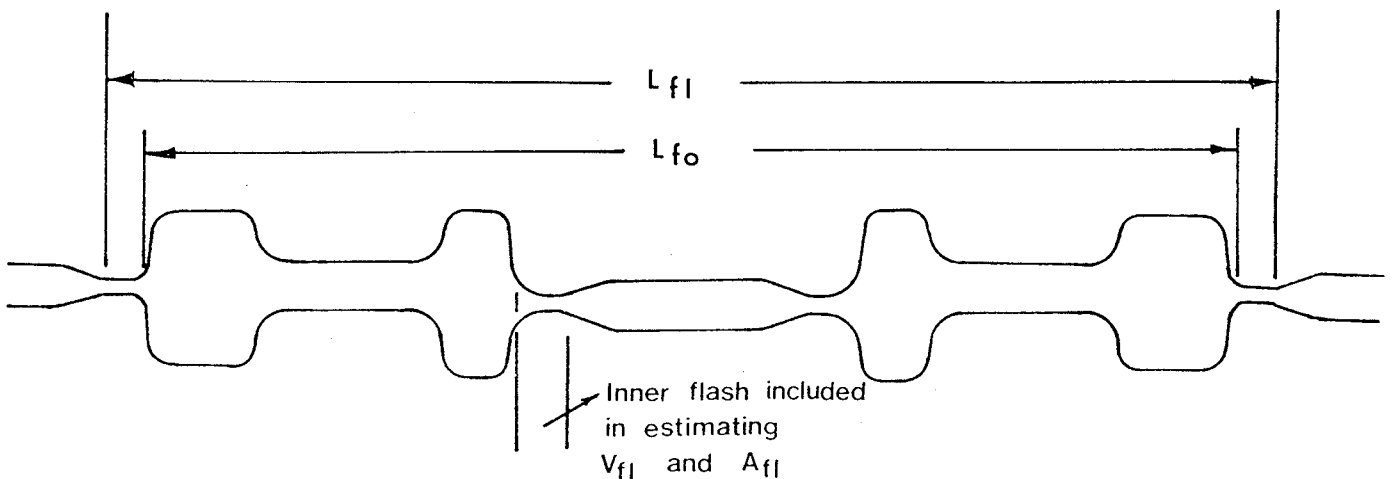


FIG. 4.12

Then as before

$$L_{fl} = 6.3 \times 6771^2 \sqrt{1/(29115 \times 221)} = 113865 \text{ kg} \\ = 114 \text{ tonnef}$$

$$L_{fo} = 6.3 \times 33084^2 \times 2.9 \sqrt{1/(600258 \times 205)} = 1802726 \text{ kg} \\ = 1803 \text{ tonnef}$$

$$LT = L_{fo} + L_f = 1803 + 114 = 1917 \text{ tonnef}$$

The forging material was SAE 8620 (cf En3) forged at 1200°C giving a load correction factor from table 4.1 of 1.2.

Thus the revised forging load is

$LT = 1917 \times 1.2 = 2300 \text{ tonnef}$ compared with a measured load of 2475 tonnef.

Example 3

For the forging shown in figure 4.13 the following data apply:

$$\text{Volume of forging excluding flash } V_{fo} = 305110 \text{ mm}^3$$

$$\text{Area of forging excluding flash } A_{fo} = 12609 \text{ mm}^2$$

$$\text{Length of forging excluding flash } L_{fo} = 292 \text{ mm}$$

$$\text{Volume of flash (ie metal in flash land)} \\ V_{fl} = 27070 \text{ mm}^3$$

$$\text{Area of flash land } A_{fl} = 6768 \text{ mm}^2$$

$$\text{Length of flash } L_{fl} = 311 \text{ mm}$$

$$\text{Flash land ratio } r = 2.5$$

Proceeding as before

$$L_{fl} = 6.3 \times 6768^2 \sqrt{1/(27070 \times 311)} = 99457 \text{ kg} = 99 \text{ tonnef}$$

$$L_{fo} = 6.3 \times 12609^2 \times 3.5 \sqrt{1/(305110 \times 292)} = 371404 \text{ kg} \\ = 371 \text{ tonnef}$$

$$LT = L_{fo} + L_f = 371 + 99 = 470 \text{ tonnef}$$

The forging was mild steel forged at 1250°C so no correction factor is necessary. The measured forging load was 480 tonnef.

Table 4.1

Load multiplying factors for steel

Steel Quality		Multiplying factor				
		Forging Temperature °C				
En No.	BS 970 No.	1100	1150	1200	1250	1300
3	070 M 20	1.6	1.4	1.2	1.0	0.9
8	080 M 40	1.5	1.2	1.1	0.9	0.7
9	—	1.8	1.6	1.4	1.2	1.0
16	605 M 36	1.7	1.5	1.2	1.1	0.9
17	608 M 38	1.6	1.4	1.2	1.1	0.9
18	530 M 40	1.5	1.3	1.1	1.0	0.9
20	—	1.6	1.4	1.2	1.0	0.9
21	—	1.9	1.7	1.5	1.4	1.2
22	—	1.9	1.7	1.5	1.4	1.2
23	653 M 31	1.9	1.7	1.5	1.4	1.2
24	817 M 40	1.8	1.6	1.3	1.2	1.0
25	826 M 31	1.8	1.6	1.4	1.2	1.1
26	826 M 40	1.9	1.6	1.4	1.3	1.1
30B	835 M 30	1.9	1.7	1.5	1.4	1.2
31	534 A 99	1.5	1.3	1.1	1.0	0.8
34	665 M 17	1.7	1.5	1.3	1.1	1.0
35	665 M 23	1.7	1.5	1.3	1.1	1.0
36	655 M 13	1.8	1.6	1.4	1.2	1.1
37	—	1.9	1.7	1.5	1.4	1.2
38	—	1.9	1.7	1.5	1.4	1.2
39	835 M 15	1.9	1.7	1.5	1.4	1.2
40	722 M 24	1.8	1.7	1.5	1.3	1.2
41	905 M 41	1.6	1.4	1.2	1.1	1.0
42	070 A 72	1.5	1.3	1.1	1.0	0.8
43	080 A 47	1.5	1.3	1.1	1.0	0.8
44	060 A 96	1.5	1.3	1.1	1.0	0.8
45	250 A 53	1.8	1.5	1.3	1.2	1.0
46	—	1.8	1.5	1.3	1.2	1.0
47	735 A 50	1.5	1.3	1.1	1.0	0.8
48	527 A 60	1.8	1.6	1.3	1.2	1.1
51	—	1.8	1.7	1.5	1.3	1.2
52	401 S 45	2.1	1.8	1.6	1.4	1.3
58	321 S 12	2.6	2.2	1.9	1.7	1.4

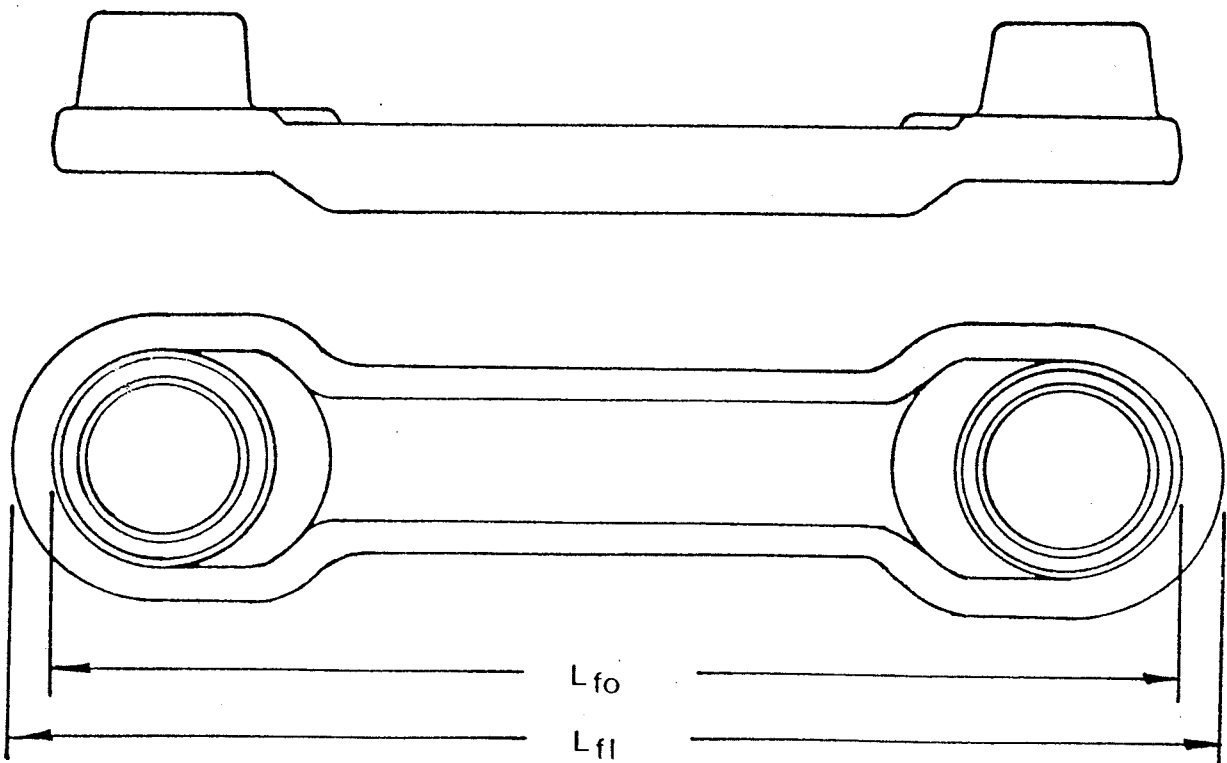


FIG. 4.13

5 FRICTION SCREW PRESSES

5.1 Basic principles

The basic principle of the friction screw press is illustrated in figure 5.1. The machine consists of a heavy flywheel which can be rotated in either direction by means of a driving mechanism. Attached to the flywheel either directly or via a slipping clutch arrangement is a long lead screw.

Depending on the design of the particular press this screw may rotate with or without vertical movement of the screw and flywheel assembly.

In the former case (figure 5.1a) the ram holding the top die moves up and down as the screw travels in a stationary nut located in the press frame.

In the case of the stationary screw type of press (figure 5.1b) the ram assembly contains the nut so that the ram moves up and down as the fixed screw rotates.

Several methods of driving the flywheel have been developed and will be described in detail later.

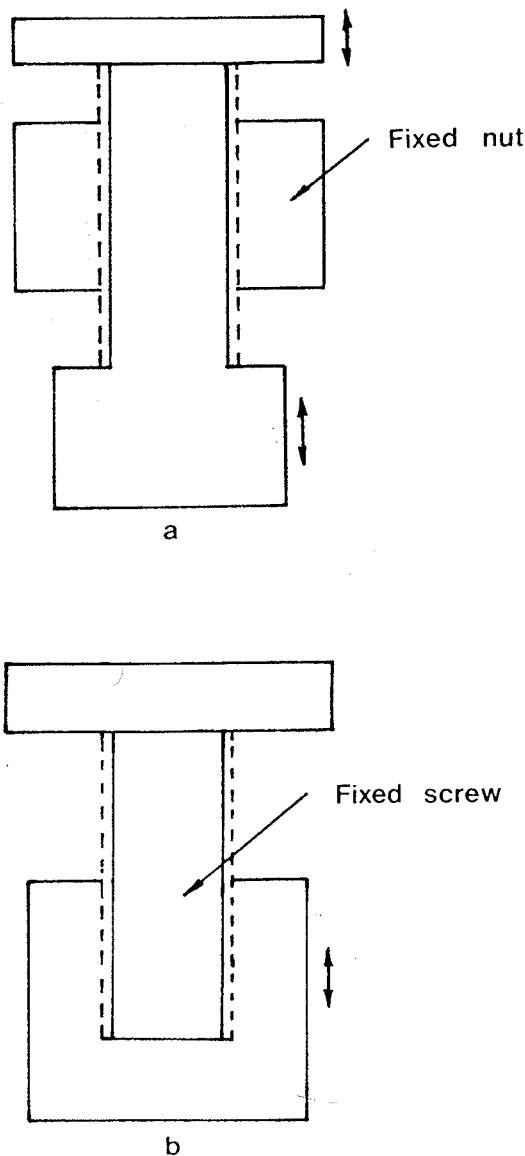


FIG. 5.1

Fixed nut and fixed screw friction screw presses.

5.2 Characteristics of the friction screw press

Although described as a press the characteristics of this machine are more akin to those of a hammer since both are energy restricted machines.

During a forging blow, as in a hammer, the tup moves down with a certain kinetic energy and deformation of the forging continues with increase in forging load until all the available energy is used.

The rotation of the flywheel and screw give the tup a certain kinetic energy E_k and this is dissipated in three ways.

Firstly part of the energy is used in overcoming frictional forces mainly in the ram guides and screw. Generally about 10-20% of the total available energy is lost as frictional energy E_f , with the highest loss coinciding with the development of the highest forging loads.

A second part of the energy E_d is used in plastically deforming the forging whilst the remainder is lost in the form of elastic strain energy E_e . This elastic loss is caused by a combination of stretching of the frame members and compression of the screw.

Figure 5.2 shows a graph of frame deflection as a function of press loading. After the take up of play in various parts of the machine the deflection d is a linear function of the press load. The slope of this linear part of the line is the stiffness of the press (C) expressed in tonnef/mm.

The energy lost in elastic deformation is given by the area under the load-deflection curve and neglecting the deflection due to play in the machine parts we may write

$$E_e = \frac{1}{2} Ld$$

Where L is the maximum load reached and d the corresponding deflection.

Since the machine stiffness (C) is defined by $C = L/d$ we may substitute L/C for d to give the following expression for elastic energy losses

$$E_e = \frac{L^2}{2C}$$

Thus the elastic energy losses during forging on a screw press are proportional to the square of the maximum forging load. It should be pointed out that frame spring in screw presses does not lead to variations in forging thickness as in crank presses since in the former machine the dies are allowed to meet and thus forging thickness is controlled.

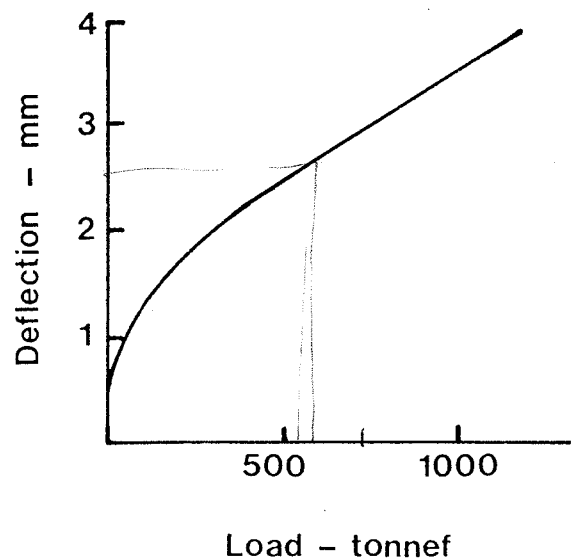


FIG. 5.2

Load-deflection curve for a friction screw press.

The factors considered so far allow a characteristic curve to be drawn representing the relationship between load and energy on a screw press. Such a curve is shown in figure 5.3.

The maximum load which can be developed by the screw press is denoted by $L_{\max}$ in figure 5.3 and occurs during a "hard-on-hard" blow, ie when empty dies clash together. However under these conditions all the available energy is lost as frictional and elastic strain energy and thus none is available for deformation work.

Although screw presses are invariably rated in terms of tonnage capacity it can be seen from figure 5.3 that this is a somewhat arbitrary method. The convention usually adopted by manufacturers is to quote a nominal tonnage rating LN at which about 70% of the total energy is available for forging work.

Depending on the design of press the maximum load which can be sustained $L_{\max}$ is about 1.6 to 2.0 times the nominal load LN. Figures 5.3 shows that provided the energy requirement is not excessive forgings requiring a load in excess of the nominal tonnage rating can be produced.

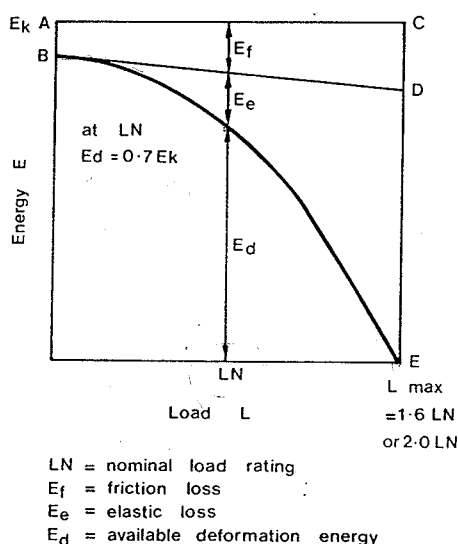


FIG. 5.3

Characteristic energy load curve for a friction screw press.

The bold curve in figure 5.3 (ie the available deformation energy as a function of forging load) is reproduced in figure 5.4 and may be used as a characteristic curve to determine whether a given forming operation can be carried out on a screw press.

If the load and energy required to produce any forging are known then a point can be plotted on figure 5.4 representative of that forging. Provided that the point lies below the characteristic curve the forging can be made in a single blow in the press.

This is the case for the points marked A and B on the diagram. Although forging B requires a load in excess of the nominal tonnage rating LN it can still be produced because the energy requirement is low.

Forging C could not be made on the screw press since the load requirement exceeds $L_{\max}$ and thus a larger machine would be required to make this component.

Forging D lies above the characteristic curve but is within the nominal load rating LN. Thus whilst this forging could not be made in a single blow it could be made on the screw press under consideration in two blows. Reference is made later to this type of forging.

The characteristic curve of figure 5.4 can also be used to determine the approximate energy setting required to produce forgings A and B.

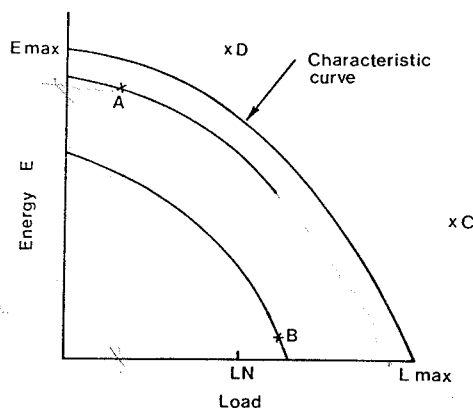


FIG. 5.4

Use of characteristic curve to determine forging conditions.

If a curve is sketched parallel to the characteristic curve and passing through the point corresponding to the forging in question it will cut the energy axis at the approximate energy setting required as shown.

Reference will be made later to methods for estimating the load and energy required to make a forging. An approximate version of the characteristic curve for a screw press can usually be sketched from data given in the manufacturers' catalogue.

For instance the following data is taken from a catalogue:

Nominal load rating	400 tonnef
Maximum load rating	800 tonnef
Gross impact energy	2500 kgm
Energy at nominal load	1750 kgm

This data can be used to plot three points on an energy-load diagram so that the characteristic curve can be sketched as shown in figure 5.5.

Two versions of the upper part of the curve are shown. The dotted line shows the curve passing through the quoted gross energy value. The solid curve has been made to pass through a point where this gross quoted energy has been reduced by 15% to allow for frictional losses.

The solid curve is probably a more accurate representation of the characteristic curve.

Other manufacturers' catalogues do not indicate the energy availability at the nominal load rating. Where this is the case the value may be taken as 70% of the gross available energy.

Although such curves are only approximate they are useful in deciding the suitability of a screw press to produce a given forging.

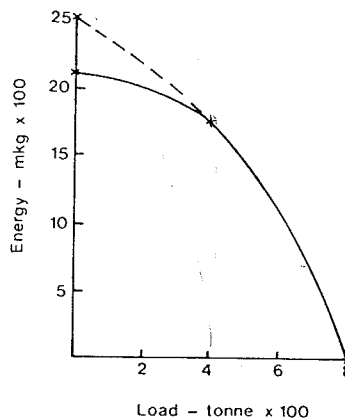
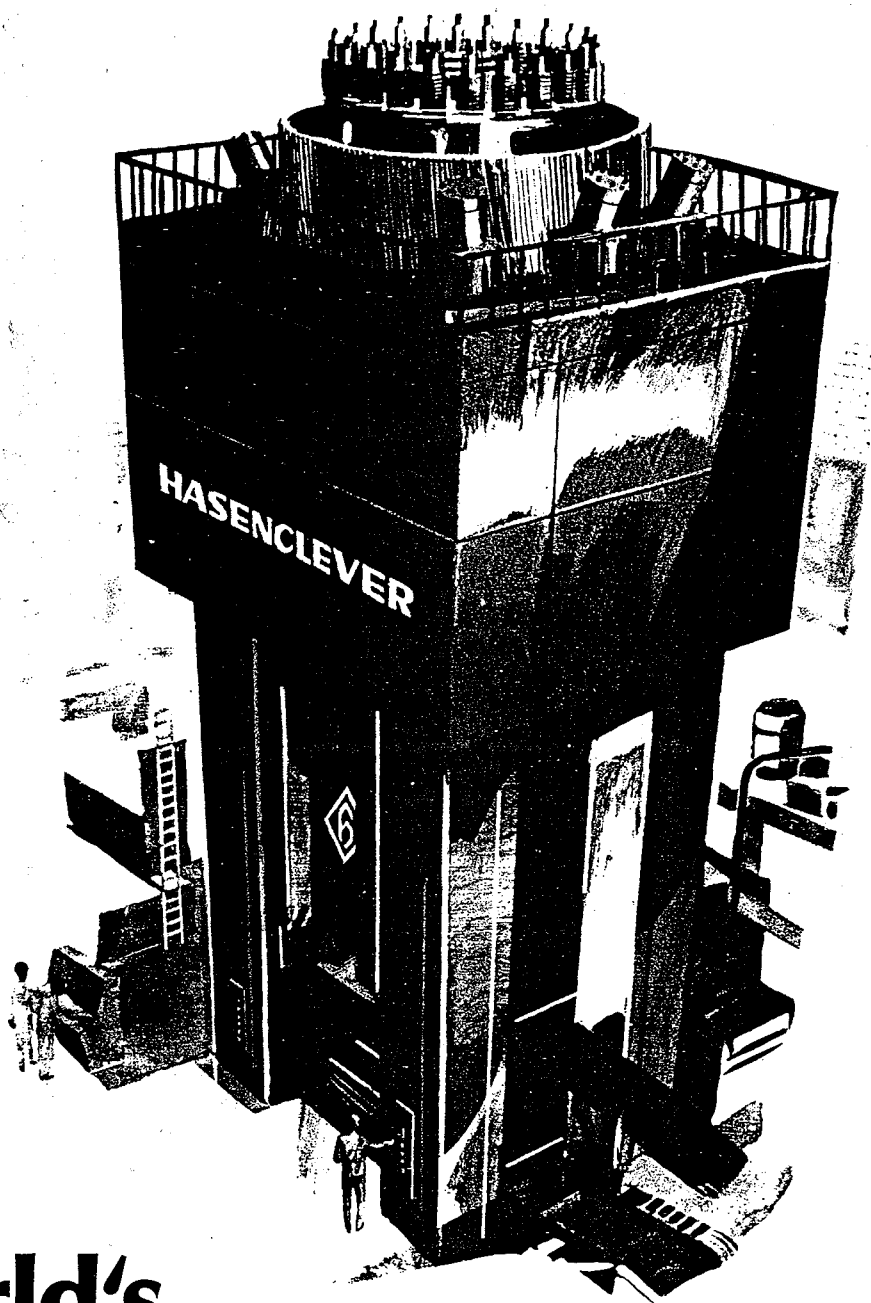


FIG. 5.5

Sketch of characteristic curve drawn from manufacturers data.



World's Largest Screw Press

Forgings continue to increase in size and weight; the necessary press forces continue to rise. The unique design of our screw presses allows us to build machines which develop the press forces required. For die forgings needing a press force of 280 MN, for example, we build a screw press with a hard-on-hard blow force of 315 MN;

the largest screw press in the world.

The trend in large drop forging machines is clearly towards screw presses. For many reasons – such as the favourable combination of converted energy, press force, precision and cost.

Experience and know-how gained from large projects are applied even to the smallest of our machines. It always

makes sense to have a word with us – even before purchasing small plants.

UK: Walter Somers Ltd., Haywood Forge Halesowen, West Midlands B62 8DZ, Phone 021-550 47 41, Telex 336711.

Germany: Hasenclever GmbH, 4000 Düsseldorf, Witzelstrasse 55, Phone (0211) 3 38 51, Telex 8 582 390.



HASENCLEVER

The Machine Builders for the Drop Forging Industry

5.3 The effect of a slipping clutch on the characteristic curve

Early versions of the friction screw press were made with the flywheel rigidly attached to the screw. As the use of these machines developed a demand arose for presses with high energy ratings. Such a demand could be met merely by increasing the size of the flywheel to provide greater energy but this results in very high levels of maximum load being developed with the consequent need for large expensive frames to withstand the high loads.

To provide machines with a high energy capacity but without excessive loading for hard-on-hard blows the slipping clutch was developed.

Figure 5.6 compares the characteristic curves for two screw presses of the same energy rating. The upper line marked "a" represents the energy-load curve for a solid flywheel and screw assembly, whilst the lower line marked "b" refers to a press where a clutch arrangement is made to slip when the load reaches the nominal load rating. At this point no further energy is transferred to the screw from the flywheel and thus the load falls more rapidly than in the former case.

The load does not fall immediately to zero at the slipping point because the screw and the ram still have residual kinetic energy which must be dissipated thus causing some further build up of load.

Nevertheless the maximum load developed is much less than when the slipping clutch is not used, in the example cited a reduction of load from 7000 to 4500 tonnef is achieved.

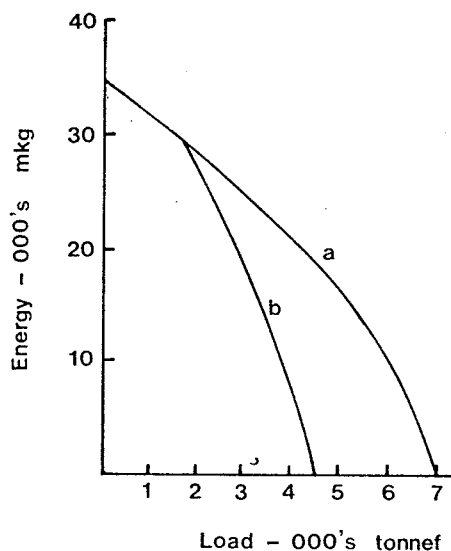


FIG. 5.6

Effect of slipping clutch on energy-load characteristics.

5.4 Types of friction screw press

Several types of drive have been developed for screw presses and the more important ones are shown in figures 5.7 to 5.10 with the ones normally encountered in modern presses described briefly below.

5.4.1 Three disc screw presses

The most widely used friction screw presses are the three disc types illustrated in figure 5.7. A large flywheel is attached to the end of the screw which passes through a fixed nut housed in the press frame. The bottom end of the screw is fixed to the ram of the press.

A rotating, motor-driven shaft carries two driving discs, one or other of which engages with the flywheel to drive the screw up or down.

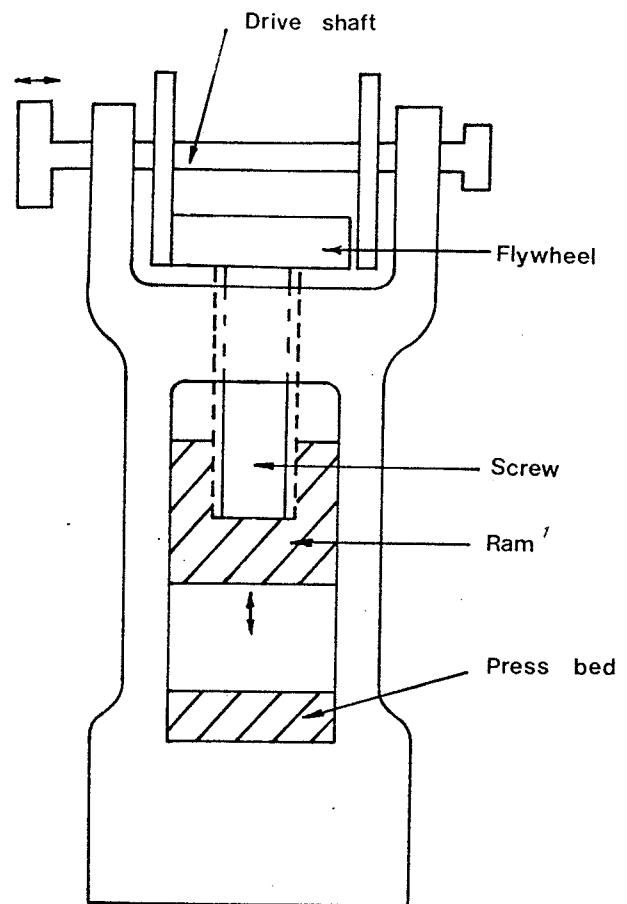


FIG. 5.7a

Three disc friction screw press

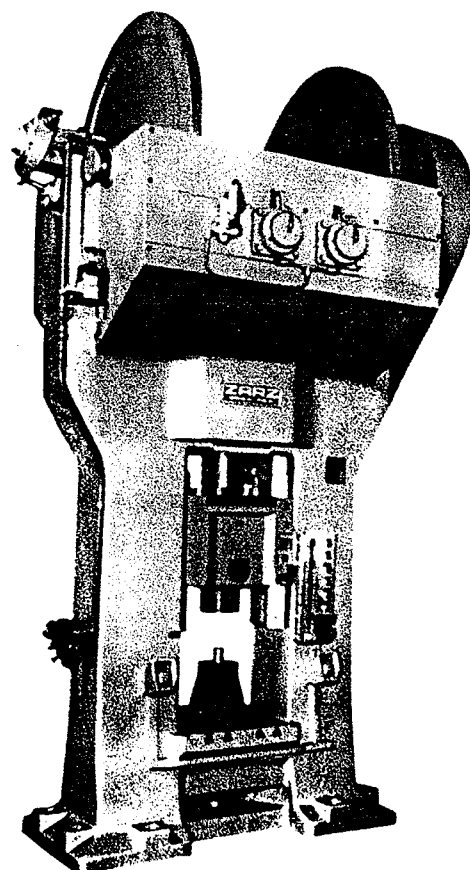
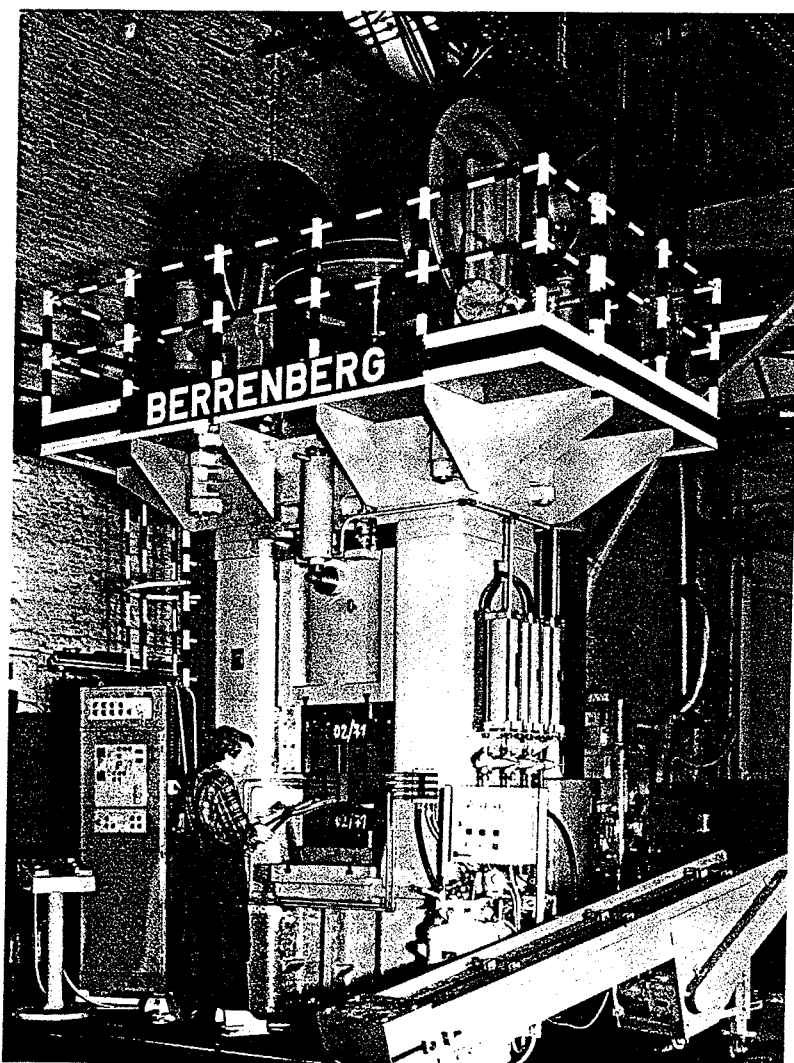


FIG. 5.7b

FORGING on SCREW-PRESSES

Drop forging of steel and non-ferrous metal
Core forging of brass parts



Model RSSP 280/800
800 t—40 strokes/min

Pressing forces
100-2000 t

PRESSES
for
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Modern presses are fitted with a torque limiting device on the flywheel usually in the form of a slipping clutch which prevents overloading of the press. Presses of this type are commonly available with load ratings up to 3000 tonne and presses up to 5000 tonne have been built.

5.4.2 Direct drive screw presses

Two European manufacturers have developed an electrically operated direct drive screw press as shown in figure 5.8. In this the rotor of one or more electric motors is attached to the screw and the stator is mounted on the press frame. The press is necessarily of the fixed screw type with the nut located in the ram mechanism.

A reversing motor is used so that the screw and hence the ram are driven in both directions. Machines with ratings of 100-16000 tonne are available and again a slipping clutch mechanism between the flywheel and the screw is used.

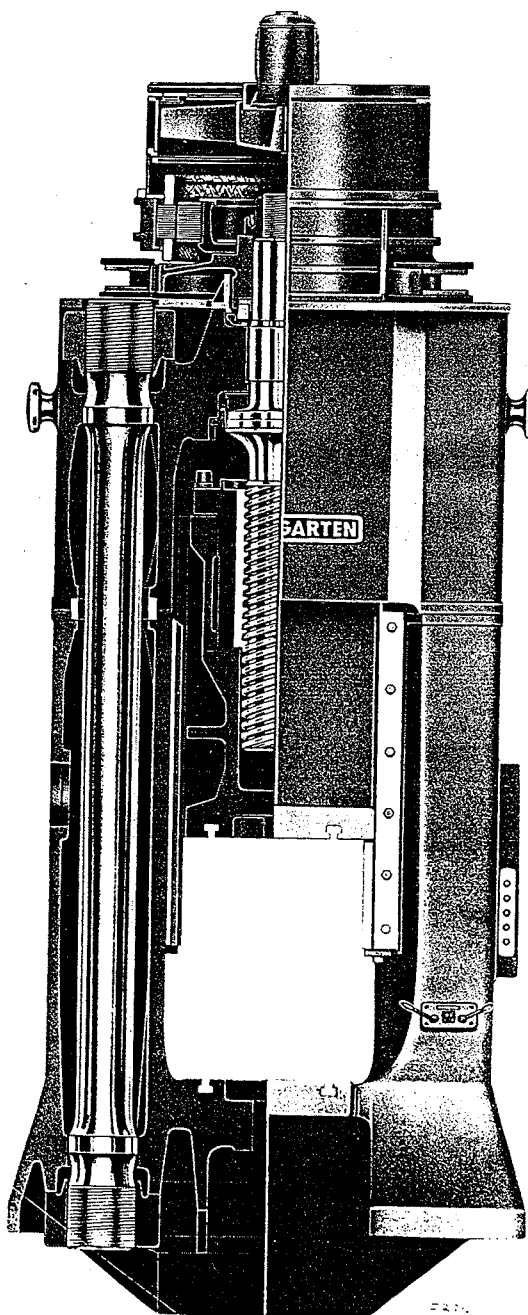


FIG. 5.8
Directly driven screw press.

5.4.3 Hydraulic drive screw presses

In the hydraulically driven screw press a large toothed gear is attached to the screw and is driven by a number of geared hydraulic motors as shown in figure 5.9.

The hydraulic motors draw oil during operation from an accumulator system. Since the direct drive press must draw the full operating current from the mains during each forging stroke the peak electrical demand of the hydraulic press is lower, since the current needed for charging the accumulators can be drawn from the mains continuously and not just during a forging stroke.

Hydraulically operated screw presses with ratings of 3000-12500 tonne are available.

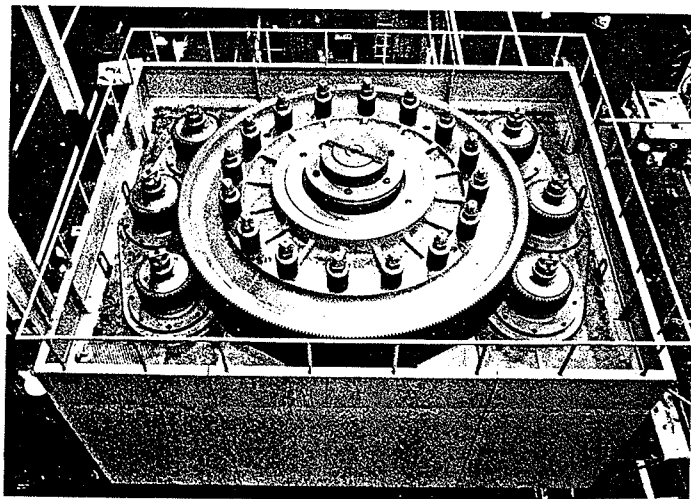
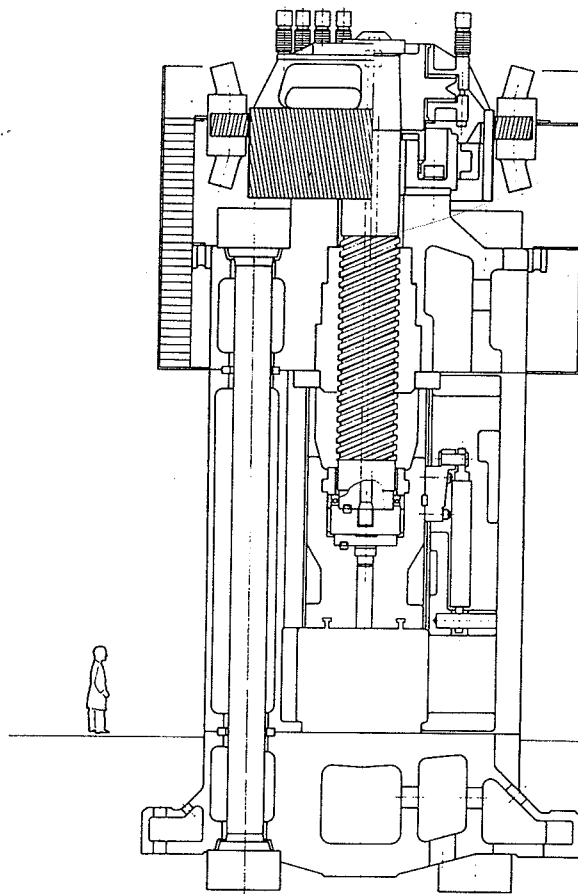


FIG. 5.9
Hydraulically driven screw press.

5.4.4 The Siempelkamp high energy forging press

Although the manufacturer prefers not to refer to this press as a friction screw press it is included in this section of the Handbook since the ram is driven by a screw and nut arrangement.

The construction of the machine is illustrated schematically in figure 5.10. Unlike the screw presses previously described the flywheel in the Siempelkamp press rotates continuously in the same direction all the time.

During forging the clutch connecting the screw to the flywheel is engaged and the screw quickly attains the rotational speed of the flywheel causing the ram and nut assembly to move downwards for the forging stroke. The flywheel continues to drive the ram until the clutch is disengaged at a preselected position of the stroke or alternatively when a preselected forging load has been attained.

The reversal of the ram and nut assembly then occurs by elastic rebound assisted by return cylinders.

The manufacturers claim that the drive arrangement used offers several advantages over conventional screw presses. Firstly because the flywheel rotates continuously the full press energy and load capacity are available at any position of the stroke.

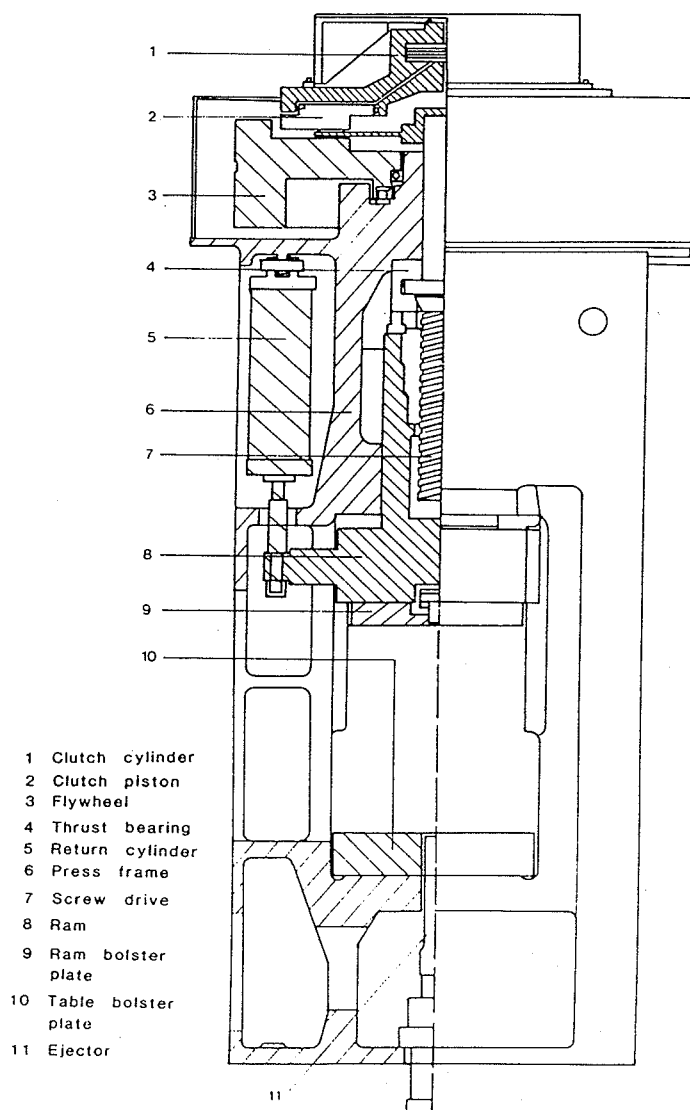


FIG. 5.10

In a conventional screw press there is an idle part of the stroke which cannot be used for forging since it is needed to allow the flywheel to accelerate and gain sufficient energy for forging.

The inability of crank presses to utilise their full load capacity high up the stroke has already been referred to earlier.

This feature of the high energy press is said to make it particularly suitable for extrusion operations.

Secondly because the flywheel does not have to be brought to rest and accelerated in an opposite direction at the end of each forging stroke the die contact time during forging is reduced and the stroking rate of the press is increased.

The air pressure in the clutch system can be preset thus determining the maximum torque and allowing slipping to occur at a preselected load to prevent overloading of dies.

5.5 Forging on friction screw presses

Friction screw press dies are very easily overloaded unless the operation of the press is understood and unless energy settings are carefully selected prior to forging.

Figure 5.11 shows a hypothetical load-deformation diagram for a forging. The maximum load required is 800 tonnef and the energy required is about 11000 mkg.

Consider this forging made on a hammer or a screw press with a load capacity of 1250 tonnef. Table 1.1 shows that the approximate energy available for machines of this rating is 1600 mkg for the hammer and 8000 mkg for the screw press.

Thus to satisfy the energy requirements of the forging would require seven hammer blows with a total energy input of $7 \times 1600 = 11200$ mkg so that the excess energy which stresses the dies would be $11200 - 11000 = 200$ mkg.

The same forging made in two blows on the friction screw press at its maximum energy setting would receive an energy input of $2 \times 8000 = 16000$ mkg. Thus the excess energy input will be $16000 - 11000 = 5000$ mkg, ie 25 times that of the hammer. Whilst this excess energy may not damage the screw press it can lead to deformation or breakage of dies.

To avoid such overloading the screw press would have to be used at a reduced energy setting. The energy control on some screw presses is achieved only by stroke control so that a given energy can be selected before forging commences but during forging the energy of each blow is constant. On such machines in the example cited it would be necessary to set the energy of each blow at slightly over half the total energy requirement for the forging to minimise overloading.

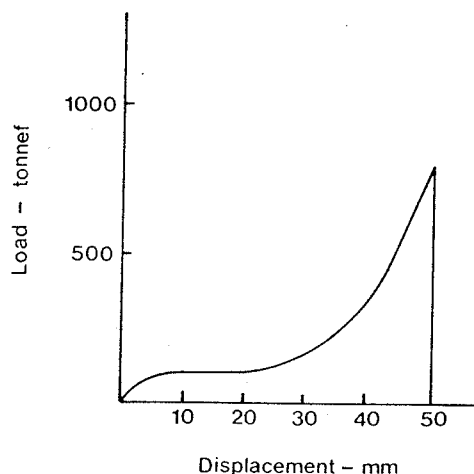


FIG. 5.11

Forging load-displacement curve.

Some screw presses are fitted with "electronic blow control" which usually allows the energy of two successive blows to be pre-set. On such machines producing a forging in two blows the required energy input can be achieved in several ways as shown in figure 5.12.

Where "electronic blow control" is used it is usual to have an energy selector marked in arbitrary units.

It is a common misconception that the setting for the second blow must always be higher than that for the first since a higher load is required during the second blow.

If it is remembered that the selector is setting blow energy and not maximum forging load reference to figure 5.12 will show that the energy setting for the second blow will depend on that used for the first and may be lower, the same or higher.

It is not usually possible to estimate accurately the energy requirements of a forging so that when setting up screw presses the total energy input should be adjusted to a level just slightly greater than that required to produce the forging.

Experience indicates that if setting of energy levels is left to operators excess energy is invariably used with consequent oversteering of the dies.

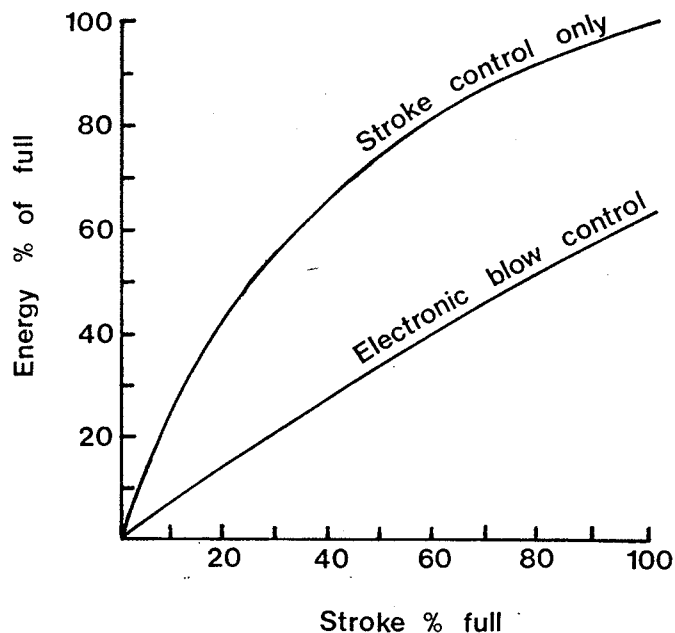


FIG. 5.13

In such cases a compromise solution must be reached by reducing the energy setting thus doing less work in the moulder but avoiding over-stressing of the dies in the finishing blow.

The great advantage of energy control of successive blows is apparent from the above consideration.

The importance of controlling blow energy on screw presses is such that a further elaboration of what happens during forging is justified.

Figure 5.11 showed a typical forging load-ram displacement diagram. By measuring that energy under the curve at any load a corresponding load-energy diagram such as that shown in figure 5.14 can be constructed.

This forging load-energy curve can then be superimposed on the characteristic load-energy curve for a screw press. Consider the case shown in figure 5.15.

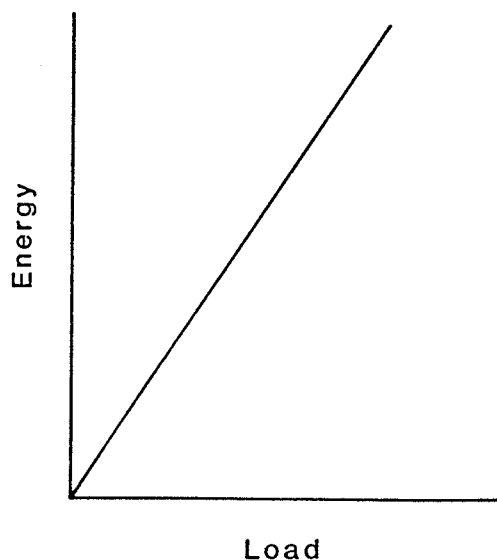


FIG. 5.14

Energy-load diagram for a forging.

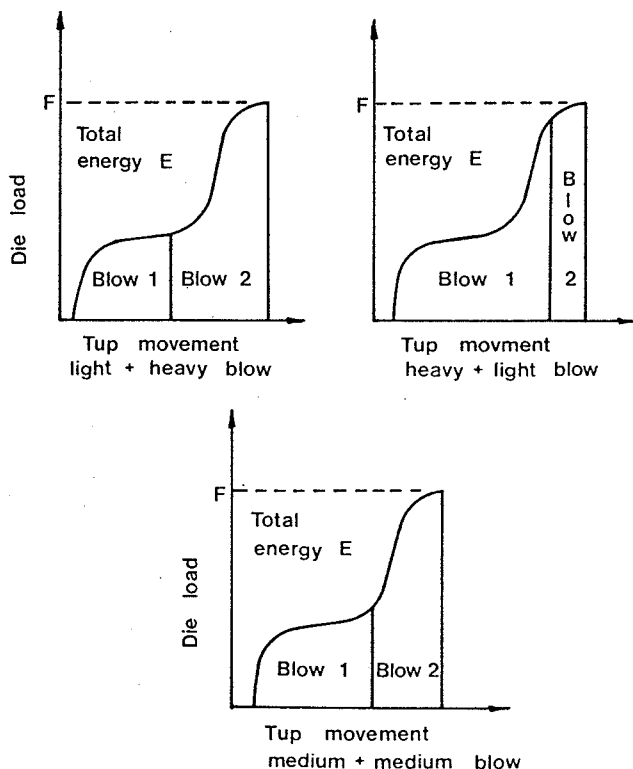


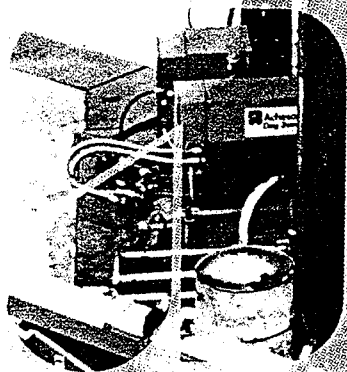
FIG. 5.12

As already indicated on older type screw presses blow energy control can be effected by reducing the stroke length. Modern presses are usually fitted with some form of electronic blow control. This usually involves measuring the flywheel speed and disengaging the drive when a speed appropriate to the required energy is achieved. The advantage of electronic blow control is illustrated in figure 5.13.

The inability of older designs of screw presses to strike successive blows of different energy is particularly disadvantageous when making forgings using a moulding and finishing impression.

If the energy level is selected to do most of the work in the mould impression to reduce wear of the finisher the second blow struck in the finishing impression may have so much excess energy that dies are broken or damaged.

Only the best would do . . .



This press represents the world's most advanced forging technology. It deserved the best die lubrication available — and it got it.

Acheson supplied two Dag 2000 automatic spray systems together with high quality Dag forging lubricants for this new screw press at Smith-Clayton's Lincoln plant. Only Acheson had the technology. Smith-Clayton did it with Dag.

Acheson

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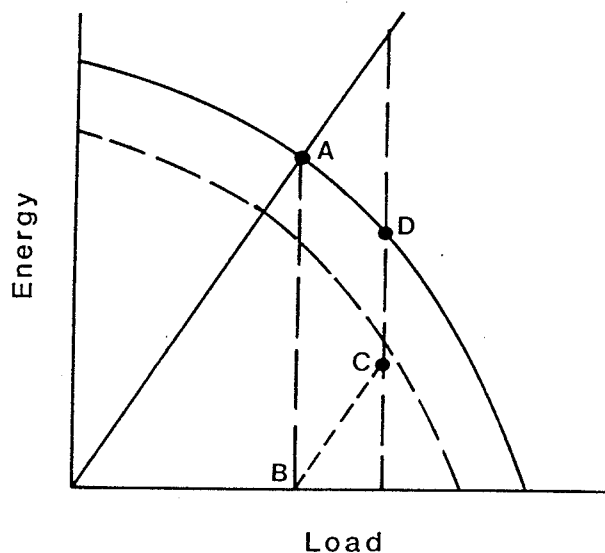


FIG. 5.15

During forging the load builds up and energy is consumed until the forging's load-energy curve crosses the characteristic curve of the press at point A. At this point the press has delivered all the energy it can to the forging and the blow is arrested. If a second blow is struck the load-energy curve for the forging follows that shown by the dashed line which is merely the continuation of the original line but starting at point B, ie the load at which the original forging blow terminated.

At point C the required forging load is attained and forging is completed. There is still however residual energy left in the screw press, the amount being represented by the length of the line C-D. If this is excessive then overloading of dies occurs. This overloading could have been avoided by reducing the energy setting of the second blow as illustrated by the chain-dotted line in figure 5.15.

In this case when forging is completed at point C there is very little residual energy remaining to overstress dies.

5.6 Off-centre forging on friction screw presses

If the centre of pressure of a die impression is not in the centre of the bed of a friction screw press the permissible forging load is reduced below the rated loading of the press. One press manufacturer suggests the following method for estimating the permissible degree of off-centre forging.

Let the rated tonnage of the screw press be R tonnef, the forging load L tonnef and the diameter of the screw D mm.

Then the permissible distance for off-centre forging a mm is found from

$$a = D \left(1 - \frac{L}{2R} \right)$$

For example consider a 400 tonnef rated press with a screw diameter of 200 mm. Let the expected forging load be 300 tonnef. Then the permissible distance for off-centre forging is

$$a = 200 \left(1 - \frac{300}{2 \times 400} \right) = 125 \text{ mm}$$

5.7 Estimation of forging energy requirement

It has already been pointed out that in selecting a suitable friction screw press to make a particular forging both load and energy requirements must be considered.

A method for estimating forging loads has already been presented in section 4.4 and a method for estimating forging energy is given here. The method only gives approximate values but it can prove useful in machine selection.

The forging shown in figure 5.16 will be considered.

The volume of the forging is 489,950 mm³ and it is assumed that it is made from a billet 15% greater in volume. The initial billet dimensions are assumed to be 71 mm diameter × 142 mm. Prior to forging this billet is assumed to be upset to 85 mm diameter × 100 mm and these latter dimensions are used for the starting billet size.

Let L_{fo} = length of forging	mm =	152
L_{fl} = length of flash	mm =	172
A_{fo} = area of forging	mm ² =	18,148
A_{fl} = area of flash	mm ² =	5,090
A = area of forging plus flash	mm ² =	23,238
A_o = original billet area	mm ² =	5,675
V_{fo} = volume of forging	mm ³ =	489,950
V_{fl} = volume of flash	mm ³ =	10,180
r = flash land ratio	=	5
σ = yield strength of material	kg/mm ² =	6.3

The total forging load L is calculated as explained previously in section 4.4.

The forging material is assumed to be mild steel at 1250°C so that no correction of the calculated load is necessary.

The final forging load L is calculated as follows:

$$\begin{aligned}
 \text{Load on flash} \quad L_{fl} &= 6.3 A_{fl}^2 \sqrt{1/(L_{fl} V_{fl})} \\
 &= 6.3 \times 5090^2 \sqrt{1/(172 \times 10,180)} \\
 &= 123350 \text{ kg} \\
 &= 123 \text{ tonnef}
 \end{aligned}$$

$$\begin{aligned}
 \text{Load on forging} \quad L_{fo} &= 6.3 \times (1+r) \times A_{fo}^2 \sqrt{1/(L_{fo} V_{fo})} \\
 &= 6.3 \times 6 \times 18148^2 \\
 &\quad \sqrt{1/(152 \times 489,950)} \\
 &= 1442619 \text{ kg} \\
 &= 1442 \text{ tonnef}
 \end{aligned}$$

$$\text{Total forging load } L = 1442 + 123 = 1565 \text{ tonnes}$$

The forging energy is then estimated using the method already outlined in section 2.2.6.

Figure 5.16 shows that the top die peg will strike the billet when the bottom of the peg is 100 mm from the base of the bottom die and load will build up until the bottom of the peg is 18 mm from the base of the die. Thus the displacement under load is 100 - 18 = 82 mm.

Since the maximum load is 1565 tonnef the energy is given by

$$E = 82 \times 1565 \times \text{correction factor}$$

From figure 2.4 the correction factor is 0.25

$$\text{Thus } E = 82 \times 1565 \times 0.25 = 32 \text{ 000 mkg}$$

Figure 5.17 shows the characteristic energy-load curve for a friction screw press with a nominal load rating of 1500 tonnef. It is clear that with such a press the forging considered would need two forging blows to provide the energy required.

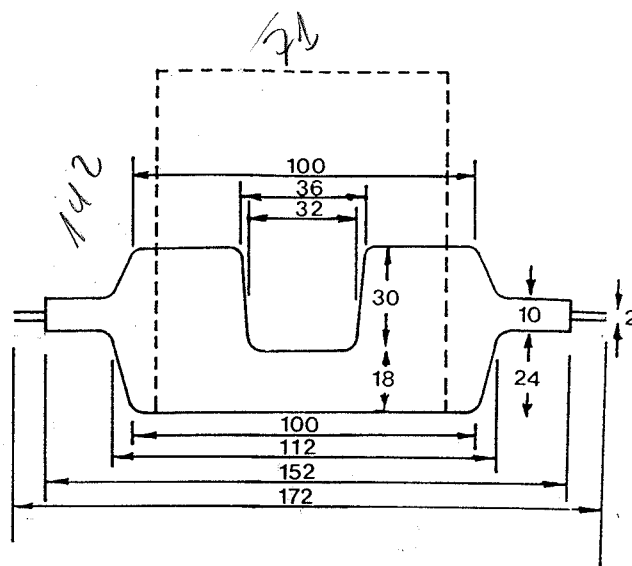


FIG. 5.16

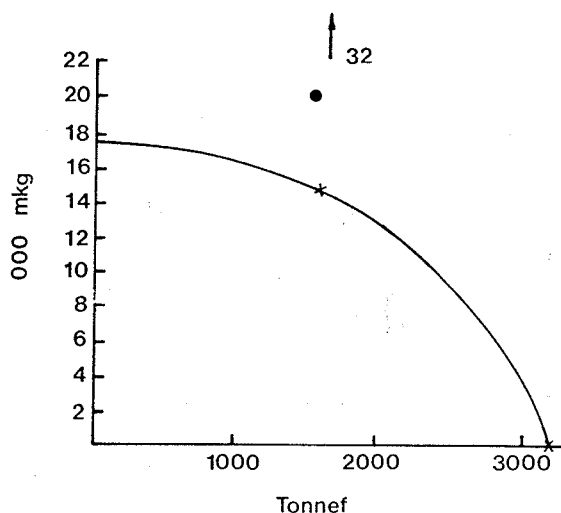


FIG. 5.17

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6 HORIZONTAL FORGING MACHINES

6.1 Principle of horizontal forging

The principle of the horizontal forging machine is illustrated schematically in figure 6.1. A bar is located in a half die cavity in a fixed die A and when the machine is actuated the moving die B closes on the bar to grip it before the heading punch C moves forward to form the bar. The punch then retracts and the die B moves to its open position allowing the bar to be removed or placed in another forging station.

Both the heading punch slide and the moving die are actuated by a crankshaft, the former by means of a pitman or connecting rod and the latter by a toggle mechanism connected to the crankshaft via a linkage system.

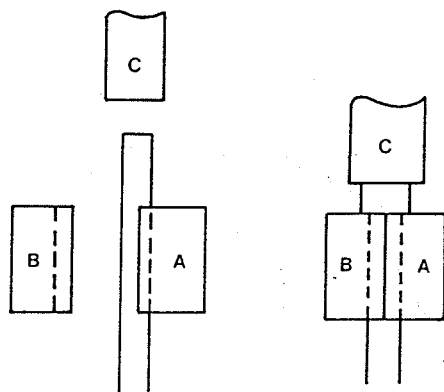


FIG. 6.1

Operation of horizontal forgings machine.

The drive system used by one manufacturer is shown schematically in figure 6.2.

To protect the machine against accidental overload caused by misplacing of bars in the gripping dies a safety device is incorporated in the link mechanism which drives the closing die toggle.

When overload occurs a link is displaced which prevents closure of the moving die but still allows the heading punch to complete its full stroke.

In older machines the displaceable link is held closed by a breaker bolt which deforms or fractures on overload and must be replaced.

In modern machines the link is held closed by a pneumatic or hydraulic cylinder which is self resetting after an overload occurs.

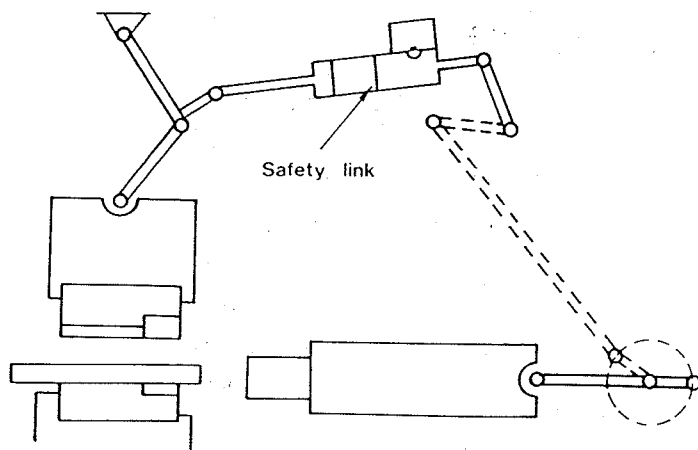
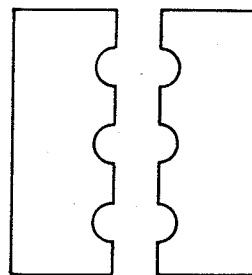


FIG. 6.2

Drive mechanism for horizontal forging machine.

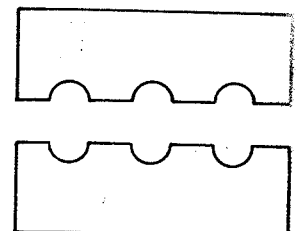
Older horizontal forging machines have the die passes disposed in a vertical manner (figure 6.3a) but many modern machines have the dies arranged horizontally (figure 6.3b).

The latter system provides improved die visibility and reduces operator fatigue since heavy bars do not have to be supported by hand when moving from one pass to another.



a

Vertically split dies



b

Horizontally split dies

FIG. 6.3

6.2 Machine rating and applications

Historically horizontal forging machines were nominally rated according to the maximum size of bar which could be upset. Thus machines were rated as 25 mm, 50 mm and so on.

Nowadays manufacturers give more precise specifications and quote for any upsetter the maximum permissible heading load and the maximum gripping load.

Typical machine specifications are shown in table 6.1.

Table 6.1

Typical horizontal upsetting machine specifications

Nominal machine size mm	25	50	75	100	125
Upsetting load—tonne	75	250	500	1000	1250
Gripping load—tonne	75	250	500	1250	1500

Since there is an increasing tendency to combine upsetting for preforming with finish forging on upsetters with horizontally disposed dies manufacturers will commonly supply machines with an increased gripping load to accommodate final forging.

In certain instances two or four additional tie bars are incorporated to reduce the press spring which occurs with the conventional C frame type design.

Careful consideration must be given to applications where the horizontal upsetter is to be used as a preforming and final forging machine by using the gripping die mechanism as a forging press.

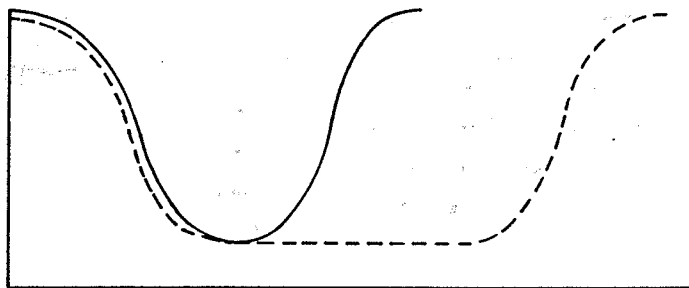
In the conventional forging press the motion of the ram carrying the dies is sinusoidal and results in a ram displacement-time curve as shown by the full line in figure 6.4a. During forging on such a press the shape of the load-time curve will be as shown by the full line in figure 6.4b.

When using the moving dies of an upsetter for press forging the displacement time curve is as shown by the broken line in figure 6.4a with an appreciable dwell time at bottom dead centre due to the mechanism used to close the dies.

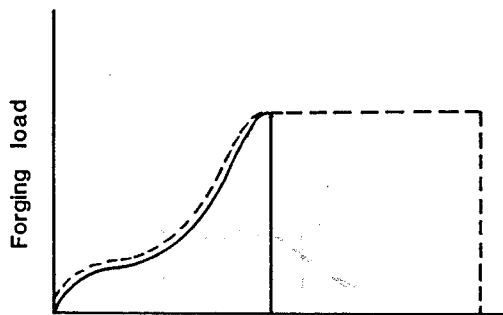
This leads to a load-time curve as shown by the broken line in figure 6.4b with the maximum forging load sustained for a relatively long period whilst the dies are held closed.

This increased die contact time under load leads to increased heat transfer from the forging to the dies and the maintenance of the forging load can lead to fatigue of the dies.

Because of these considerations die lives when using a horizontal upsetter as a forging press may be lower than would be the case when forging on a conventional crank press.



Time
FIG. 6.4a



Time
FIG. 6.4b

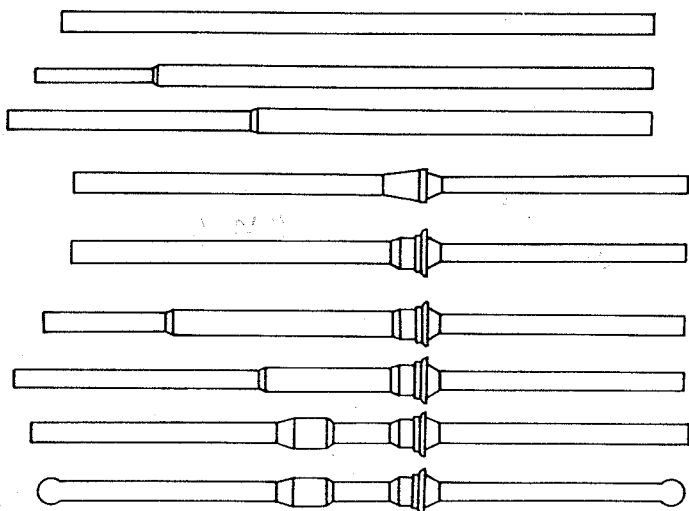


FIG. 6.6

In spite of this there are many reported applications of the use of horizontal upsetters as preforming and finish forging machines, some of which are illustrated in figure 6.5.

Where extrusion operations are carried out in the split dies very high closing loads must be used to ensure that the dies do not open and cause fin formation during extrusion. This may necessitate the use of a specially built machine.

Cold forging operations have also been carried out on upsetters as illustrated by figure 6.6 which shows the manufacturing sequence for the production of a cycle crank and spindle by a combination of cold extrusion and cold upsetting.

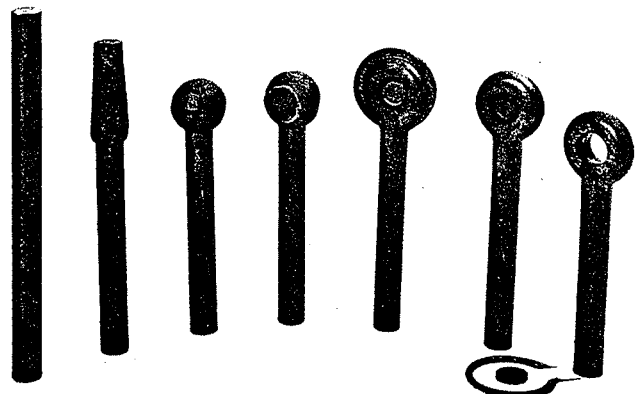
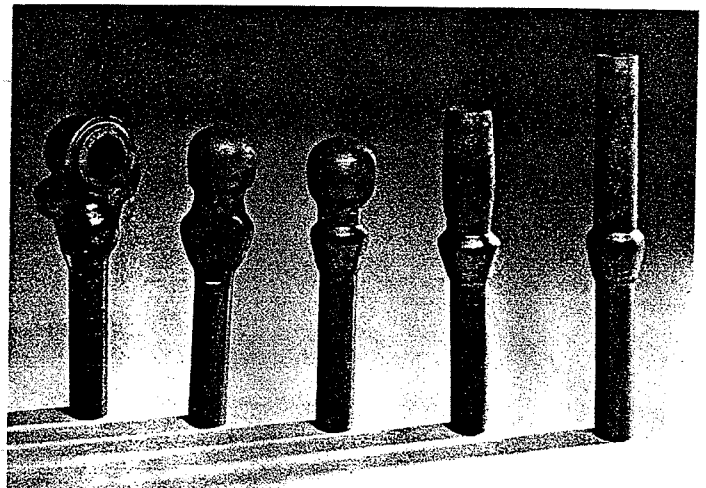
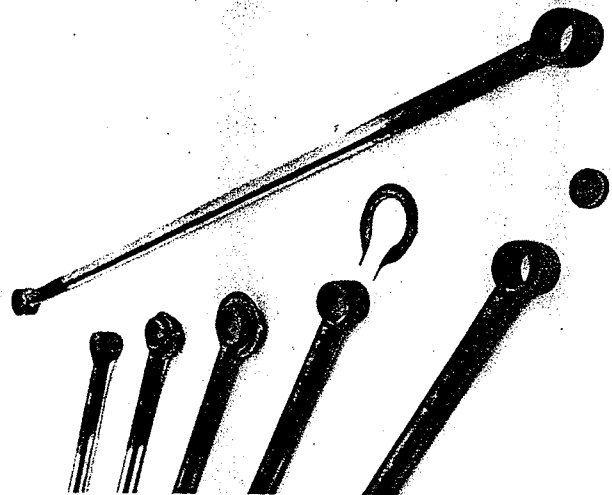


FIG. 6.5

6.3 Types of heading tool holder

Horizontal upsetters with vertically split dies may be supplied with adjustable punch holders as illustrated in figure 6.7. The use of packing below and behind the individual components of the punch holder allows vertical and horizontal adjustment for tool alignment as shown.

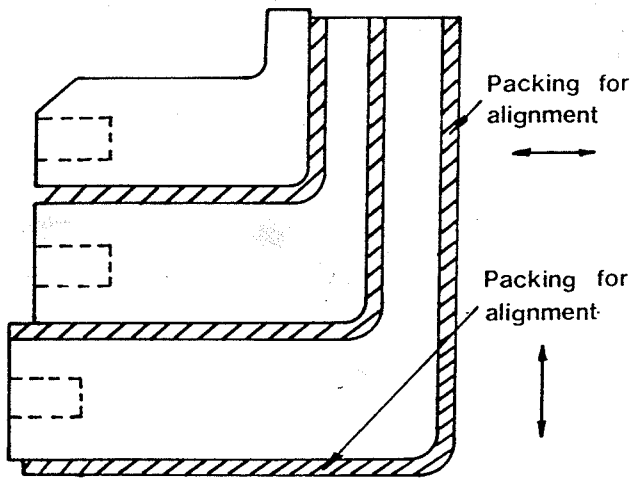


FIG. 6.7
Fully adjustable punch holders.

Alternatively a solid punch holder may be used as shown in figure 6.8. In this case only back to front adjustment is possible and the die bore centres must be machined accurately in relation to the punch centres.

Whilst this type of header may be initially more troublesome than the fully adjustable one once the respective punch balance has been established the setting of dies and punches is simplified and the arrangement is very robust.

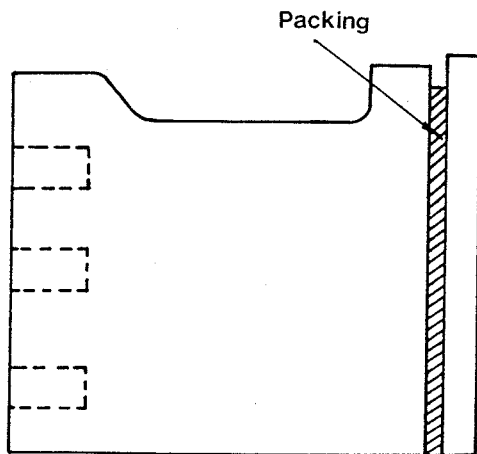


FIG. 6.8
Solid punch holder.

In machines with the dies split horizontally individual punch adjustment is obtained by a system of wedges as shown in figure 6.9. This arrangement facilitates rapid tool adjustment.

6.4 Forging in horizontal upsetters

When upsetting in horizontal forging machines the early metal gathering passes are usually coning operations with the cones slightly under filled to avoid the formation of fins at the mouth of the cone. The final operation may be performed in a die with a flash land and gutter (figure 6.10a) or in an enclosed die (figure 6.10b).

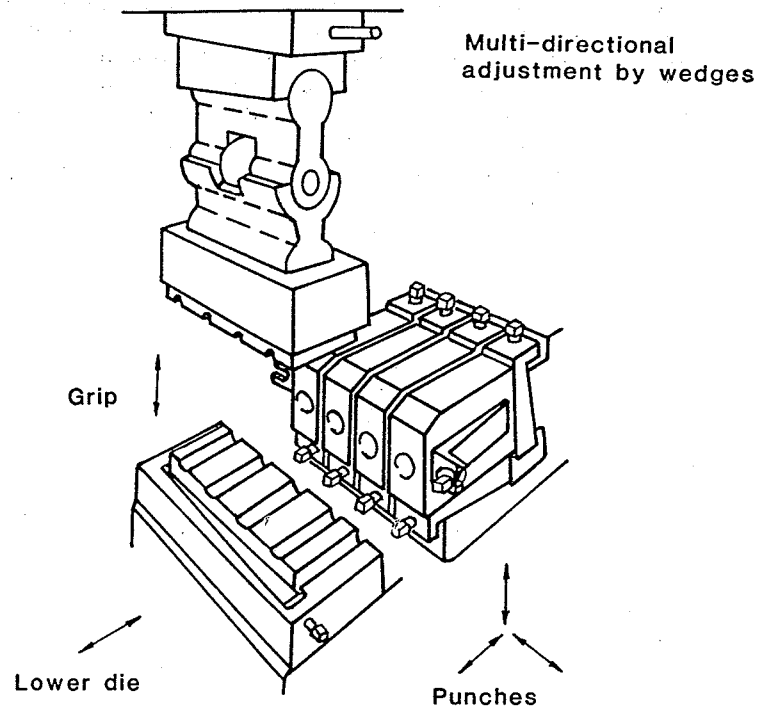


FIG. 6.9
Die and punch adjustment.

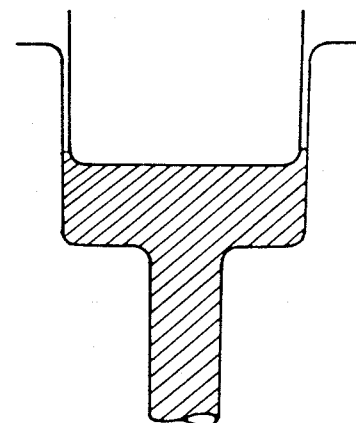
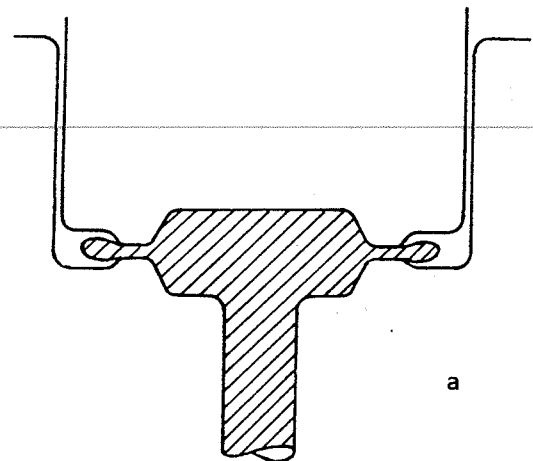


FIG. 6.10
Design of finishing dies.

Flashed and guttered dies for horizontal upsetting dies are designed on exactly the same principles as those used on crank presses. The gutter must be adequate to accept the flash and the header punch surface beyond the gutter must not contact the die surface or over loading of the machine can occur.

The use of flashed dies does, of course, involve an extra clipping operation.

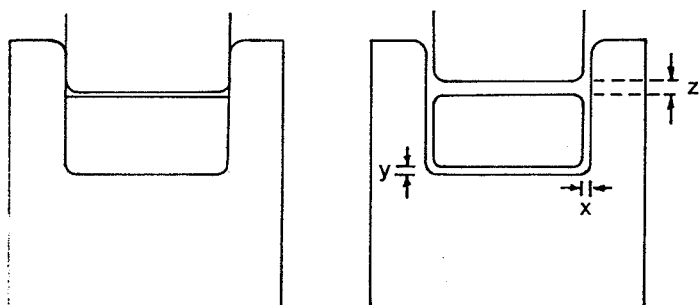
Where the enclosed upsetting die is used lower loads are encountered for a given shape provided the metal available only just fills the die.

If excess metal is presented to a closed die a slight fin is formed by metal extruding between the die and the punch. This may have to be ground off after forging.

If significant amounts of excess metal are presented to closed dies very high forging loads are built up because the excess metal has no ready escape route as is the case in flash and gutter dies.

In closed dies the excess metal is accommodated partly by the formation of the fin already referred to, partly by elastic expansion of the dies and partly by elastic stretching of the machine frame. This mechanism is illustrated in figure 6.11 whilst figure 6.12 presents the results of theoretical calculations which show how forging load is influenced by excess metal when closed dies are used.

It is evident from figure 6.12 that overfilling of closed die passes can lead to serious overloading of both dies and machine and should be avoided.



x = radial elastic die growth
y = die elastic compression
z = machine deflection

FIG. 6.11

Accommodation of excess metal in a closed die.

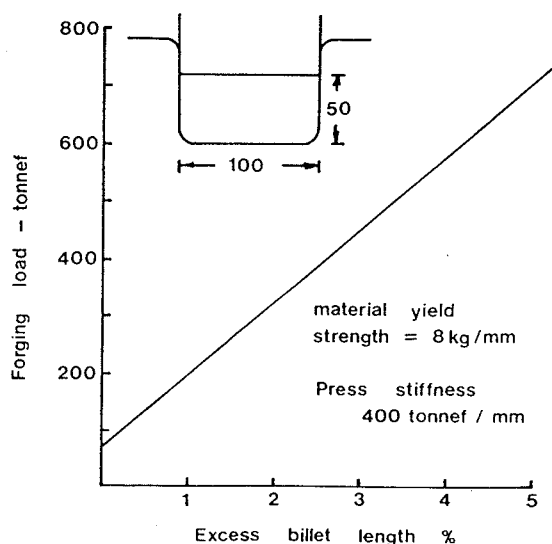


FIG. 6.12

Influence of excess metal on forging load in closed die forging.

Where a high final upsetting load is anticipated it is advantageous to position the last pass in the centre of the dies.

To obtain consistent results in upset forging the length of heated bar is important and generally the correct length must be determined by trial and error.

Pushing back of the bar during forging can occur leading to under filled forgings. This can sometimes be overcome by increasing the grip by adjusting the moving die.

Over-adjustment however can lead to the safety mechanism already referred to operating and thus in some cases it may be necessary to use some form of back stop.

This can be achieved in three ways as shown in figure 6.13. If the bar length allows an adjustable back stop plate may be fixed to the machine (figure 6.13a). Alternatively specially made back stop tongs may be used (figure 6.13b). The third method involves the use of swan-necked tongs which allow a stop to be machined in the die cavity (figure 6.13c) against which the end of the bar rests.

Occasions may arise where a heading tool is so long that it does not leave the dies even in the retracted position.

In this case the maximum diameter is limited by the die opening unless a slot can be machined through the die bores to allow the upset to be moved forward and then lifted between the dies.

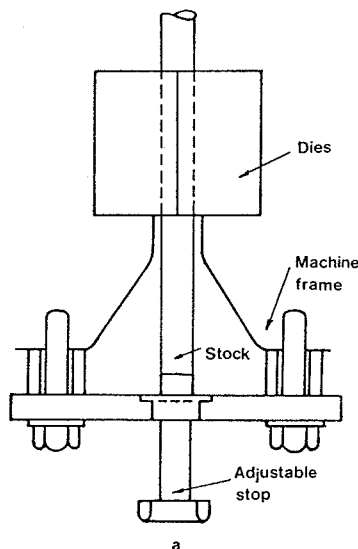


FIG. 6.13a

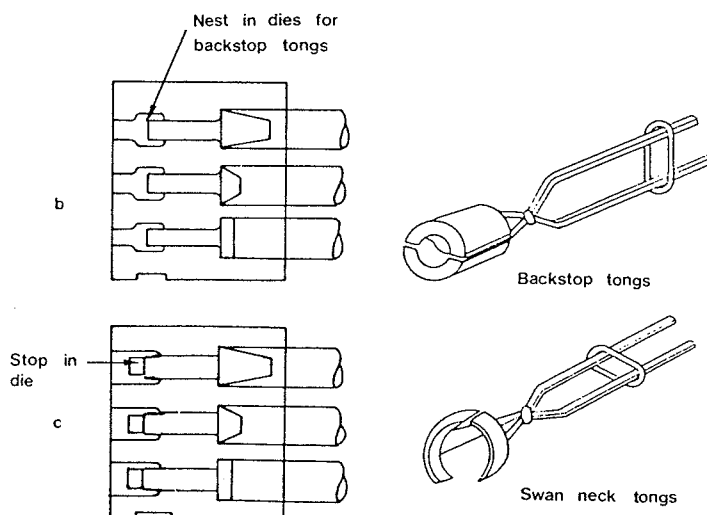
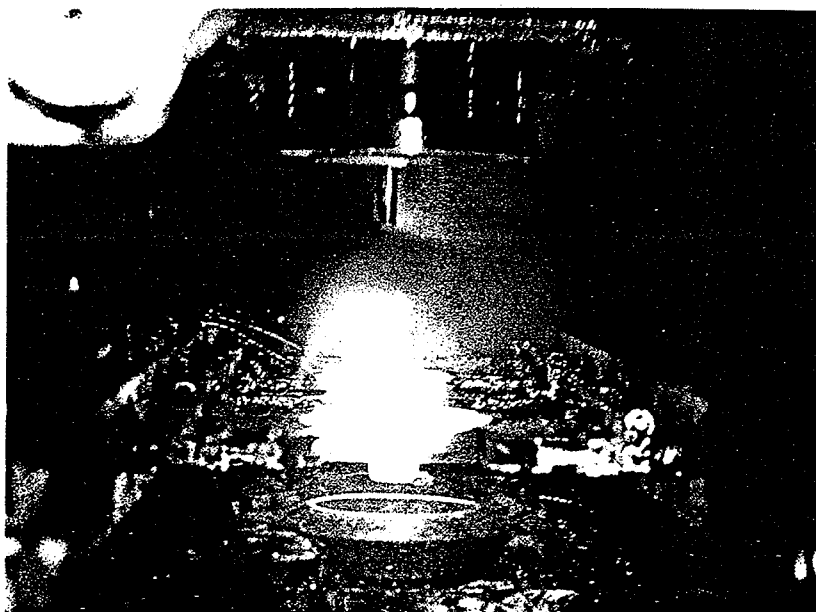


FIG. 6.13 b and c

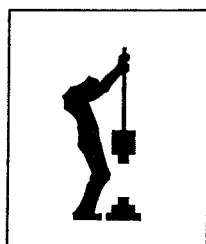
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6.5 Load requirements for upsetting

Load estimation for horizontal forging is even more uncertain than for press forging. The method presented here in figure 6.14 is based on that given in the Russian Forging Handbook.

Examples of the application of the data are given below:

Example 1

Consider a simple coning tool with a mouth diameter of 50 mm. Suppose the material being forged is 605M36 (En 16) at 1150°C.

Then from figure 6.14 $K=1$
 from table 4.1 $F=1.5$ and
 $D=50$ mm

Then the load is given by

$$L = 0.005 \times 50^2 \times 1 \times 1.5 = 19 \text{ tonnef}$$

Example 2

Consider a forging of type III in figure 6.14 with $t=12$ mm and $D=40$ mm. Assume the forging material is 080M40 (En 8) forged at 1200°C.

Then from figure 6.14 type III forging $K=4.2$
 from table 4.1 $F=1.1$ and
 $D=40$ mm

Then the load is given by

$$L = 0.005 \times 40^2 \times 4.2 \times 1.1 = 37 \text{ tonnef}$$

Where the final forging operation is performed in flash and gutter dies the forging load may be estimated using the method already given for press dies. That part of the forging held in the gripper dies is neglected.

Thus for the forging shown in figure 6.15 the load is calculated as follows:

$$\begin{aligned} \text{Volume of forging} &= \frac{\pi \times 90^2 \times 18}{4} + \frac{\pi \times 50^2 \times 14}{4} \\ &= 142018 \text{ mm}^3 \end{aligned}$$

$$\text{Area of forging} = \frac{\pi \times 90^2}{4} = 6363 \text{ mm}^2$$

$$\text{Length of forging} = 90 \text{ mm}$$

$$\text{Volume of flash} = \frac{\pi \times 110^2 \times 2}{4} - \frac{\pi \times 90^2 \times 2}{4} = 6284 \text{ mm}^3$$

$$\text{Area of flash} = \frac{\pi \times 110^2}{4} - \frac{\pi \times 90^2}{4} = 3142 \text{ mm}^2$$

$$\text{Length of flash} = 110 \text{ mm}$$

$$\text{Flash land ratio} = 10/2 = 5$$

Following section 4.4

$$\begin{aligned} L_{fl} &= 6.3 \times 3142^2 \times \sqrt{1/(6284 \times 110)} \\ &= 74806 \text{ kg} = 75 \text{ tonnef} \end{aligned}$$

$$\begin{aligned} L_{fo} &= 6.3 \times 6363^2 \times (1+5) \times \sqrt{1/(142018 \times 90)} \\ &= 428077 \text{ kg} = 428 \text{ tonnef} \end{aligned}$$

$$\text{Total load} = 75 + 428 = 503 \text{ tonnef}$$

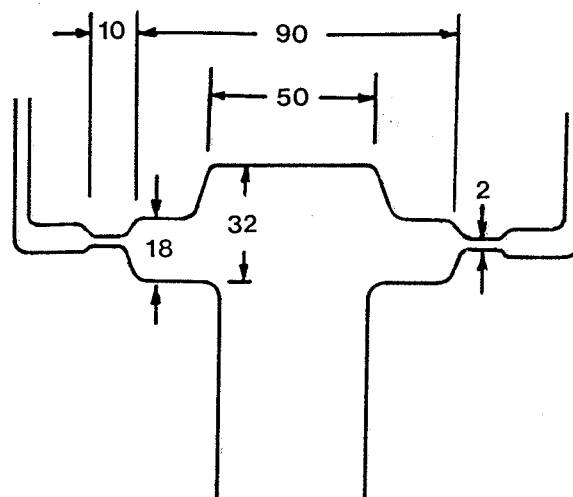


FIG. 6.15



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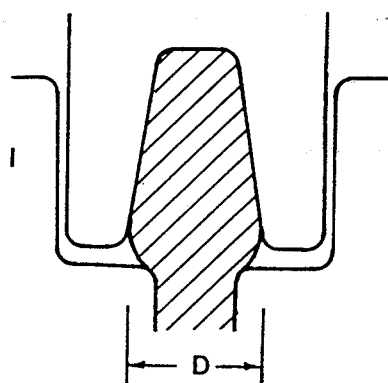
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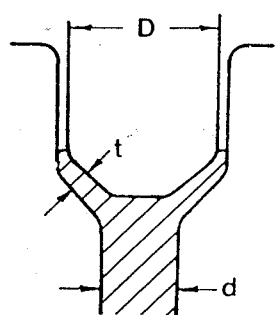
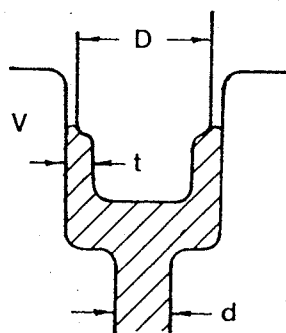
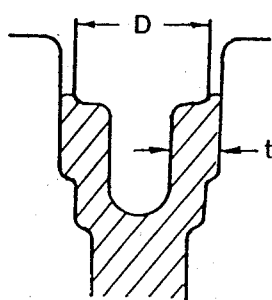
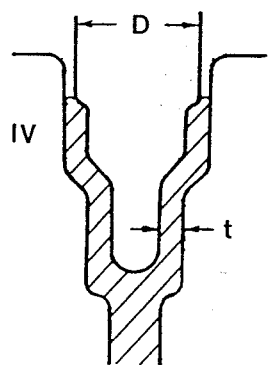
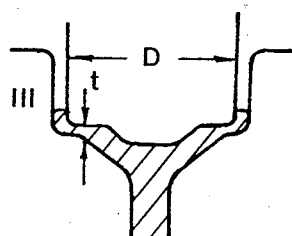
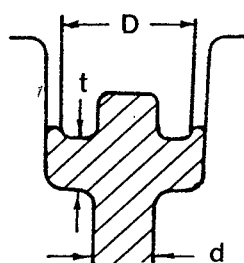
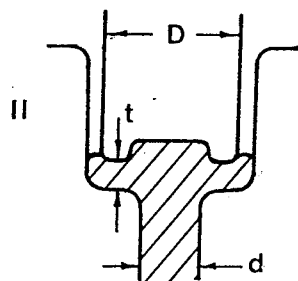
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$K = 1$



$$L = 0.005 D^2 K F \text{ tonnef}$$

D in mm K from graphs

F from table 4.1

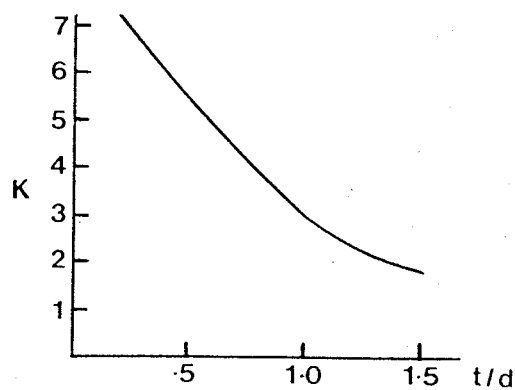
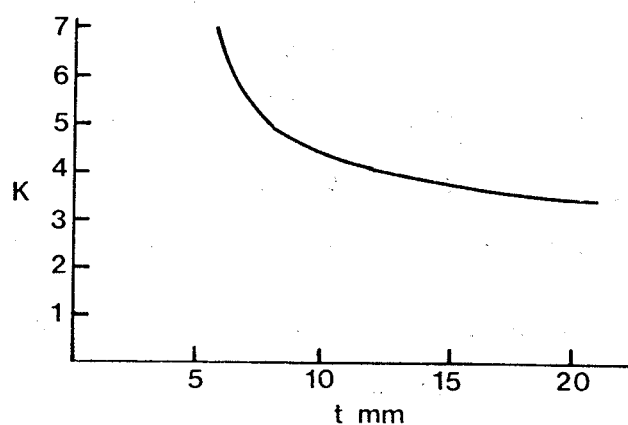
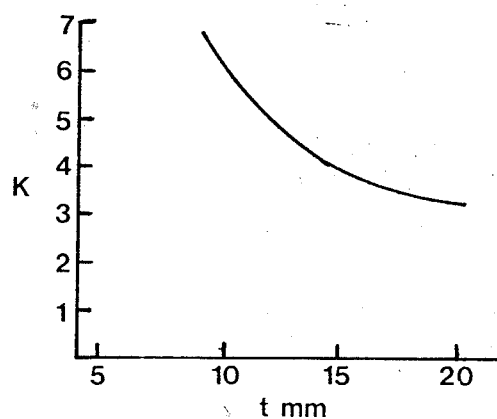
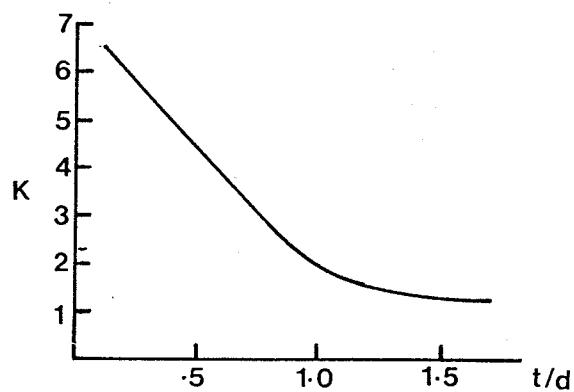


FIG. 6.14

7 ELECTRIC UPSETTERS

7.1 Principle of the electric upsetter

Forgings such as the half-shaft shown in figure 7.1 have a very big diameter flange in relation to the diameter of the shaft so that a large amount of metal must be gathered on the end of the bar to forge the flange.

To achieve the required degree of gathering in a conventional horizontal upsetting machine would require an unacceptably large number of coning passes.

For such forgings the electric upsetter allows large amounts of metal to be gathered using the principle illustrated in figure 7.2.

The bar "a" to be upset is clamped between electrodes "d" and is pressed against an electrode anvil "b" by means of a pressure cylinder "c".

An electric current is passed through the end of the bar heating it between the electrodes. During operation the hydraulic cylinder "c" pushes the bar through the electrodes "d" thus causing the end of the bar to upset as illustrated.

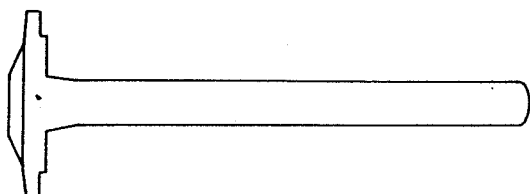


FIG. 7.1

Half-shaft forging with large flange on the end of a small shaft.

In this way long lengths of bar can be continuously upset to produce a large diameter head as shown in figure 7.3. Where unconstrained upsetting is used the preform can be immediately transferred to another machine for finish forging.

Where a greater degree of shape control of the upset is required, as in producing a finished component rather than a preform, it is possible to upset into a die cavity as illustrated in figure 7.4.

The principle is similar to that already described except that the bar is upset against a cylinder which gradually retracts as the bar upsets to fill the die cavity.

During upsetting into a die considerable cooling occurs so that at the end of the operation the temperature of the upset may have fallen to 600-700°C.

The potential of the electric upsetting process is illustrated in figure 7.5 which shows a number of upset components.

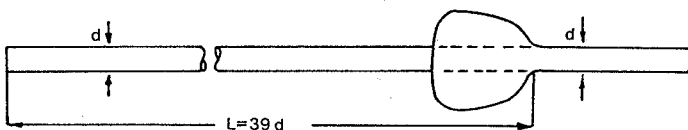
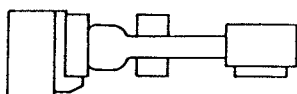
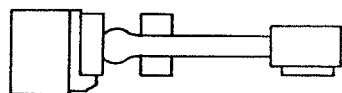
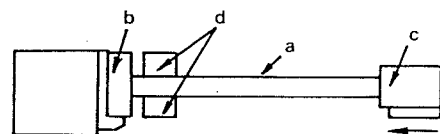


FIG. 7.3



a = bar stock
b and d = electrodes
c = hydraulic cylinder

FIG. 7.2

Principle of electric upsetting.

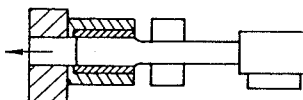
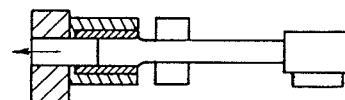
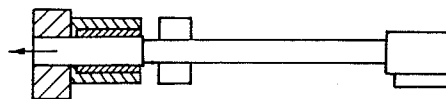


FIG. 7.4

Upsetting into a die cavity.

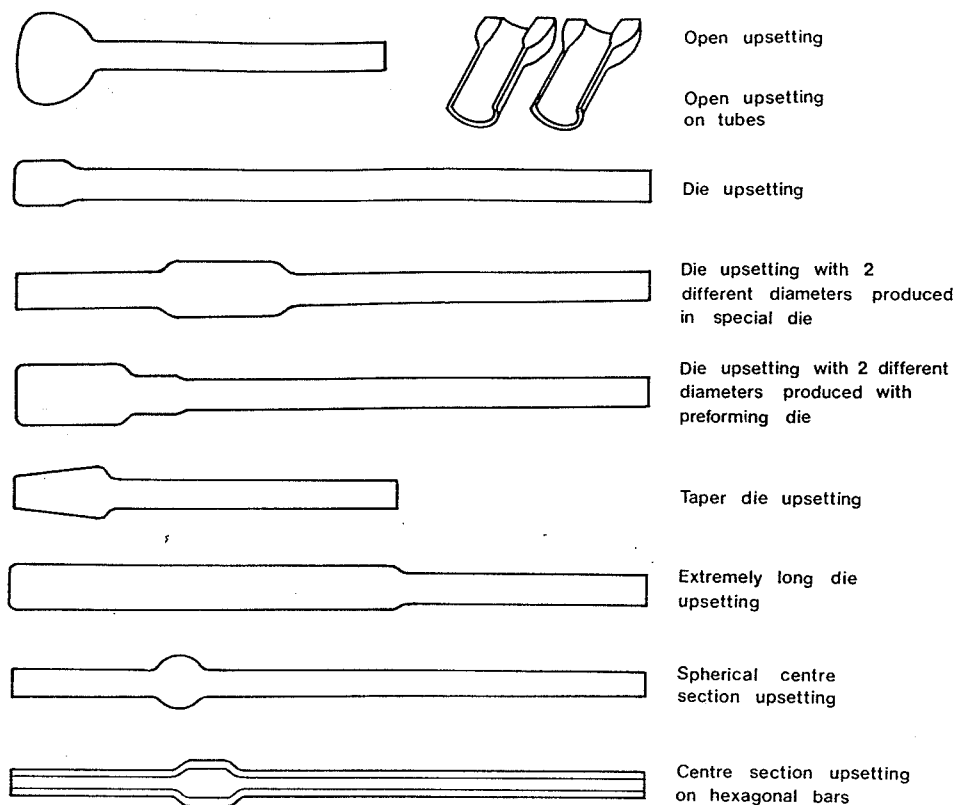


FIG. 7.5

Range of components produced by electrical upsetting.

7.2 Materials for upsetting

Most materials which are commonly forged can be electrically upset with the exception of copper where the low electrical resistivity leads to inadequate heating.

Both low alloy and high alloy steels and nickel based alloys are readily upset but aluminium alloys may present problems. This is particularly so for those alloys with a small solidus-liquidus temperature range and it is usually necessary to conduct trials to establish whether a particular alloy can be successfully upset.

Round bar is most commonly used but as figure 7.5 shows other shapes, including tube, can be used.

Because bars must slide between the electrodes and maintain good electrical contact, a smooth surface is essential. A maximum surface roughness of 0.02 mm is recommended. Bars with a drawn or peeled surface are preferred although ground and reeled bars may be satisfactory. Black bar is generally unsuitable for electric upsetting.

The bar end which contacts the anvil electrode must be smooth, flat and at right angles to the bar axis. The maximum permissible surface roughness of the bar end is about 0.05 mm.

7.3 Machine types

There are three types of electrical upsetter available. Horizontal machines (figure 7.6) are intended primarily for long bars where a long upset length is required. The machines also have facilities to prevent buckling of the long bar subject to the necessary upsetting force. Such machines will also accept die upsetting units and equipment for section upsetting.

Vertical upsetters (figure 7.7) are more economical of floor space but can accept only limited bar lengths and are therefore only produced at the smaller end of the size range.

Fully automatic machines are also produced (figure 7.8) which incorporate both upsetting and forging stations.

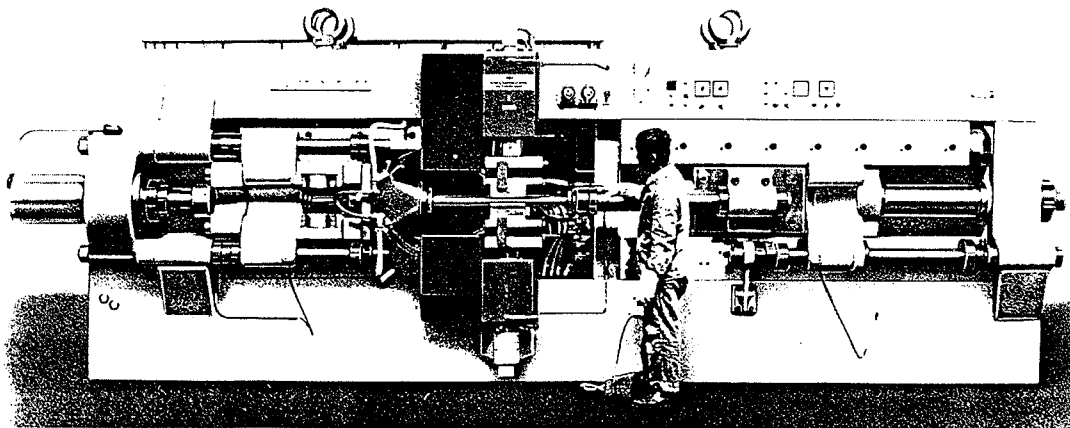


FIG. 7.6

Horizontal electrical upsetter.

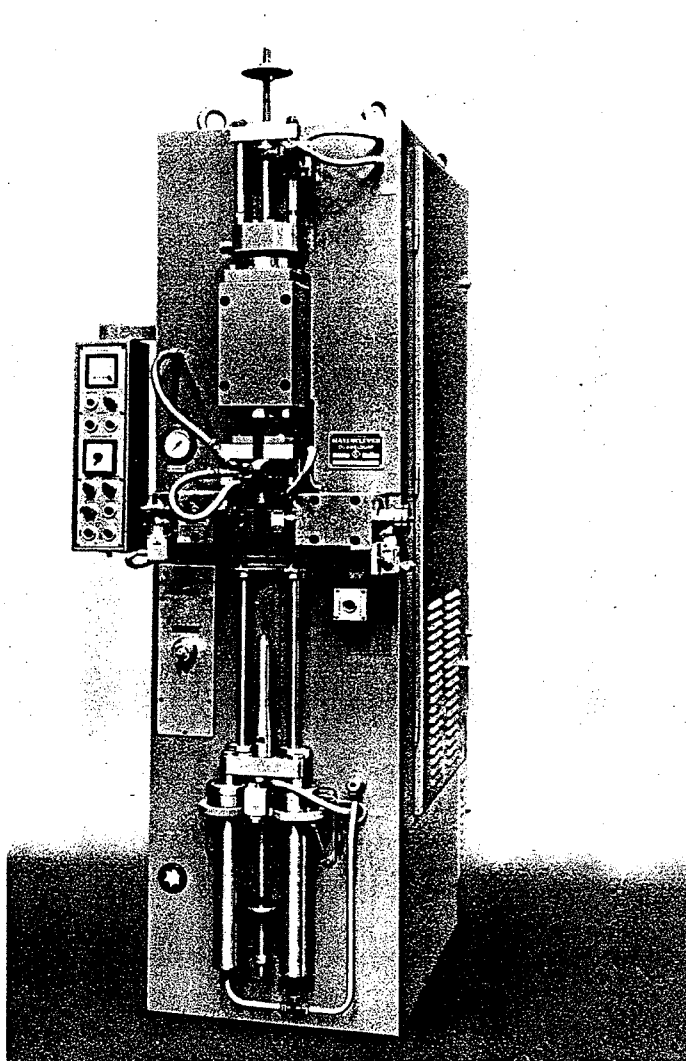


FIG. 7.7
Vertical electrical upsetter.

7.4 Machine rating and performance

Electrical upsetters are characterised by the nominal power rating of the transformer in kVA. An approximate relationship between the power rating and the range of bar sizes which can be upset is shown in figure 7.9. The data in the figure refer to low alloy and carbon steels. If the machine rating k in kVA is known the maximum bar size d mm which can be upset is given by

$$d = 4\sqrt{k}$$

The speed at which a bar can be upset depends on many factors but the main ones are power rating and bar diameter. Speeds generally vary between 5 and 10 mm/s and the relationships for carbon and low alloy steels are shown in table 7.1.

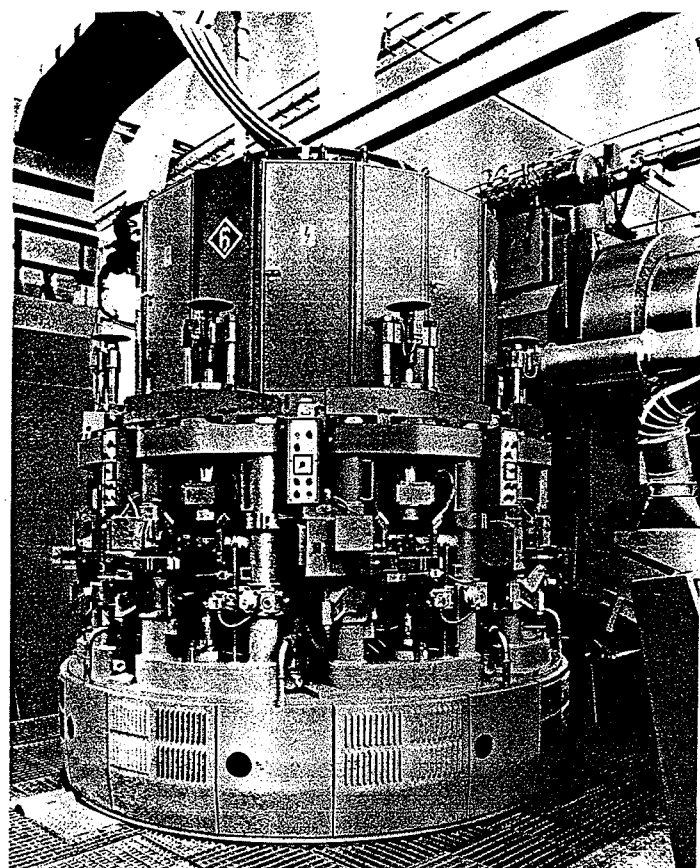


FIG. 7.8
Automatic electrical upsetter.

Example

A preform with an upset volume of 9600 mm^3 is to be made from 10 mm diameter bar on a 20 kVA electrical upsetter.

$$L = 1.27V/d^2 = 1.27 \times 9600/100 = 122 \text{ mm}$$

$$L_H = L + 0.5d = 122 + 5 = 127 \text{ mm}$$

From table 7.1 the upsetting speed $S = 10 \text{ mm/s}$, ie the maximum speed of the machine.

$$\text{Thus } t_u = L_H/S = 127/10 = 12.7\text{s}$$

Suppose the handling time t_H is 10 seconds

$$\text{Then } t_T = t_u + t_H = 12.7 + 10 = 22.7\text{s}$$

and the production rate P is

$$P = 3600/t_T = 3600/22.7 = 158 \text{ pieces/hour}$$

Where the electrical upsetter is used as a preforming machine to feed a final forging machine such as a friction screw press it is commonly found that the upsetter cannot match the production rate of the forging machine and so two upsetters may be necessary.

Table 7.1

Machine Size	Bar diameter $d = 8$	10	12	14	16	18	21	24	28	30	35	40	45	50	56	63	70 mm
	Upsetting speed																
12 kVA	10.0	8.2	6.0														mm/s
20 kVA			10.0	7.2	5.8	5.0											mm/s
32 kVA				10.0	8.0	7.0	5.5										mm/s
50 kVA						10.0	7.5	6.1	5.0								mm/s
80 kVA								8.7	7.0	6.4	5.2						mm/s
125 kVA										10.0	8.0	6.5	5.0				mm/s
315 kVA														10.5	8.0	6.2	5.0 mm/s

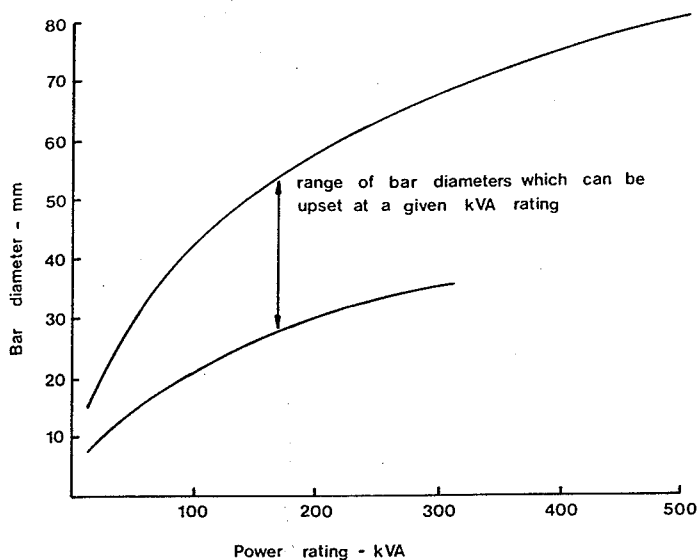


FIG. 7.9

Relationship between bar size and power rating.

8 WIDE RAM PRESSES

8.1 Machine characteristics

A modern trend in forging is the use of wide ram presses in conjunction with both hammer and press forging lines.

These machines, as shown in figure 8.1 are four point suspension presses and this arrangement allows for an exceptionally large ram area and the facility to sustain a high degree of off-centre loading.

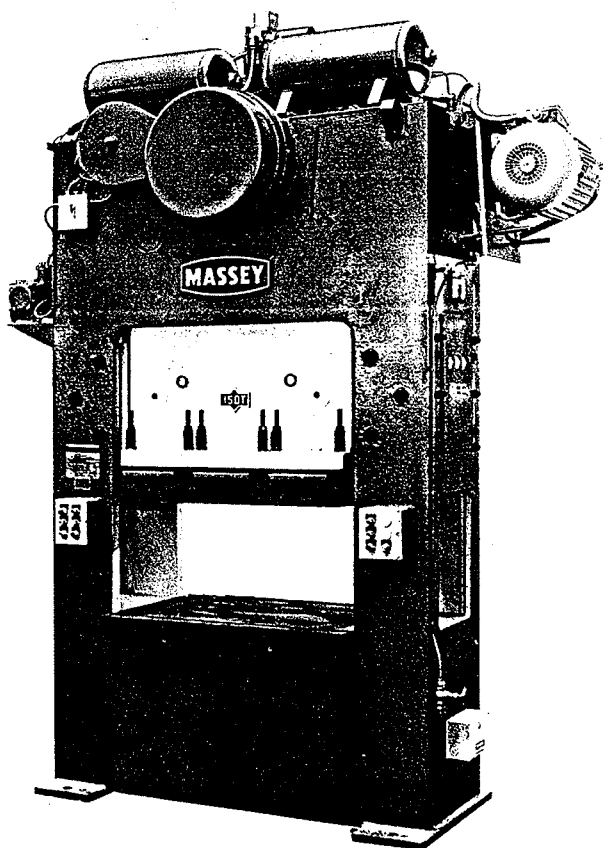


FIG. 8.1a

Wide ram press.

Figure 8.2 may be used to establish the loading capacity of a wide ram press at any point on the bed area. Suppose for instance an operation is performed on the press such that the centre of loading is three quarters of the distance from the centre of the ram to the centre line of the pitmans ($x=0.75$) and halfway back on the press from the centre line ($y=0.5$). This corresponds to the point marked P in figure 8.2 and the diagram shows that the permissible loading at this point is 80% of the nominal press rating, ie on a 500 tonnef press the permissible load at P would be $500 \times 0.8 = 400$ tonnef.

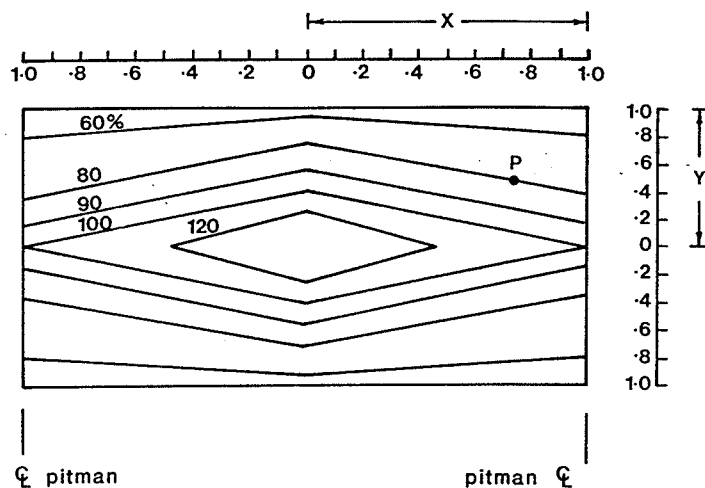


FIG. 8.2

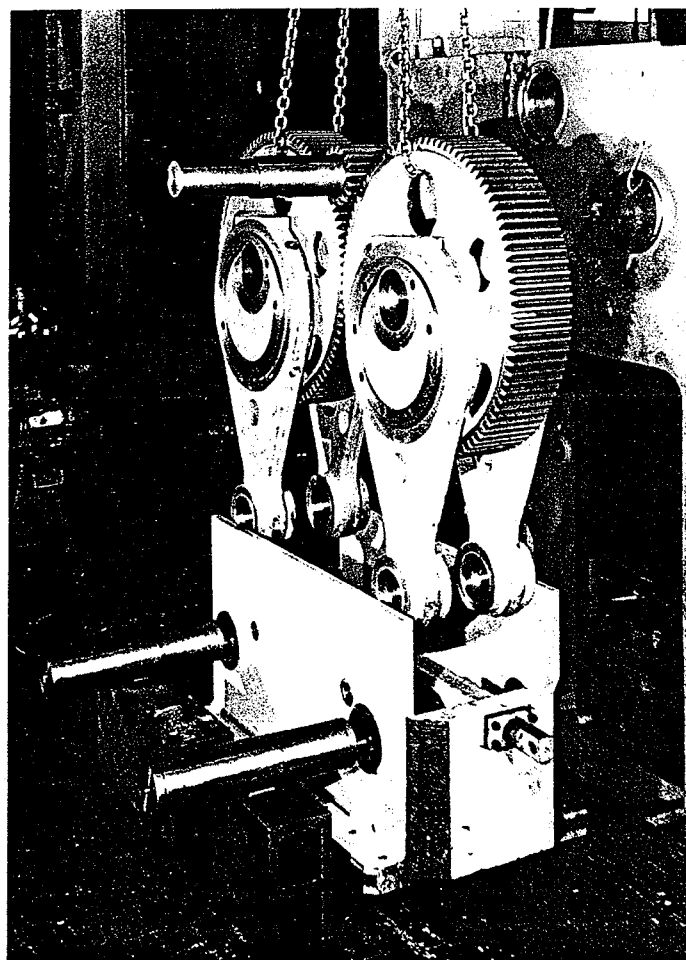


FIG. 8.1b

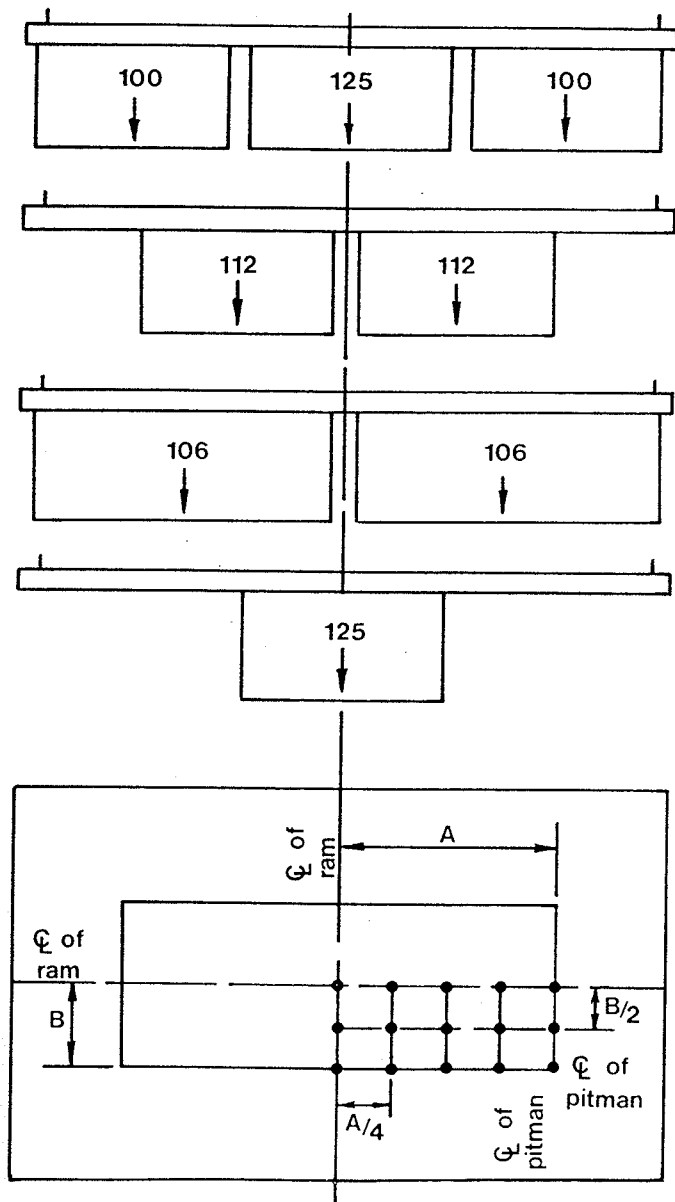
Wide ram press—construction details.

Alternatively figure 8.3, which is self explanatory, may be used to establish allowable loading values.

Because several stations can be accommodated in wide ram presses they can be used for other functions in addition to clipping and piercing. Operations commonly performed are upsetting of billets prior to forging and hot coining of forgings.

It is common when using wide ram presses for upsetting operations to find that although the press has a high enough load capacity for the upset it has insufficient energy capacity to perform the forging in one blow.

Methods for estimating load and energy requirements together with worked examples are given below.



125	118	112	106	100
94	88.5	84	80	75
62.5	59	56	53	50

% of rated press load

FIG. 8.3

8.2 Estimation of upsetting load and energy

If the final diameter of the upset piece is d_f and the final height is h_f then assuming mild steel upset at 1250°C the forging load L is given by

$$L = 0.005 d_f^2 (1 + d_f/6h_f)$$

If d_f and h_f are in mm the load L is in tonnef.

If the material is other than mild steel and the forging temperature is other than 1250°C the calculated load must be multiplied by a correction factor obtained from table 4.1.

To calculate the energy required the volume V of the billet and the initial and final heights h_o and h_f must be known.

The energy E is then found from

$$E = 0.0063V \left[A + \frac{\sqrt{V}}{8} (B) \right]$$

Where the values of A and B depend on the ratio h_o/h_f and the initial height h_o . The values of A and B can be found from the graphs in figures 8.4 and 8.5 respectively.

If the volume of the billet is in mm^3 and the heights are in mm the energy E is in mkg.

As an example of the use of those formulae consider a billet $75 \text{ mm square} \times 115 \text{ mm long}$ upset to a disc 25 mm thick .

Then the data required for the load and energy calculation are

$$V = 75 \times 75 \times 115 = 646875 \text{ mm}^3$$

$$h_o = 115 \text{ mm}$$

$$h_f = 25 \text{ mm}$$

$$d_f = 180 \text{ mm calculated from } V \text{ and } h_f$$

$$h_o/h_f = 4.6$$

$$\begin{aligned} \text{Thus } L &= 0.005 d_f^2 (1 + d_f/6h_f) \\ &= 0.005 \times 180^2 (1 + 180/6 \times 25) \\ &= 162 (1 + 1.2) \\ &= 356 \text{ tonne} \end{aligned}$$

To calculate the energy the values of A and B must be read from the graphs

$$A = 1.52 \text{ for } h_o/h_f = 4.6$$

$$B = 0.008 \text{ for } h_o/h_f = 4.6 \text{ and } h_o = 115$$

$$\begin{aligned} \text{Then } E &= 0.0063V \left[A + \frac{\sqrt{V}}{8} (B) \right] \\ &= 0.0063 \times 646875 \left[1.52 + \frac{(804)}{8} (0.008) \right] \\ &= 4075 [1.52 + 0.8] \\ &= 9454 \text{ mkg} \end{aligned}$$

For materials other than mild steel and temperatures other than 1250°C the calculated energy is corrected by the multiplying factors given in table 4.1

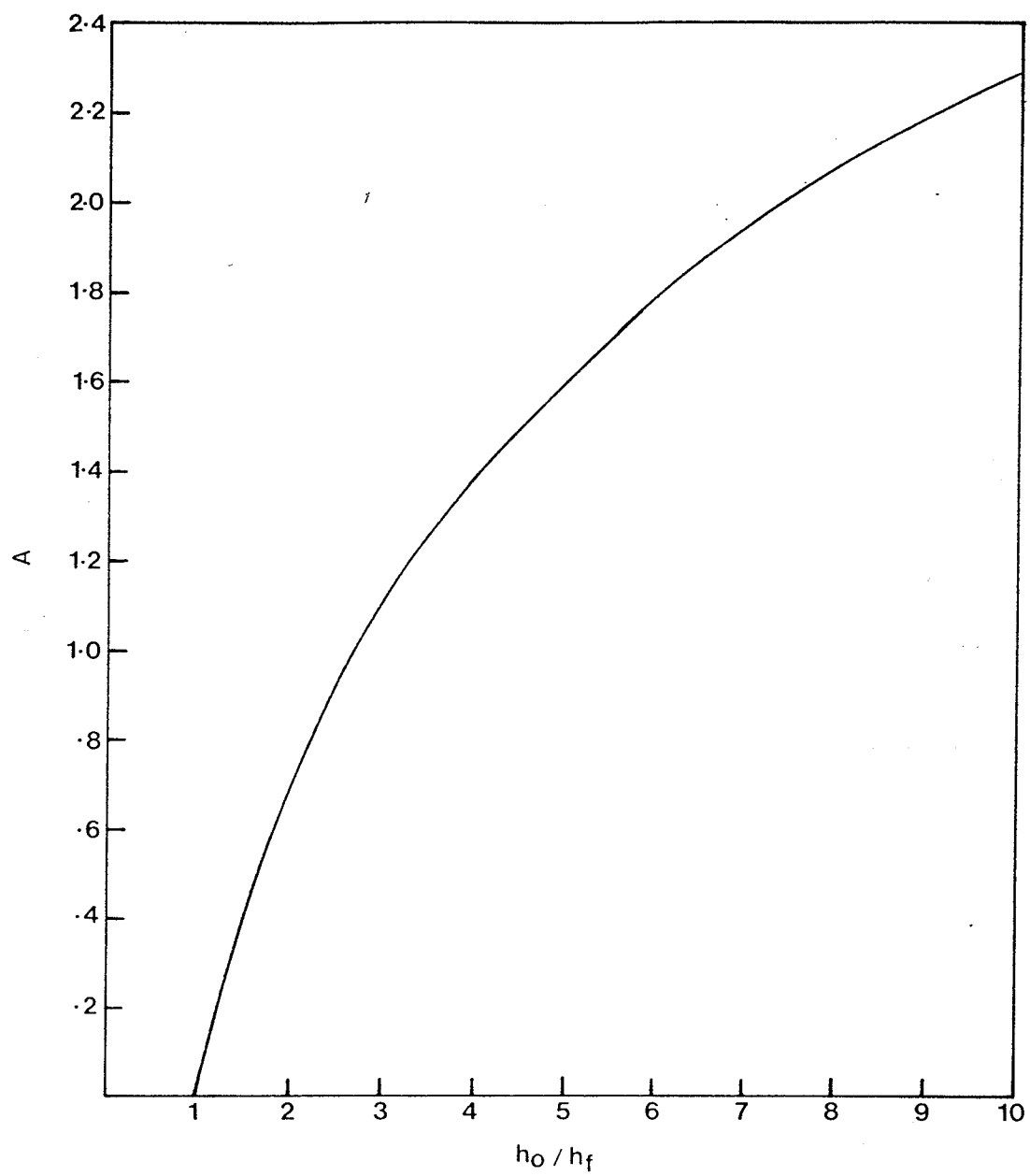


FIG. 8.4

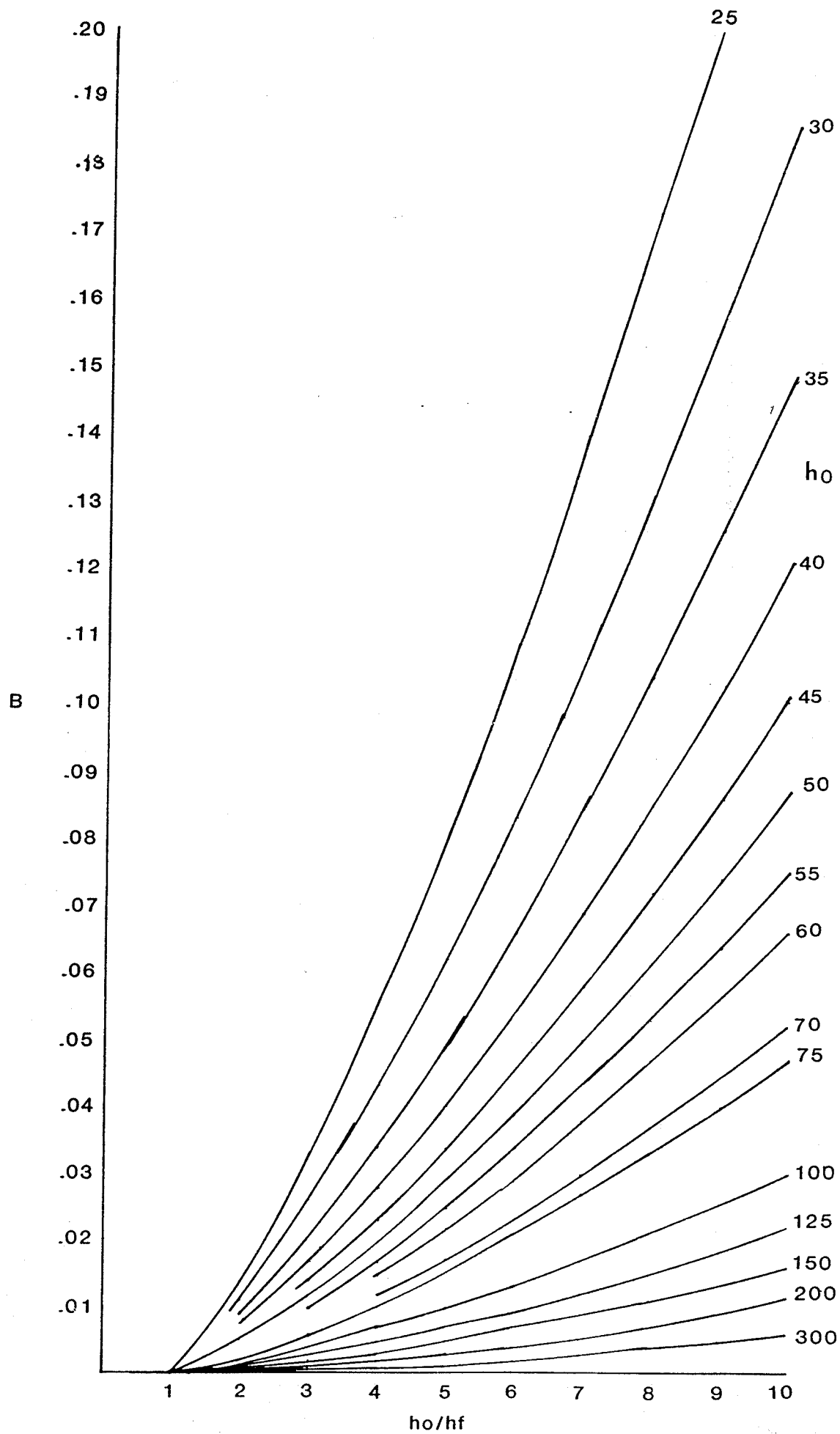


FIG. 8.5

9 THE HAMMER PRESS

9.1 Machine characteristics

It has already been shown in Section 1 of this handbook that different metal forming operations have different load-energy-displacement characteristics.

Thus extrusion operations may require only a moderate load but because the displacement is high considerable energy capacity is required. Forging of thin flanges however does not require a high energy but does demand a very high load.

A recent addition to the range of forging plant is the Lasco hammer-press so called because it combines in one machine the characteristics of a hydraulic press and a gravity drop hammer.

When operating in the press mode the machine can deliver its full rated tonnage over the full stroke length thus making it suitable for upsetting and extrusion type operations.

In addition the machine has the facility for lifting the heavy ram hydraulically and allowing it to fall under gravity thus allowing hammering operations capable of generating very high loads greatly in excess of the rated press tonnage.

Table 9.1 below summarises the characteristics of the standard hammer-presses available at the time of writing.

Table 9.1
Characteristics of Lasco hammer-presses

Press rating—tonnef	400	500	630	800	1000
Hammer energy—mkg	3150	3150	4000	8000	8000
Press stroke—mm	800	800	800	800	800

A hydraulic ejector is fitted in the bed and in addition to its use for releasing forgings and extrusions it can function as a hydraulic draw cushion allowing the press to be used for deep drawing operations.

The long ram guides and rigid press frame allow off-centre loading so that extrusion and hammering operations can be performed successively with the same die set.

The characteristics of the machine make it particularly suitable for producing forgings where forward or backward extrusion are combined with hammering operations.

Typical publicised applications are shown in figures 9.1 and 9.2.

9.2 Loads required for extrusion operations

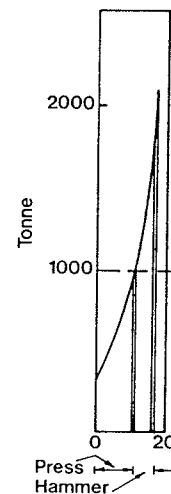
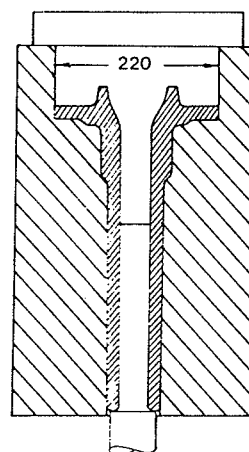
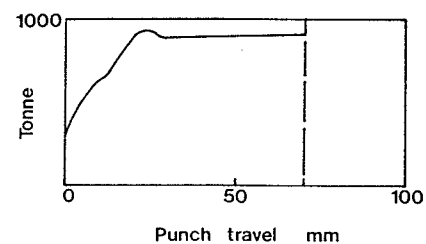
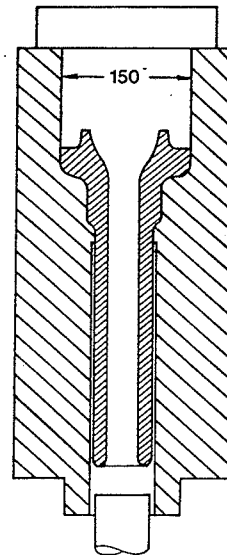
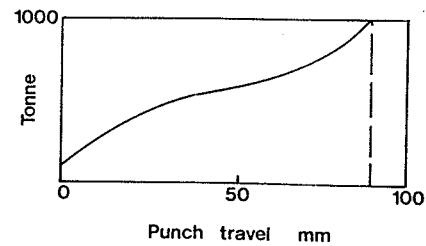
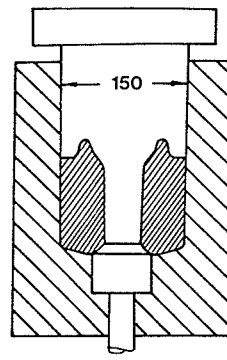
The manufacturers of the hammer-press have produced a graph for estimating forging loads based on tests made in their works and in forges.

The graph is reproduced in figure 9.3 and two examples of its use are given below. The values of p are the cold UTS of the forging stock. Line 2 is used of $p = 50 \text{ kg/mm}^2$ and for $p = 40 \text{ kg/mm}^2$ when D^2/d^2 is greater than 5.

Example 1

The tube extrusion shown in figure 9.1b is reproduced with the appropriate dimensions needed for load estimation in figure 9.4.

The mean diameter of the tube $d_m = (70 + 35)/2 = 52.5 \text{ mm} = 5.25 \text{ cm}$ and the outside diameter $D = 150 \text{ mm} = 15 \text{ cm}$.



FIGS. 9.1

Thus the area required is given by

$$A = \pi/4 (D^2 - d_m^2) \\ = 0.786 (15^2 - 5.25^2) = 155 \text{ cm}^2$$

From the graph using curve 3 the load corresponding to this area is 920 tonnef.

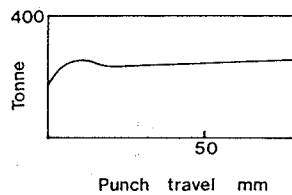
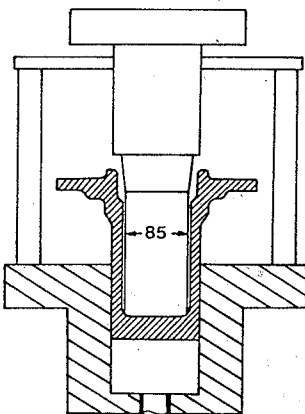
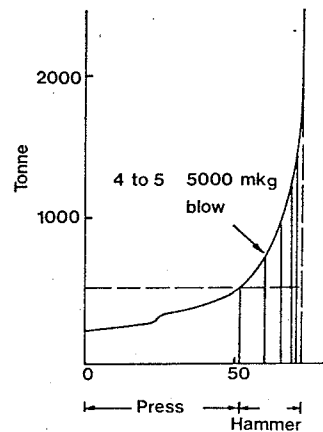
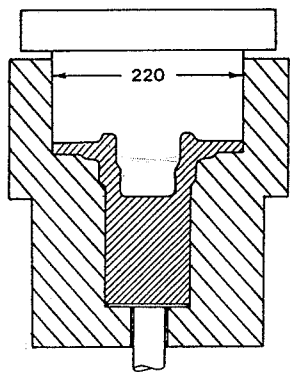
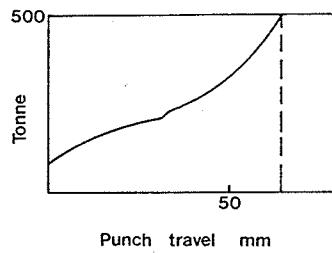
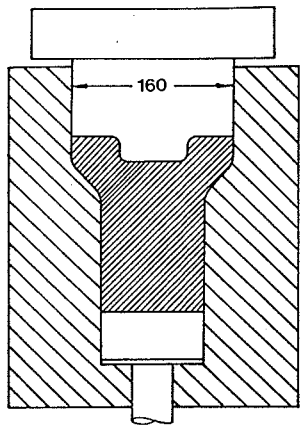


FIG. 9.2

Example 2

The extrusion shown in figure 9.2a is reproduced in figure 9.5. In this case $D = 16$ cm and $d = 10.2$ cm. The area is thus given by

$$A = \pi/4 (D^2 - d^2) \\ = 0.786 (16^2 - 10.2^2) = 119 \text{ cm}^2$$

The diameter ratio $D^2/d^2 = 16^2/10.2^2 = 2.46$ so that curve 1 in figure 9.3 is used. The load corresponding to an area of 119 cm^2 is 480 tonnef.

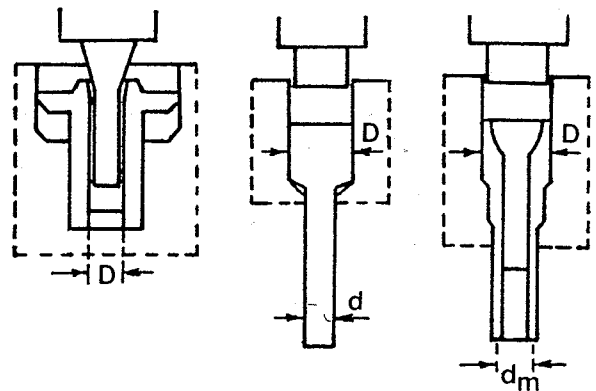
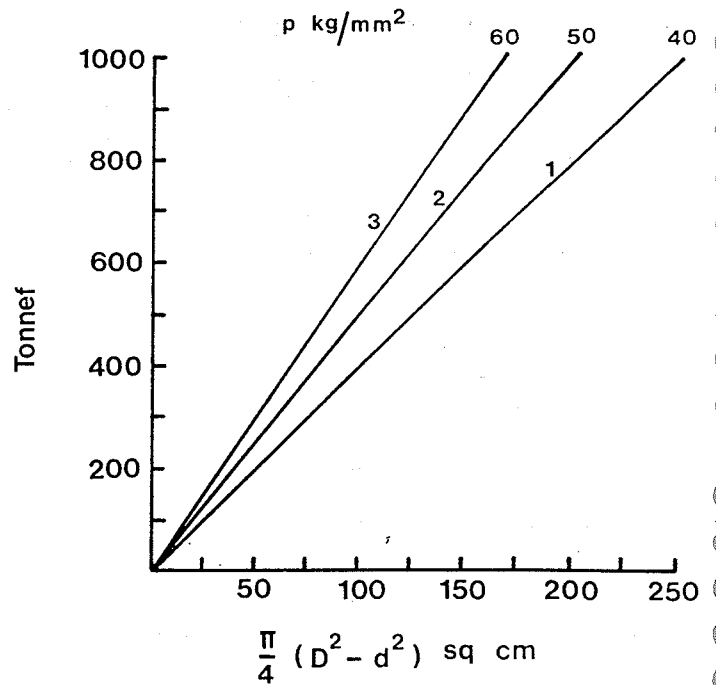


FIG. 9.3

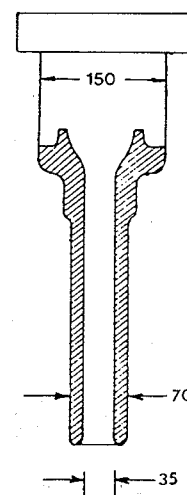


FIG. 9.4

The method of load estimation suggested by Lasco has obvious limitations since it is an empirical method applicable only to carbon and low alloy steels.

To calculate loads when forging other materials requires a more fundamental approach and a useful method has been described by Sturgess and Dean in *Journal of Mechanical Working Technology*, October 1979.

For forward extrusion of rod as illustrated in figure 9.6 the expression derived for punch pressure p is

$$p = \{[s(A + B \ln R + 2 m L/D)]\} \times [1 + 0.5 m]$$

For forward extrusion of tube as shown in figure 9.7 the corresponding expression for punch pressure is

$$p = \{[s(A + B \ln R + 2 m L/(D - d))]\} \times [1 + 0.5 m]$$

s = material flow stress

$$R = \text{extrusion ratio} = \frac{\text{original billet area}}{\text{final extruded area}}$$

$\ln R$ = natural logarithm of R

m = friction factor between billet and container

L , D and d are defined in figures 9.6 and 9.7.

A and B are constants whose values depend on the value of m .

For zero friction $m = 0$ $A = 0.45$ and $B = 0.9$.

For sticking friction $m = 1$ $A = 0.60$ and $B = 1.38$.

For intermediate values of m A and B may be found by interpolation.

Example of use — forward extrusion of rod

Figure 9.8 shows an example of forward extrusion supplied by Lasco where the measured load was 500 tonne.

The load is calculated as follows:

$$L = 160 \text{ mm}$$

$$D = 157 \text{ mm} \quad A_o = \pi/4 \times 157^2 = 19\,362 \text{ mm}^2$$

$$d = 72 \text{ mm} \quad A_f = \pi/4 \times 70^2 = 3\,849 \text{ mm}^2$$

$$R = A_o/A_f = 5.03$$

$$\ln R = 1.615$$

The friction factor m is assumed to be 0.4 a common value when hot working steel. In this particular instance the lubricant was oil and graphite.

The extrusion temperature was 1100°C and so a flow stress value of $s = 8 \text{ kg/mm}^2$ has been assumed.

For $m = 0.4$ $A = 0.51$ and $B = 1.09$.

The punch stress p is thus given by

$$\begin{aligned} p &= \{[8(0.51 + 1.09 \times 1.615 + 2 \times 0.4 \times 160/157)]\} \\ &\quad \times [1 + 0.5 \times 0.4] \\ &= \{[8(0.51 + 1.76 + 0.82)]\} \times 1.2 \\ &= 30 \text{ kg/mm}^2 \end{aligned}$$

The punch area $A_o = 19362$ so that the extrusion load is $30 \times 19362 \text{ kgf}$

or $30 \times 19.362 \text{ tonnef} = 580 \text{ tonnef}$ which agrees well with the measured load.

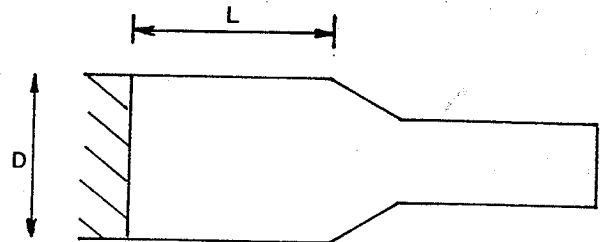


FIG. 9.6

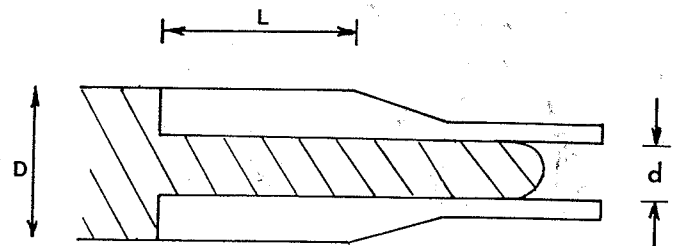


FIG. 9.7

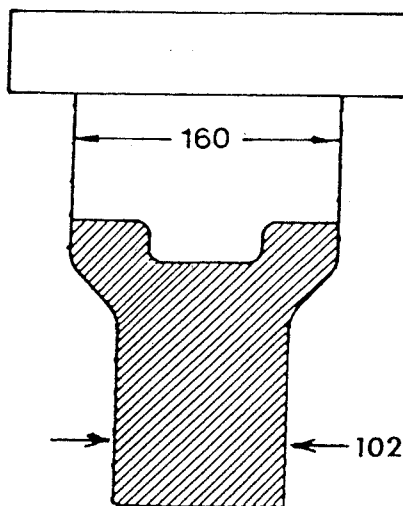


FIG. 9.5

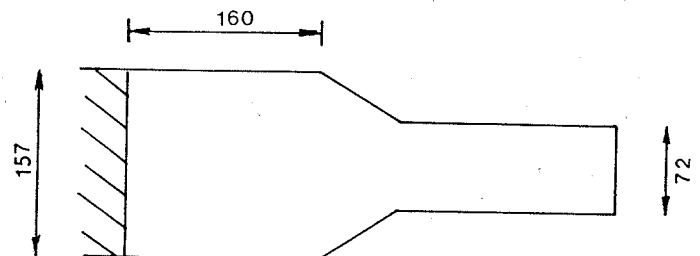


FIG. 9.8

10 ORBITAL FORGING PRESSES

10.1 Introduction

The load (L) required to make a forging is given by the area of the forging (A) multiplied by an effective resistance to deformation (S). Thus we may write

$$L = AS$$

where the effective resistance S depends on the material being forged, the forging temperature and the frictional resistance to metal flow.

The development of the orbital press stems from the fact that if only a small part of the forging is deformed at any time the load required to produce the forging can be considerably reduced.

In cold orbital forging the load reduction is due primarily to the reduced contact area A since the effective stress S depends mainly on material properties due to the low friction values encountered in cold forging.

In hot orbital forging however both A and S are decreased so that a considerable reduction in the load L can be achieved.

The principle of the orbital forging press is illustrated in figure 10.1. The upper die can be orbited by a few degrees about the vertical axis whilst the lower die is mounted on a hydraulic ram and is moved upward during the forging operation.

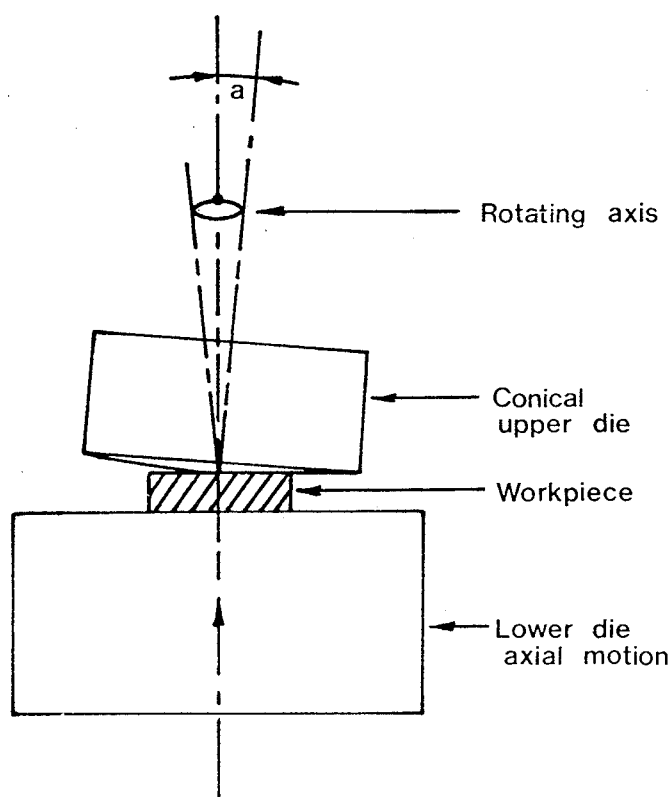


FIG. 10.1
Principle of orbital forging.

Two types of machine have been developed. A British machine usually referred to as a Rotaform machine is intended for warm forging and in this machine the top orbits as shown in figure 10.2a with the contact area sweeping round in a circular fashion.

An Eastern European machine developed primarily for cold forging applications can in addition to the orbital motion of figure 10.2a perform linear, spiral and planetary motions as shown respectively in figures 10.2b to 10.2d.

In this machine the orbital motion is most commonly used and is best suited for circular shapes where most of the deformation is required at the outer diameter of the forging.

The linear motion is used to form elongate shapes requiring metal flow predominantly in one direction. The spiral movement is used for circular parts containing intricate features at the centre whilst the planetary motion is favoured for parts where radial metal flow is required as for instance in filling the teeth of bevel gears.

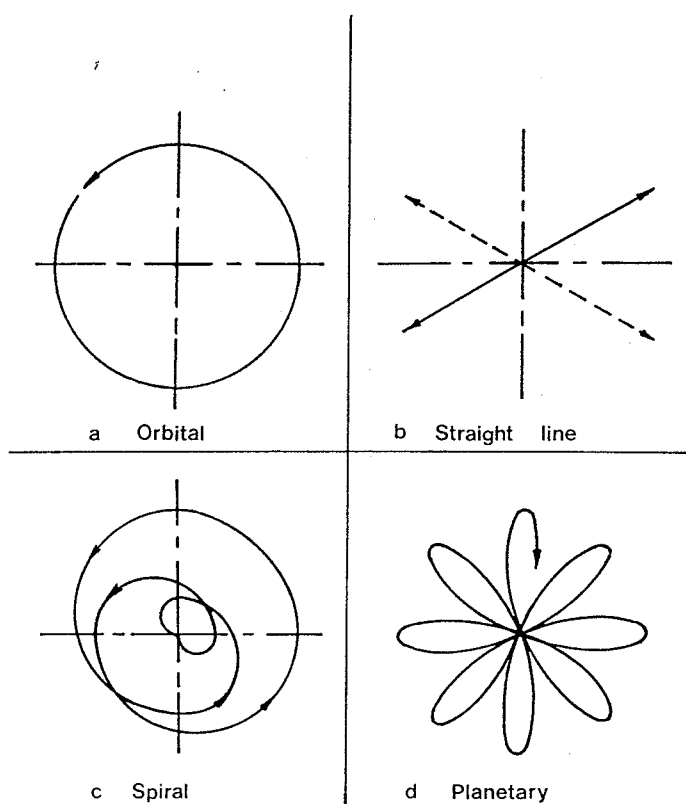


FIG. 10.2
Types of motion in orbital forging.

10.2 Characteristics of orbital forging

Metal deformation characteristics in orbital forging differ considerably from those in conventional press forging.

During the early stages of upsetting on an orbital press contact is made between the workpiece and the upper orbiting tool over a fairly large area but as upsetting proceeds the area in contact with the tool decreases until in the final stages of forging only a small area is being worked.

This is illustrated in figure 10.3 which also shows the contact area in conventional upsetting.

This mechanism leads to a relatively constant upsetting load during orbital forging compared with a continuously increasing load during conventional forging as shown in figure 10.3.

Another characteristic feature of orbital forging is the tendency for mushrooming to occur during the early stages of forging if low deformation rates with consequent small contact areas are used.

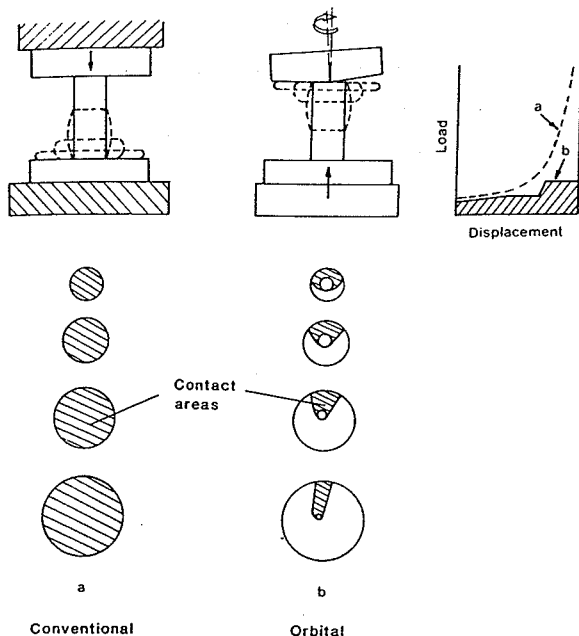


FIG. 10.3

Deformation zones and load-displacement curves for conventional and orbital forging.

This tendency to mushrooming increases as the initial deformation rate decreases and as the height to diameter ratio of the initial slug increases. The phenomenon is illustrated in figure 10.4.

The parameter which in fact controls the tendency to mushrooming is the draft per oscillation, ie the amount of deformation of the workpiece per revolution of the orbiting tool. If this is too low mushrooming occurs but on the other hand if it is too high tensile fractures can occur at the centre of the deformed workpiece.

For simple upsetting the draft per revolution, d is easily calculated if the ram speed S in mm per second and the orbiting speed r in revolutions per second are known. Then d is given by

$$d = S/r \text{ mm per revolution.}$$

In real forging shapes the draft per revolution will of course vary throughout the forging.

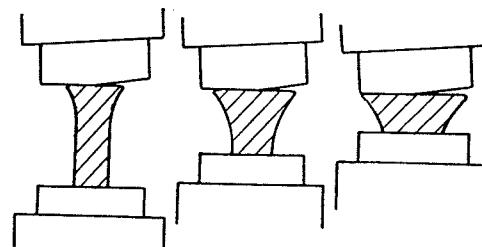


FIG. 10.4

Mushrooming effect in orbital forging.

10.3 The Rotaform machine

Since orbital forging is a new process it is undergoing continual development and the characteristics of machines may therefore change. The details of the process quoted here are those which obtain at the time of writing.

The billet to be forged is placed on the lower die located on the hydraulic ram and when the machine is actuated the ram and die assembly move upwards with a fast approach speed of 300 mm/s until an initial load of about 25 tonne is reached. Closure then continues at a reduced rate of about 75 mm/s until a load of 100 tonne is established when the closure rate is further reduced to 40 mm/s until the ram reaches a pre-determined stop position. The ram is then held in this position during a 'roll out' period and then rapidly retracted to its lower position at 600 mm/s. The finished forging is then ejected and lubricant sprayed if required. This forging sequence is illustrated schematically in figure 10.5.

The orbital speed of the upper die is high (1000 rpm) to minimise die contact times and this speed together with the ram approach rates used gives drafts per revolution of the order of 6 mm/rev in the early closure stage and 3 mm/rev in the final closure stage. The facility to operate the ram against a dead stop allows good control over forging thickness which is claimed to be much closer than on crank presses where thickness variations occur due to springing of the press.

Although the machine was originally conceived for use at conventional hot forging temperatures of about 1250°C unacceptably low die lives were experienced and the process was subsequently developed for warm forging in the range 600-850°C.

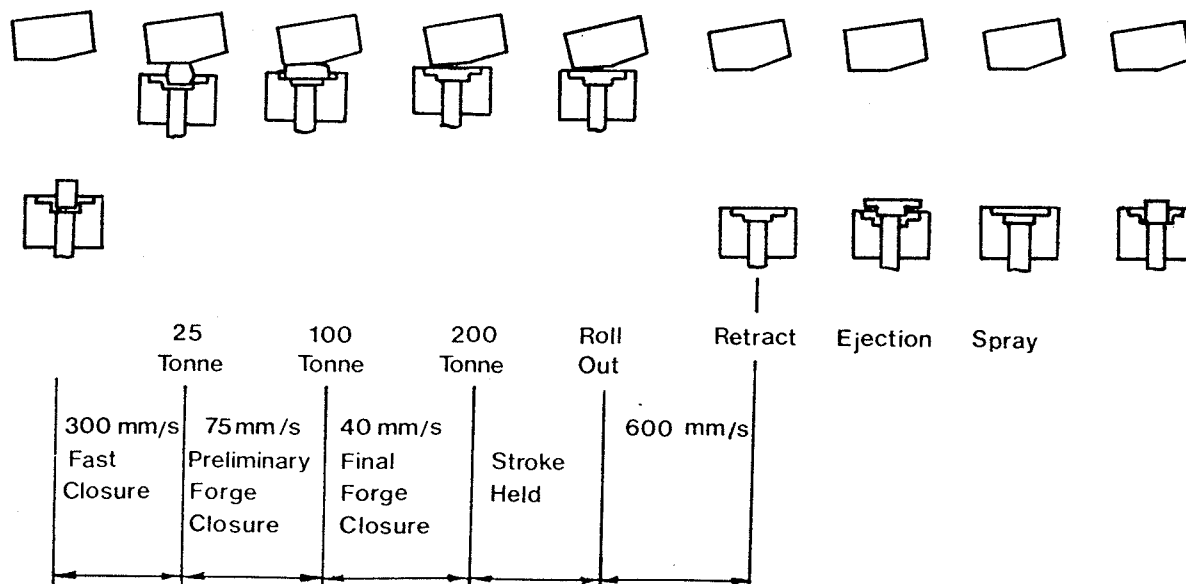


FIG. 10.5

Operating sequence of Rotaform Machine.

Production experience has been confined mainly to the production of axisymmetric forgings and the method is particularly suited to components having large thin flanges particularly those requiring close thickness control. A selection of forgings produced is shown in figure 10.6.

Because the Rotaform process utilises only a single die station automation is simplified since the only requirement is to place the billet on the bottom die forging station and there are no problems associated with in press handling from one station to another. In fact automatic feeding equipment is supplied as a standard feature of the machine.

10.4 The VSI Orbital Forging Press

This machine was originally developed in Poland and is now distributed by VSI Automation Assembly Incorporated, of Troy, Michigan in the USA.

It is intended for cold forging and the machine ranges available at the time of writing are shown in table 10.1 below.

Table 10.1
VSI Orbital Cold Forging Presses

Model	OFP 30	OFP 40	OFP 100
Maximum load—tonne	3.8	9	158
Maximum piece diameter—mm	18	34	100
Die stroke—mm	34	80	140
Upper die movements	orbital	orbital	orbital planetary spiral linear

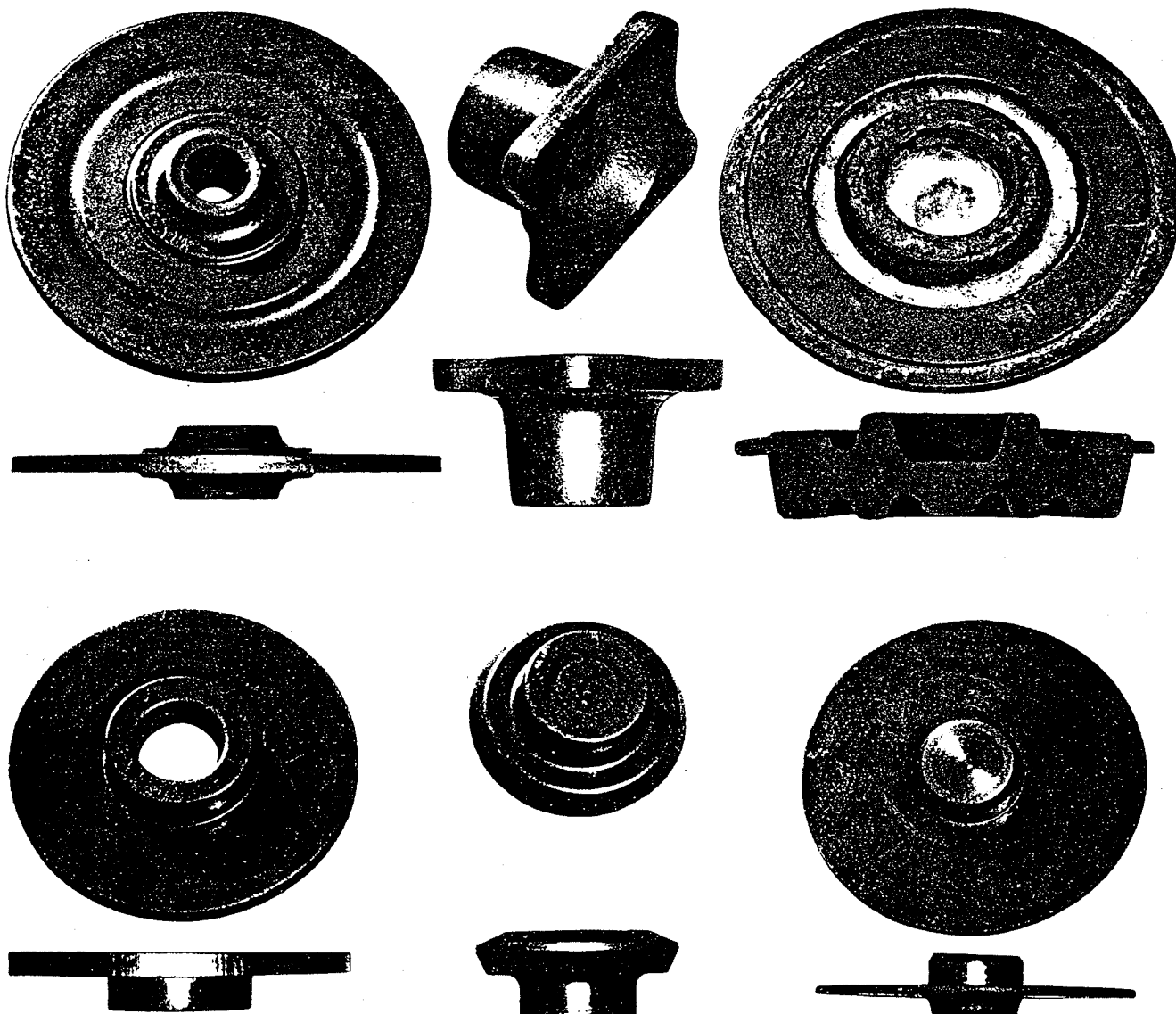


FIG. 10.6
A selection of forgings made under the Rotaform.

11 AUTOMATIC HORIZONTAL FORGING PRESSES

Automatic transfer machines for cold heading to produce nuts and bolts from coiled feedstock have existed for a long time. It was natural therefore that machines based on similar principles should be developed to hot forge components which because of their size or material composition could not be cold forged.

Two manufacturers now supply automatic horizontal forging presses. The operating principle of these machines is illustrated schematically in figure 11.1.

Heated bar stock is presented to the machine and a piece of suitable length is sheared and then automatically transferred through three or four forming stations.

Spring loaded gripping fingers in the feeding device hold the blank or part formed piece until the punch in the moving die pushes the piece into the stationary die cavity.

All the die stations can be fitted with ejectors in both the moving and stationary dies. Forgings are removed from the final station punch by a stripper plate and where a wad is punched it is pushed through the die for removal. Because of the automatic transfer system between die stations and because all stations are simultaneously occupied the machines are capable of exceptionally high production rates.

Machines of this type are produced by Hatebur Metal-forming Equipment and The National Machinery Company. Brief details of the standard range of machines available are given in table 11.1 below.

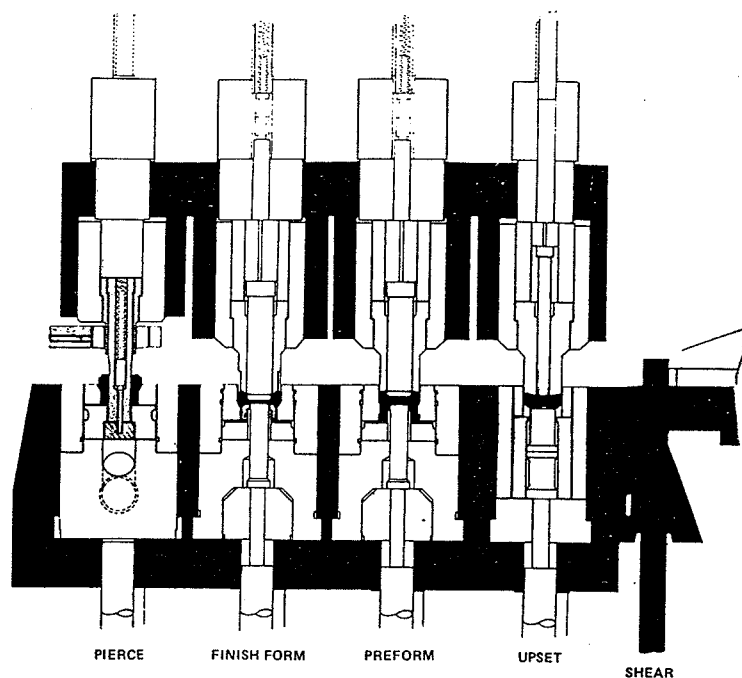


FIG. 11.1

Tooling layout for automatically producing a forging in four die stations.

Table 11.1
Details of automatic horizontal forging presses

Manufacturer — Hatebur				
Size rating	AMP 20	AMP 30	AMP 50	AMP 70
Weight of forgings — g	20—150	50—700	170—1700	400—5000
Maximum diameter of round parts — mm	35	64	92	145
Bar diameter — mm	14—25	18—40	28—50	36—75
Cut off length — mm	15—40	20—72	32—110	45—150
Number of die stations	3	3	4	4
Production rate — parts/min	120—180	85—140	60—100	50—80
Tonnage rating — tonnes	60	230	800	1500
Ram stroke — mm	110	160	240	320
Ejector stroke — mm	55	70	90	130—150

Manufacturer — National Machinery							
Size rating	2—3	3—3	3—4	5—4	6—4	7—4	10—3
Weight of forgings — g	37—398	56—1080	56—1080	150—1700	360—3100	360—5440	1380—7460
Maximum diameter of round parts — mm	45	67	67	92	120	145	195
Bar diameter — mm	18—32	19—44	19—44	28—50	36—60	36—75	50—90
Cut off length — mm	16—63	25—88	25—88	31—110	45—140	45—152	65—150
Number of die stations	3	3	4	4	4	4	3
Production rate — parts/min	150	120	85—120	55—100	40—70	50—80	30—45
Tonnage rating — tonnes	120	230	230	800	1200	1500	2700
Ram stroke — mm	203	254	254	320	381	381	450
Ejector stroke — mm	75	100	100	100	150	38—152	40—180

The forgings made on automatic horizontal forging presses are essentially closed die forgings with very small draft angles. Figure 11.2 indicates typical forging tolerances and machining allowance as suggested in publicity literature from the Hatebur company.

Because of the high capital cost of these machines, their high production rate and special tooling development they are applicable only to large volume orders.

Furthermore the shape of the components produced must be axisymmetric or nearly so. Figure 11.3 shows a typical range of components produced, while figure 11.4 shows a photograph of the die area of a Hatebur AMP 70 machine producing bearing races.

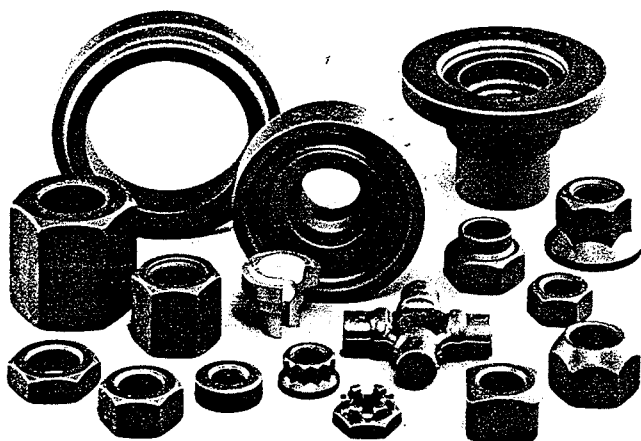


FIG. 11.3

Selection of components made on Hotmatics. Output from 80 to 180 a minute.

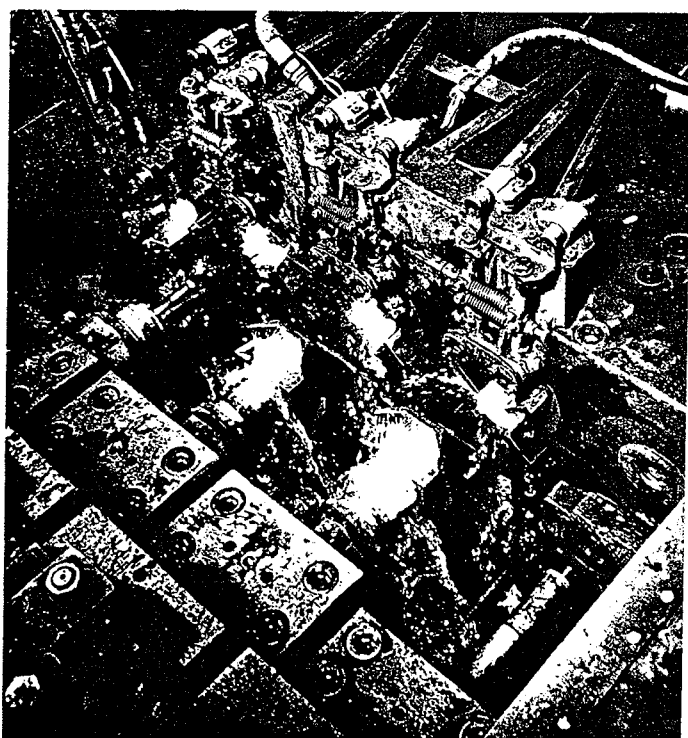
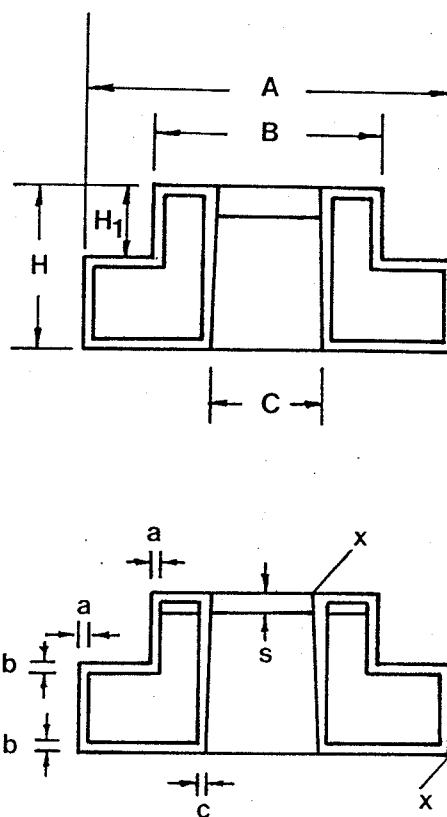


FIG. 11.4

Die area of AMP 70 Hotmatic producing bearing races by combination forging. Piercing and separating done at 4th station.



Machine	AMP 20	AMP 30	AMP 50	AMP 70
Diameter A max.	35	64	90	120
Tolerance on A, B — mm	+0.2	+0.3	+0.4	+0.4
Tolerance on C — mm	-0.3	-0.4	-0.6	-0.6
Tolerance on H, H ₁	± 0.2	± 0.25	± 0.3	± 0.3
Difference in wall thickness up to — mm	0.5	0.6	0.8	1.0
Edge radii	1-2 mm			
Corner radii	2.4 mm			
Internal draft angles	1-2°			
External draft angles	½°			

Minimum machining allowances considering the maximum wall thickness difference and minimum depth of cut in machining.

Diameter A up to — mm	30	50	80	120
Allowance "a" — mm	0.35	0.5	0.65	0.75
Allowance "b" — mm	0.5	0.75	1.0	1.20
Allowance "c" — mm	0.6	0.6	0.8	1.0

Average slug thickness S is about $0.1c + 3$ mm

Where deep bores occur the slug thickness should be greater than this to prolong the life of the ejector and punch in the main forging station.

At points marked x a burr of no more than 1 mm may occur.

FIG. 11.2

Tolerances and machining allowances.

12 HYDRAULIC PRESSES

12.1 Press construction and press drives

Hydraulic press manufacturers have developed many designs according to the particular requirements of different users. In this section of the handbook only the basic principles of design can be considered.

The hydraulic press consists essentially of a framework carrying a hydraulic cylinder to the piston of which is attached a platen to carry forging tools which act against tools carried on a stationary bed.

In spite of the many design variations hydraulic presses can be classified into two types of construction, being either of the push down or pull down type.

The earliest press designs were of the push down type illustrated schematically in figure 12.1. The main hydraulic cylinder is mounted in a stationary cross-head and pushes down a moving ram which carries the upper forging tools, the lower ones being mounted on the press bed.

Because the hydraulic system is mounted on top of the press considerable head room is required and in addition any oil leakage from the system is likely to spill onto the forging thus constituting a fire hazard.

In an attempt to overcome some of the problems associated with the push down design press manufacturers virtually stood existing designs on their head and developed the pull-down press shown schematically in figure 12.2. Here the main hydraulic cylinder is mounted in the press bed and pulls down a moving cross-head which carries the upper forging tools as shown.

The hydraulic system is contained in a pit below floor level and consequently less head room is required and any oil spillage represents far less of a fire risk.

This design of press also accommodated a greater degree of off-centre loading since the guiding was within the bed structure.

The main disadvantages of the pull-down design are the considerable increase in foundation costs and the difficulties encountered when planishing at high stroking rates. These result from the need to accelerate, stop and reverse about 70% of the total press weight at stroking rates up to about 80 per minute. In the push-down design the moving part weight is much less.

Another major division of press types, irrespective of design, is the drive system which may be a direct oil drive or an accumulator drive.

Early press designs frequently had a water accumulator drive system such as that shown in figure 12.3. In this system gas pressure in the accumulators is used to pressurise the hydraulic fluid in the main cylinder. With this type of drive the rate of penetration into the workpiece is not directly dependent on the pump characteristics and can vary according to the accumulator pressure and the deformation resistance of the forging.

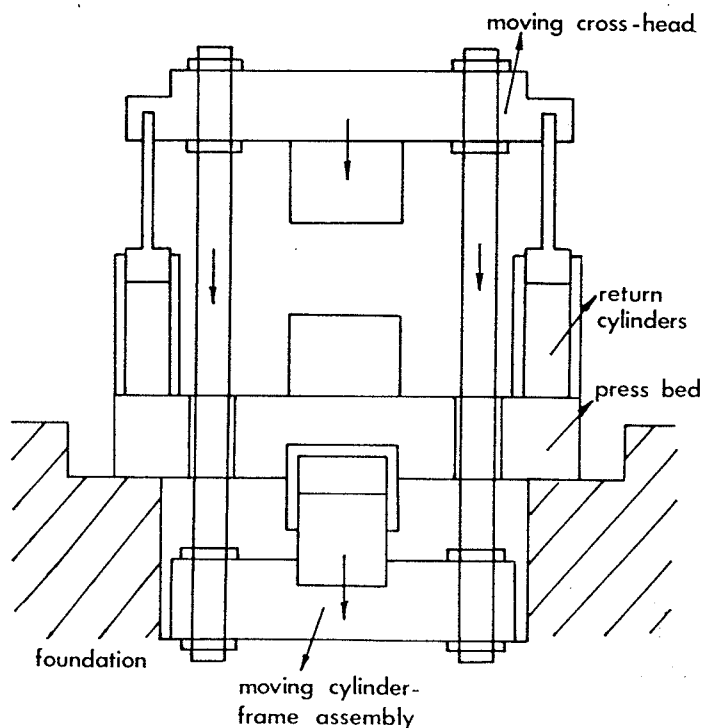
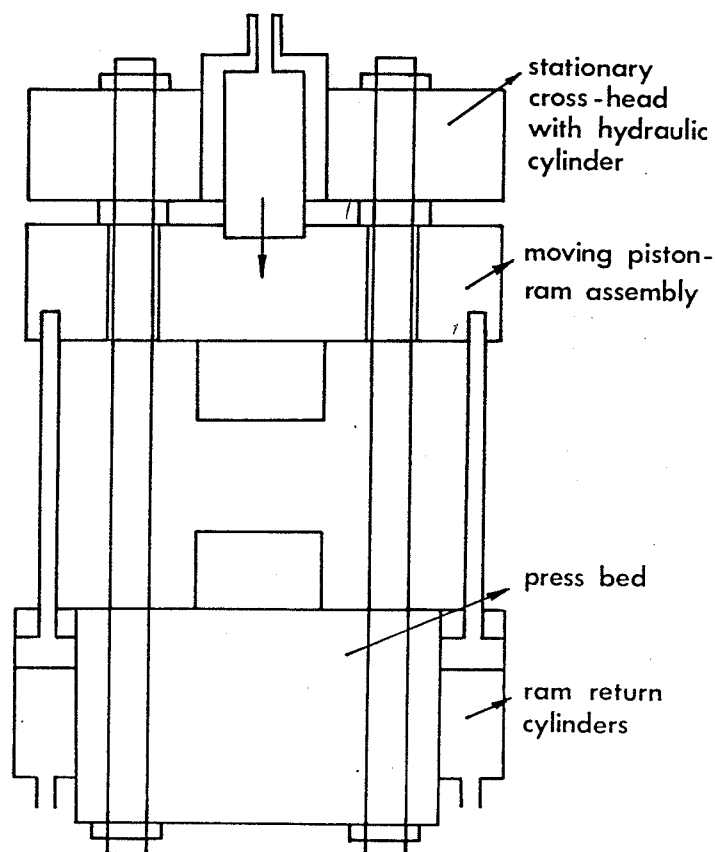
In presses with direct oil drive, oil, as shown in figure 12.4, is drawn into the main cylinder from a prefill tank via a valve which closes when the press engages the workpiece. During the forging stroke oil is supplied directly to the cylinder by the pumps which must have sufficient capacity to maintain the forging pressure throughout the stroke.

At the end of forging, which is signalled by a predetermined tool position or maximum pressure, the main pumps are diverted to the lifting cylinders and oil from the main cylinder exhausts to the prefill tank via the prefill valve.

The choice of press drive system involves many factors and depends on the exact requirements of the machine. In general direct oil drive is favoured for small to medium size presses but very large presses of 10 000 tonne capacity upwards are usually accumulator driven since pumps with

sufficient capacity to supply the large volumes of oil required are very expensive.

Accumulator drive becomes even more attractive when an accumulator system can be used with more than one press.



12.2 Hydraulic press applications

Whilst hydraulic presses find very wide application for open die forging where they have largely replaced hammers their use in closed die forging is far more restricted.

Because of the long contact times between forging and die excessive cooling occurs when hydraulic presses are used for closed die forging and this leads to poor filling of die cavities and low tool lives.

Hydraulic presses are however used for forging the light alloys of aluminium and magnesium. Since these materials have a low forging temperature heat losses can be adequately compensated by preheating of dies.

The particular application in this field is the production of large close-to-form forgings for the aerospace industry.

In the general drop forging industry the main application of hydraulic presses is for cold coining operations.

12.3 Press specification

Euroforge have issued a trilingual booklet giving comprehensive details of the specifications required to define the capability of a hydraulic press. The booklet is entitled "Form of enquiry, quoting and ordering of drop forging plant — Hydraulic Presses". Copies are available from the following addresses.

National Association of Drop Forgers & Stampers
Grove Hill House
245 Grove Lane
Handsworth
Birmingham B20 2GB
England

Fabrimétal
21 rue des Drapiers
1050 Bruxelles
Belgique

Syndicat National de l'Estampage et de la Forge
10 Avenue Hoche
75382 Paris Cedex 08
France

Institut för Verkstadsteknisk Forskning
Mölnadalsvägen 85
412 85 Göteborg
Sweden

Verband Deutscher Gesenkschmied
Goldene Pforte
5800 Hagen
Bundesrepublik Deutschland

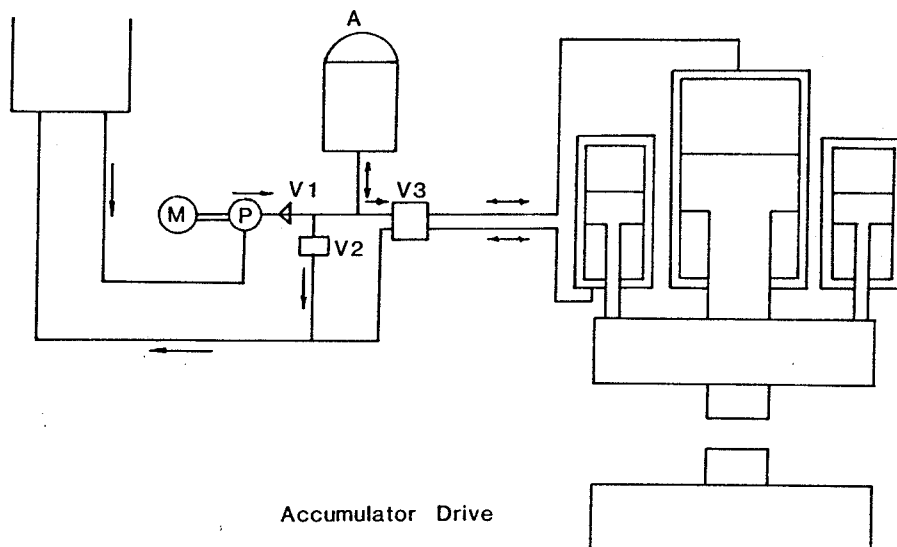


FIG. 12.3

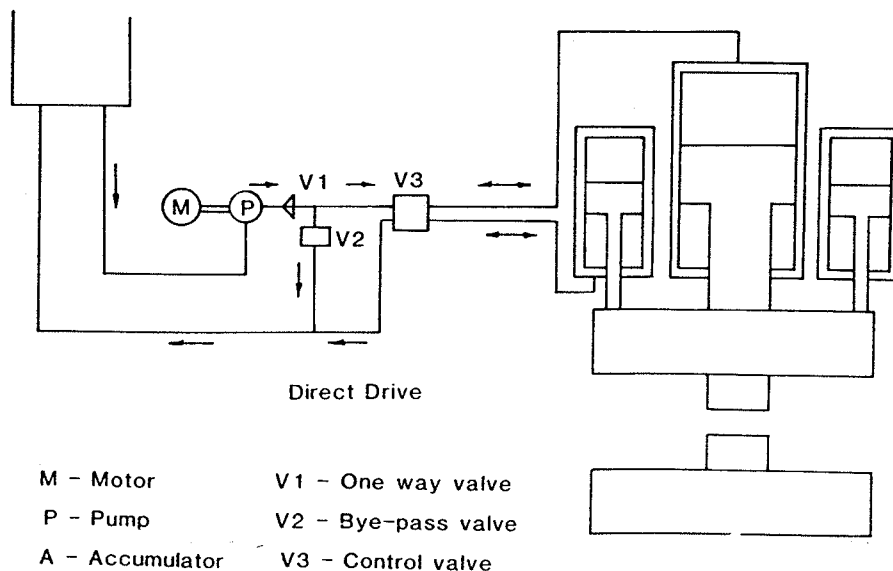


FIG. 12.4

SIMPLE

SUPERIOR

SAFE

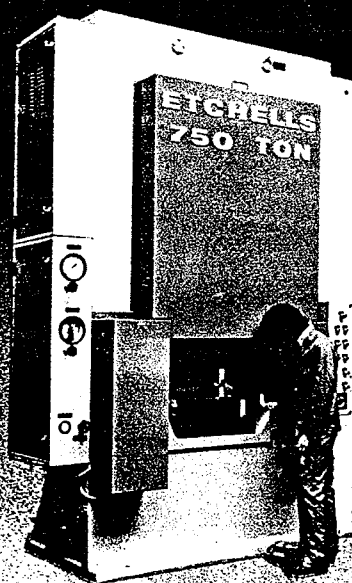
RAPID

HEAVY DUTY

VERSATILE

ECONOMIC

AUTOMATIC



for coining, calibration and setting,
Etchells Hydraulic Coining Presses are available
in a range of models of 500-1500 t. capacity all demanding lower
investment for greater productivity and security.

To know more details of our many claims
for these advanced presses which have influenced
their selection by leading forges in Europe,
N. America, S. America and Africa,

contact:

ETCHELLS MACHINERY LIMITED

Stafford Road, Darlaston, Wednesbury, West Midlands. WS10 8UA. Tel: 021-526 2461. Telex: 337530 ETMACH G.

13 MULTIRAM FORGING PRESSES

Multiple ram presses have been developed which allow the production of forgings with cores and with undercuts. The horizontal forging machine may be regarded as a simple form of multiram press but is not considered in this section.

The presses which have been constructed consist of a main ram or rams operating in a vertical direction and up to four other rams operating in a horizontal plane.

Arrangements have been designed which allow multiple ram forging on hydraulic presses and also crank and friction-screw presses.

13.1 Hydraulic multiram presses

A large hydraulic multiple ram press operated by Cameron Ironworks at Livingston in Scotland consists of a main ram rated at 30 000 tonf with a stroke of 3 metres and main side rams each rated at 6 000 tonf. An auxiliary piercing ram of 6 000 tonf capacity can be carried by the main ram.

A further ram acting as an ejector or bottom piercing ram is rated at 1 000 tonf. The press can be operated in three basic modes as described below.

13.1.1 The vertical mode

The vertical mode of operation is illustrated in figure 13.1. Split dies are mounted on the side rams of the press and a contoured die segment or piercing punch is attached to the main vertical ram.

The sequence of operations during forging is as follows. The heated billet is placed on the lower platen of the press and the side rams close the split dies initiating metal deformation. The main ram is next actuated and the piercing punch or top segment then completes the forging operation to produce a flashless forging.

13.1.2 The horizontal mode

In the horizontal mode the split dies are mounted on the base of the press and the main ram with shaped die segments or piercing punches is carried by the horizontal rams as shown in figure 13.2.

The heated stock is placed in the lower die cavity and the main ram operated to close the dies and begin forging which is then completed by the actuation of the side rams. The main ram then retracts to open the dies and withdrawal of the side rams allows removal of the forging.

13.1.3 Combined vertical and horizontal modes

In this combined process the main dies are located on the base of the press and the vertical ram. The piercing punches are carried on both the side rams and the vertical ram as shown in figure 13.3.

The heated stock is placed in the bottom die half and the main ram closes the dies to begin forging. The side rams then operate to form the horizontally disposed cavities in the piece and forging is completed by actuation of the vertical piercing punch.

Withdrawal of the piercing punches followed by opening of the dies allows the forging to be removed.

Whilst the press described has been successful in producing large forgings attempts to apply the same techniques at the smaller end of the forging range have been less satisfactory. This is largely due to poor tooling performance especially when long, small diameter piercing punches have been used. Due to their small heat capacity premature wear and distortion are more likely than with larger tooling of much greater heat capacity.

The British company of John Shaw and Sons produced hydraulic presses with a main ram and four horizontally disposed side rams. Figure 13.4 shows the production of a steel elbow forging in a press with a main ram of 750 tonf

capacity and side rams rated at 150 tonf. In the example illustrated only two of the side rams carry forging tooling.

Whilst this method of forging offers attractive material savings its increased use for production of small steel forgings probably awaits the development of improved tool materials at an economic price.

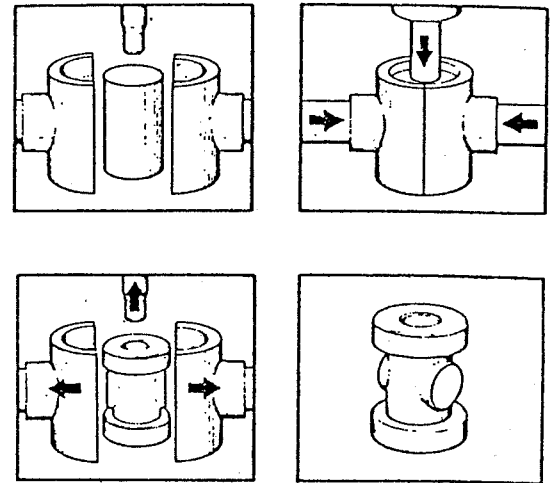


FIG. 13.1
Multiram press—vertical mode.

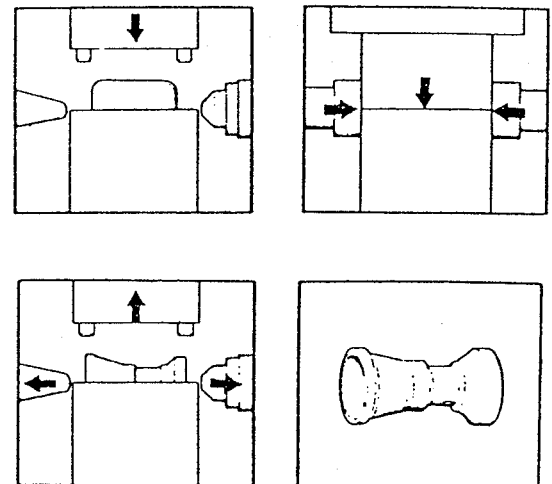


FIG. 13.2
Multiram press—horizontal mode.

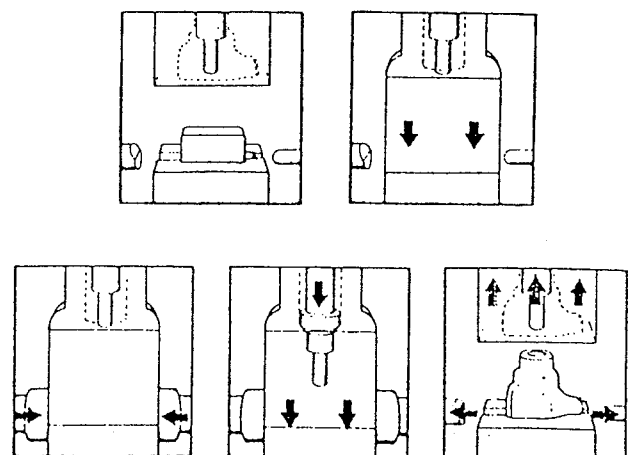


FIG. 13.3
Multiram press—combined mode.

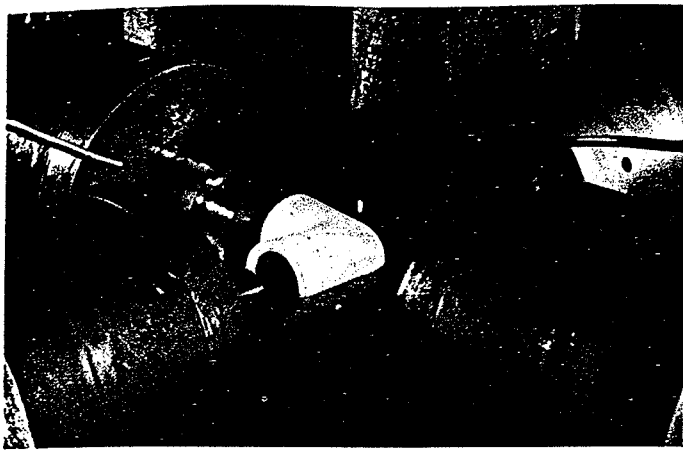


FIG. 13.4
Elbow forging produced in Shaw press.

13.2 Multiple ram subpress assemblies for use on mechanical presses

Subpress assemblies have been developed for split die and cored forging on both crank presses and friction screw presses. Currently their main application has been in forging of brass components where the low working temperatures and absence of abrasive scale lead to acceptable tool lives. The principle of forging is however applicable to steel and a limited range of such forgings is produced.

Both vertical and horizontal sub-presses have been developed and those described below are the arrangements offered by the British press manufacturer, Wilkins and Mitchell.

13.2.1 The vertical sub-press

This unit consists of a base plate fastened to the bottom bolster of a crank press. The base plate carries a main punch together with a centre body on which are mounted four cone slides which act as die or punch holders. The centre body also carries levers and an actuating cylinder. A cone arrangement is fastened to the press ram.

In the loading position, which is illustrated in figure 13.5, the centre body is supported on pressure pins from an air cushion and the cone slides are in an open position. The main working punch is fixed to a base plate and projects through the centre body into the die cavity.

For the forging cycle the heated billet is placed on the main punch and rests in the cavity of the right hand die.

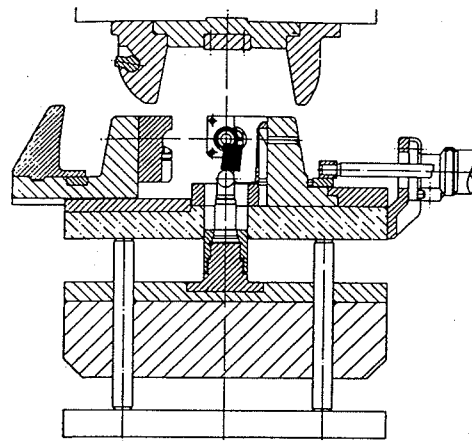
On actuating a foot switch the cone slides carrying appropriate die segments close round the billet and a limit switch operates the press ram. Descent of the ram locks the lower dies by means of the top cone engaging with the die segments. Further travel of the ram causes the centre body to move downwards against the cushion pressure causing metal to flow over the stationary punch to produce the closed die forging. Figure 13.6 illustrates the situation at the bottom of the press stroke.

The vertical sub-press is suited to the production of difficult cored forgings which require a heavy forging load in the vertical direction.

13.2.2 The horizontal sub-press

This unit comprises top and bottom plates bolted to the press ram and bed respectively and a central body which carries the punch stations and which is supported by pressure pins from an air cushion.

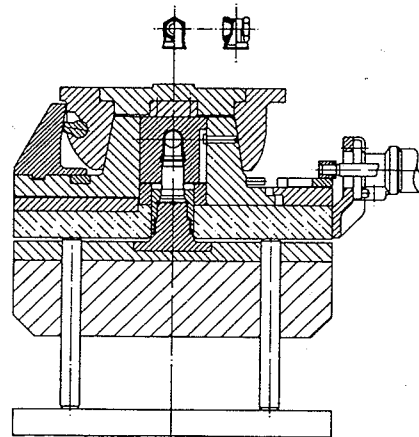
Dies are fixed to the top plate and the centre body. The arrangement with dies and punches in the open position is shown in figure 13.7.



Open Position

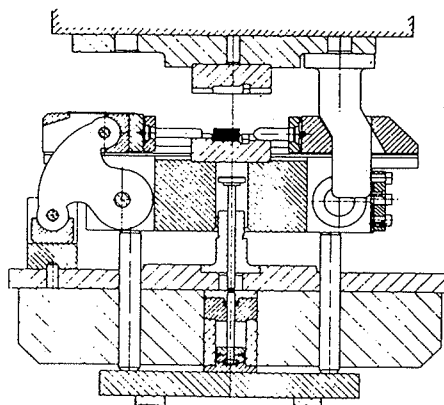
FIG. 13.5
Vertical sub-press-open position.

Component:
Gate Valve Body.



Closed Position

FIG. 13.6
Vertical subpress—closed position.



Open Position.

FIG. 13.7
Horizontal subpress-open position.

For the forging operation a billet is placed in the bottom die cavity and the press ram descends to close the die faces. The whole die assembly then continues to move down against the air cushion and bell crank levers built into the centre body force the punches into the die cavity to produce the forging.

If required two of the bell crank mechanisms can be replaced by stations actuated from the press ram by means of cam pillars. With this arrangement punches can be placed in their final position before the die faces meet so that they perform no work on the billet which is extruded round the stationary punch. The position of dies and punches in the fully closed condition is illustrated in figure 13.8.

In addition to the four side cores two more can be accommodated, one moving up through the bottom die and the other located in the top die.

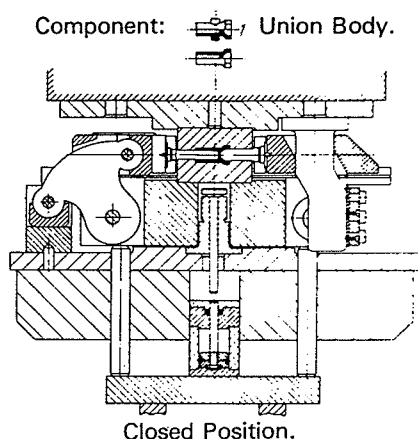


FIG. 13.8
Horizontal subpress—closed position.

14 FORGING ROLLS

Where volume production of preforms is required as in the press forging of elongate parts they may be produced in forging rolls which are also sometimes called reducer rolls.

The principle on which forging rolls operate is illustrated in figure 14.1. Heated bar stock is placed between the rolls against a back stop. When the rolls are actuated they rotate so that the bar is fed back towards the operator and the required part of the bar is reduced in cross-section.

Forging rolls may be of the cantilever type in which the working part of the roll shaft overhangs the roll bearing as shown in figure 14.2. Alternatively they may be of the double bearing design in which the roll shaft has supporting bearings at each end as shown in figure 14.3. Frequently the double-bearing type also has a small cantilever shaft as shown in figure 14.4. figure 14.5 shows a photograph of a cantilever type machine.

Generally more rolling passes can be accommodated on the double bearing design due to the greater support of the roll shaft.

Rolling passes are cut in alloy steel segments which are then keyed onto the roll shaft in the appropriate position. Sets of roll segments are shown in figure 14.6.

In use, depending on the particular application the rolls may rotate continuously or once through an angle of 360°C or, where very short roll segments are used, once through 180°C, thus allowing two roll passes to be mounted at the same roll position.

Many manufacturers supply transfer equipment for forging rolls so that rolling may be done automatically.

The machines are rated according to the maximum size of bar which can be rolled. Table 14.1 shows details of machine capabilities taken from manufacturers catalogues.

Table 14.1
Maximum square billet size (S) and maximum rolled length (L) as a function of machine roll diameter (D)

All dimensions in mm

Eumuco			Hasenclever			National Machinery			Wilkins and Mitchell		
D	S	L	D	S	L	D	S	L	D	S	L
—	—	—	240	30	365	250	55	508	—	—	—
300	40	460	300	45	455	300	75	610	—	—	—
370	55	570	370	60	560	380	100	760	370	55	570
460	75	710	460	75	700	—	—	—	460	75	710
—	—	—	—	—	—	510	125	1010	—	—	—
560	100	870	560	100	860	—	—	—	560	100	870
680	125	1050	680	125	1040	—	—	—	680	125	1050
850	150	1240	800	150	1230	—	—	—	—	—	—
—	—	—	950	180	1450	—	—	—	—	—	—

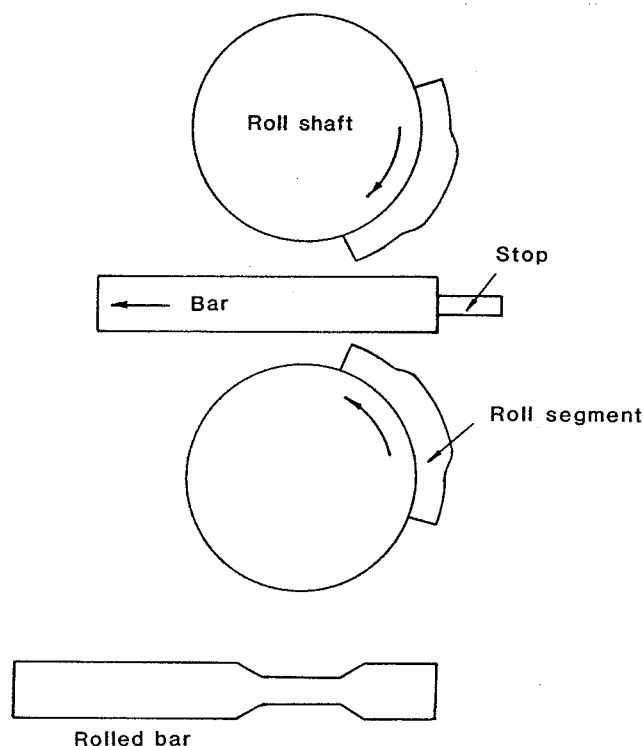


FIG. 14.1
Principle of operation of forging rolls.

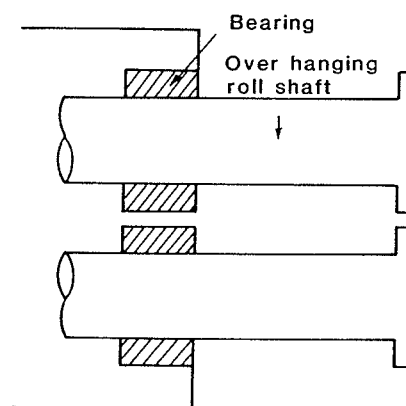


FIG. 14.2
Cantilever type forging rolls.

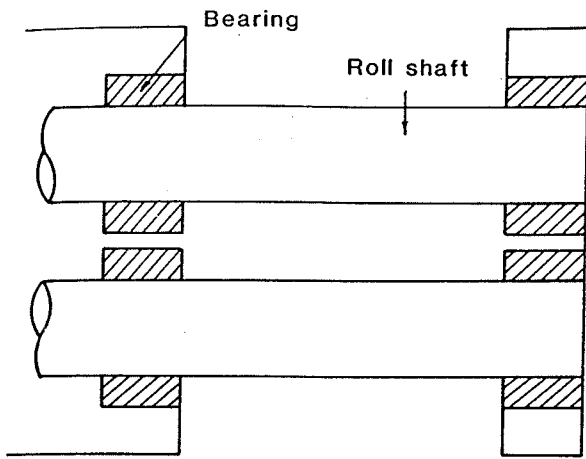


FIG. 14.3
Double bearing forging rolls.

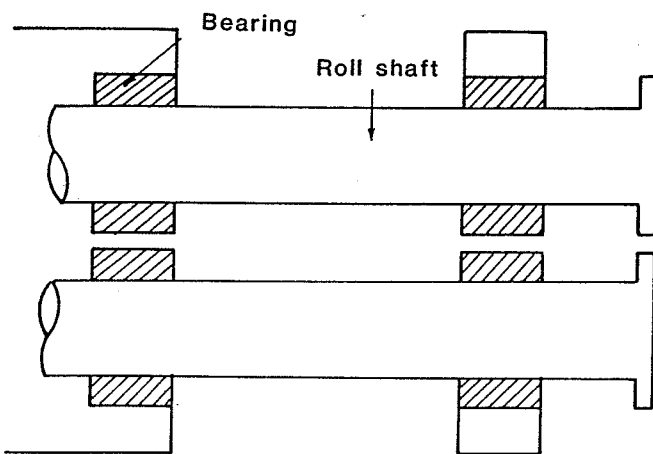


FIG. 14.4
Double bearing forging rolls with cantilever section.

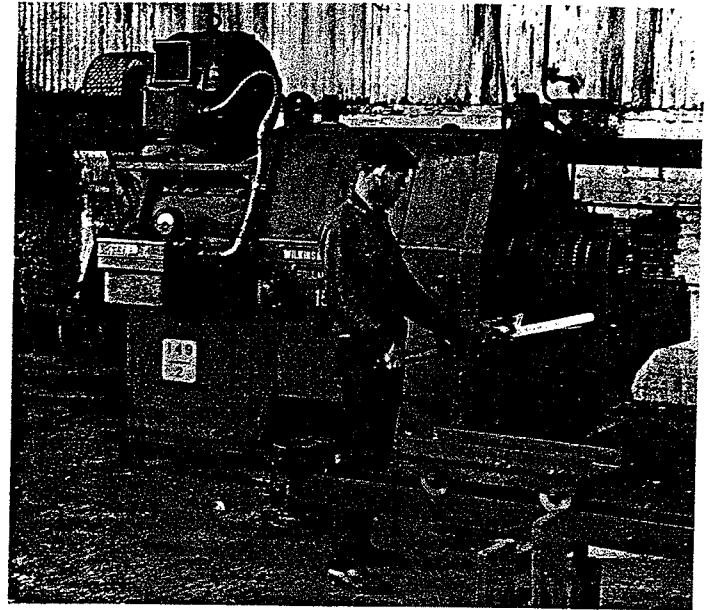


FIG. 14.5



FIG. 14.6

15 TRANSVERSE ROLLING MACHINES

The process of transverse rolling or cross rolling has been developed to produce finished components for subsequent machining or preforms for subsequent forging.

Two commercially available systems have been developed and each is described below.

15.1 The Smeral Transverse Rolling System

The principle of the transverse rolling system manufactured by the Czechoslovakian Company Smeralovy Zavody is illustrated in figure 15.1.

Induction heated bar stock is positioned with its axis parallel to the axes of two large diameter rolls on which are mounted V-shaped wedge segments.

During rolling the rolls make one complete revolution and the wedges gradually reduce and elongate sections of the bar stock.

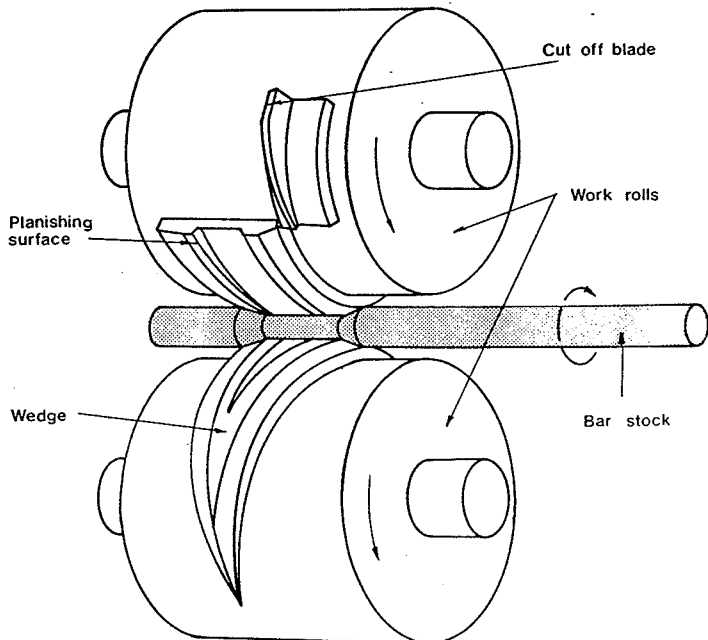


FIG. 15.1

Principle of Smeral transverse rolling machine.

There are two basic types of wedge design. The first shown in figure 15.2a reduces a central section of the bar leaving the two ends at the original diameter.

The second type of wedge design shown in figure 15.2b simultaneously reduces sections of the bar leaving a central unreduced region. Alternatively a single wedge of this type may be used to displace material in one direction only.

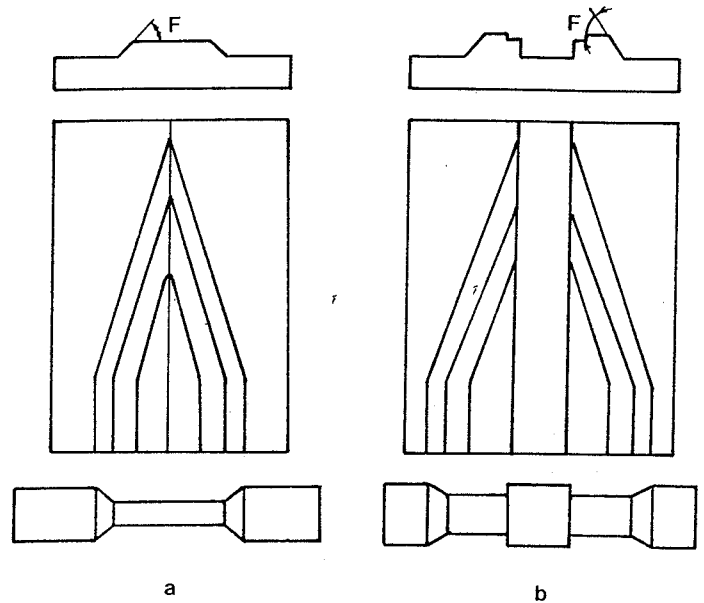


FIG. 15.2

Basic types of rolling wedge.

The transition region between reduced and original bar sections can take several forms as illustrated in figure 15.3. Wedge segments can be combined in a variety of ways. Figure 15.4 shows two type A segments mounted side by side on a roll whilst figure 15.5 shows a type A and a type B segment mounted in tandem.

It is usual to complete the deformation by one segment before further rolling by another wedge commences.

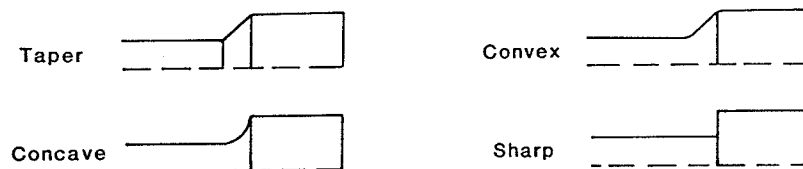


FIG. 15.3

Types of transition between reduced and unreduced sections.

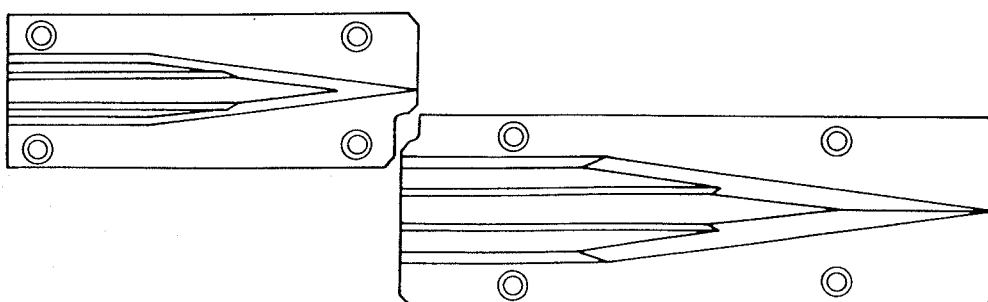


FIG. 15.4

Type A segments mounted in echelon.

Each wedge as shown in figure 15.6 contains a reducing or knifing section, a stretching section and a planishing section. The flank sections of the wedge have shallow grooves or dimples to provide frictional grip to prevent the wedges slipping over the bar stock during rolling.

Details of the machine specification taken from the manufacturer's catalogue are shown in table 15.1 below.

Table 15.1
Smeral machine specification

Diameter of feedstock — mm	15-50
Maximum length of feedstock — mm	250
Maximum length of rolled product — mm	400
Maximum reduction in one operation — %	75
Work rolls	
Diameter — mm	600
Width — mm	400
Mean distance between axes — mm	725
Lower roll adjustment — mm	±25
Maximum length of tool	240°

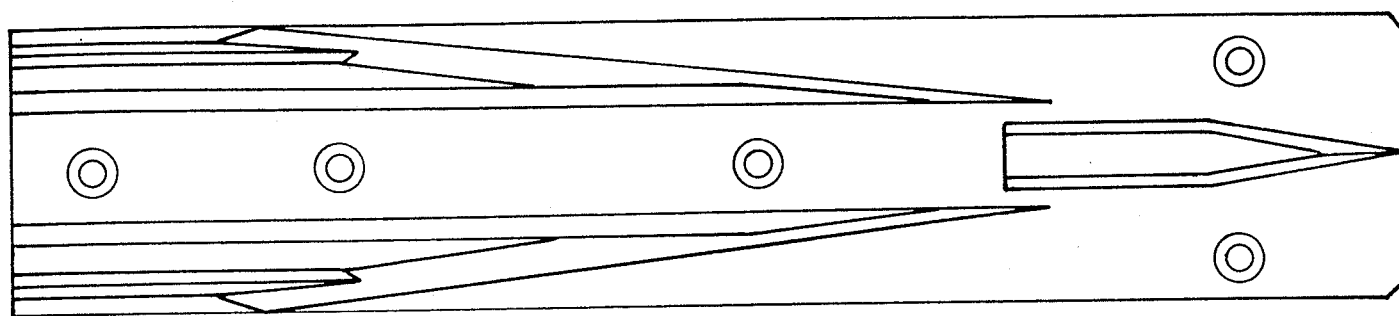
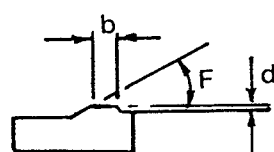


FIG. 15.5
Type A and type B segments.



Section A-A

W = Wedge angle (10-30)
F = Flank angle (25-45)
b = Forming land
d = Relief to avoid
over rolling

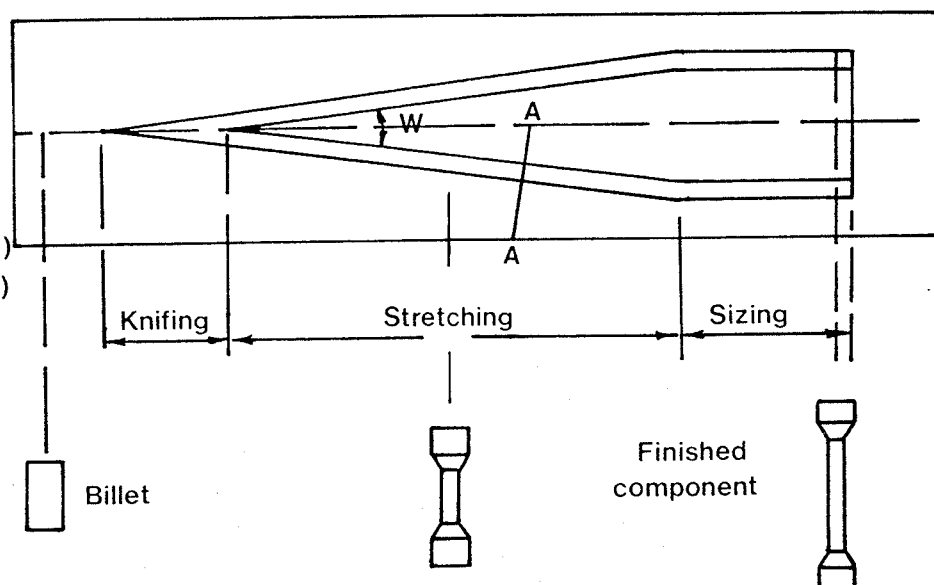


FIG. 15.6

15.2 The Erfurt Transverse Rolling System

The Erfurt cross rolling machine is based on essentially the same principle as the Smeral version except that the wedges are carried on flat, vertically reciprocating platens as shown in figure 15.7.

Details of the Erfurt transverse rolling machines again taken from the manufacturer's catalogue are shown in table 15.2.

Table 15.2
Erfurt machine specification

Machine size	40.1	100.1
Maximum diameter of feedstock — mm	40	100
Maximum length of rolled product — mm	400	630
Maximum working stroke — mm	1600	2500

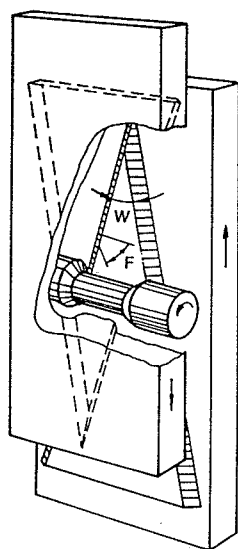


FIG. 15.7

15.3 Tool Design in Transverse Rolling

The basic parameters involved in tool design are, as shown in figure 15.8, the wedge angle W , the flank angle F and the degree of reduction R to be achieved over a length L .

The wedge angle W determines the length of the rolling path required to produce a given length of reduced section as shown in figure 15.9.

Incorrect tool design can lead to the following defects in the rolled product.

- (1) Surface overlapping.
- (2) Necking in the reduced section which in extreme cases can cause tensile fracture.
- (3) Slipping of the wedges over the workpiece.
- (4) Formation of central cavities or bursts in the reduced section.

Know-how regarding tool design is vested in the manufacturers and users of the machine and is not generally available.

Erfurt suggest that the included wedge angle W should lie within the range $10-30^\circ$ whilst the flank angle F may take values of $15-45^\circ$.

Hayama, of Yokohama National University has made a theoretical study of the deformation process in transverse rolling and has suggested several design recommendations. Full details of these may be found in reference 1 given at the end of this section.

Figure 15.10 shows Hayama's recommendations for the relationship between wedge and flank angles. These angles should be chosen to lie within the curves shown in solid lines. If however, slipping occurs the choice of angles should be restricted to the area enclosed by the dashed curves.

Reference 1

"Optimum working conditions in the cross-rolling of a stepped shaft" M Hayama — *Journal of Mechanical Working Technology*, Vol 3 No 1 June 1979. Elsevier Scientific Publishing Company.

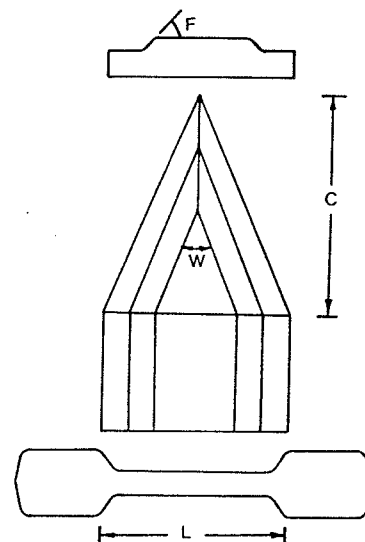


FIG. 15.8

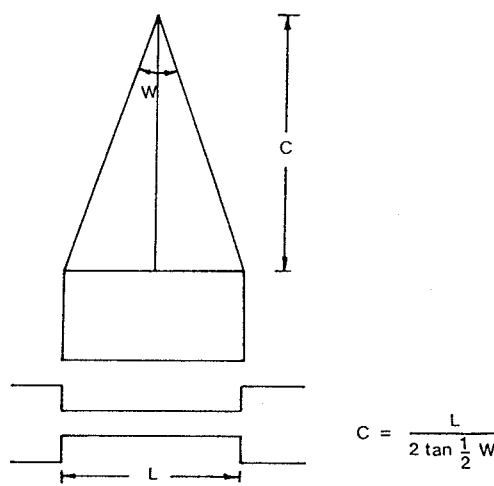


FIG. 15.9

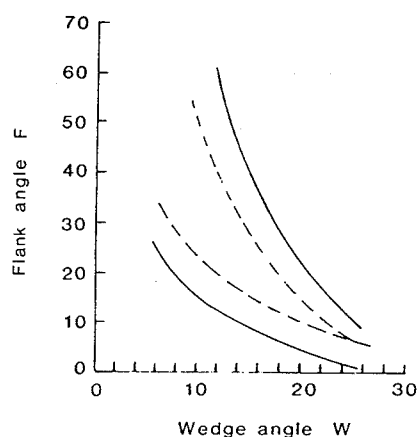


FIG. 15.10

16 CLEARSPACE HAMMERS

Clearspace hammers such as that shown in figure 16.1 are widely used for making free hand forgings and preforms for drop forging.

Simple tools are used and the quality of preforms produced depends entirely on the skill and dexterity of the operator.

The approximate size of hammer required to forge a given size of square mild steel bar is shown in figure 16.2.

The upper curve shows a maximum bar size and is applicable where a hammer is used only occasionally on a particular bar size.

Where a given bar size is to be forged regularly the lower curve should be used for hammer selection in the interests of speed of production.

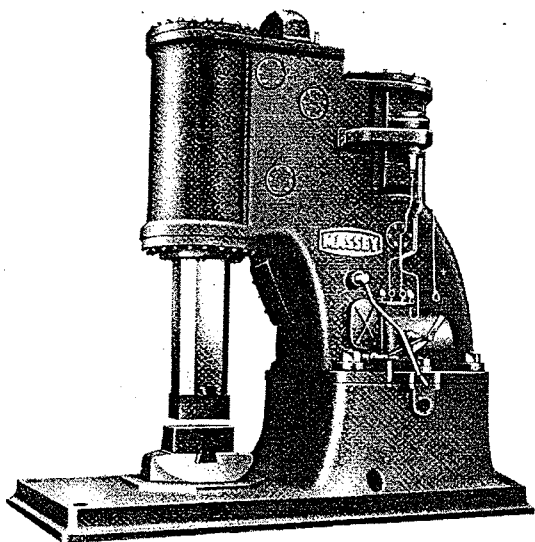


FIG. 16.1

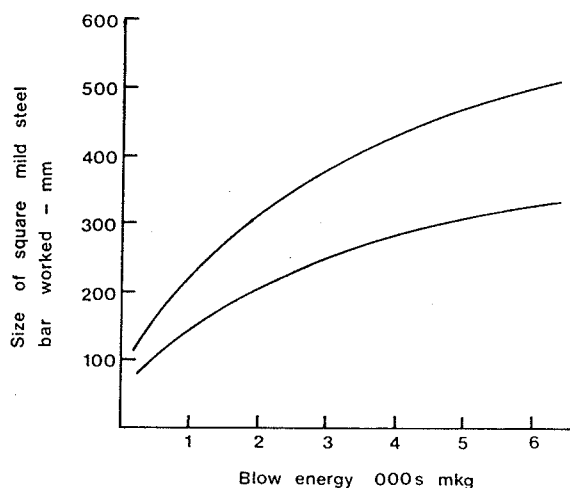


FIG. 16.2

17 KEY DRIVING MACHINE

The traditional method of driving and loosening keys on hammer dies is to use a sledge hammer or, on larger plant, a heavy ram swung from an overhead support.

The German company, J Banning AG, has developed a pneumatically operated key driver. The equipment consists of a heavy body piece which can be clamped securely to the forks of a fork-lift truck or suspended from an overhead crane. Both types are illustrated in figure 17.1.

An air actuated ram is used as an impact device acting against a guided key driver.

A hand lever is moved forward to actuate the ram and drawn back to return the ram to its rest position.

The actuating lever can be used to control the force of the impact blow or alternatively a slide valve can be set to give blows of a preselected energy.

Four sizes of the key driver are available as shown in table 17.1 below which also gives an indication of the maximum key size for which each is suitable.

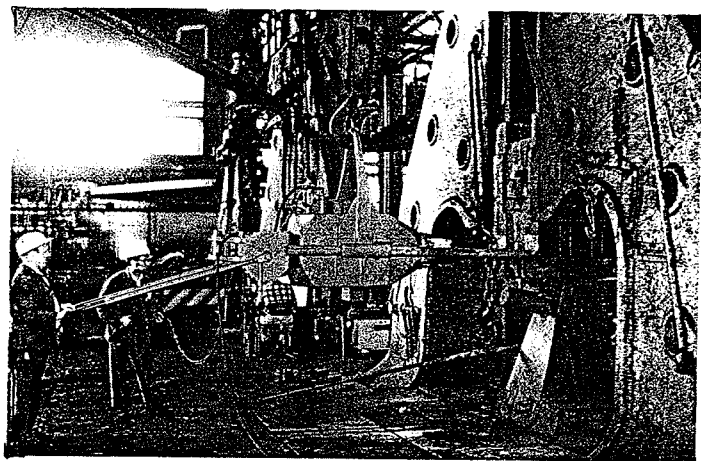


FIG. 17.1a

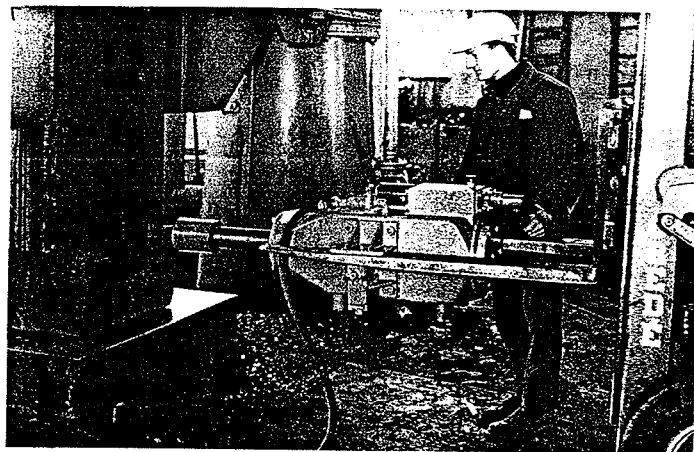


FIG. 17.1b

Table 17.1

Details of Banning key drivers

Size rating	KERA 100	KERA 200	KERA 400	KERA 800
Blow energy — mkg ¹	100—200	150—300	300—500	700—950
Maximum key size — mm	60 × 80 × 500	80 × 120 × 1000	100 × 160 × 2000	any

¹energy depends on air pressure

18 HIGH ENERGY RATE FORGING MACHINES

In the early 1960's a number of manufacturing companies produced new designs of impact forging machines which became known as high energy rate forging (HERF) machines.

Figure 18.1 illustrates schematically the operating principle on which HERF machines were based. In the container above the piston which carries the tup T gas is hydraulically compressed to a high pressure P and this high pressure gas acts on a small area a of the top of the piston. A seal s is maintained by low pressure gas p acting on a large area A . Provided the product pA exceeds Pa the seal is maintained and the machine remains in the cocked position ready to operate.

The seal s may be broken by mechanical or other means allowing the high pressure gas P to act on the whole area A_1 of the piston head. The product PA_1 now greatly exceeds the supporting force pA and the piston and ram assembly are rapidly accelerated downwards to perform a forging blow.

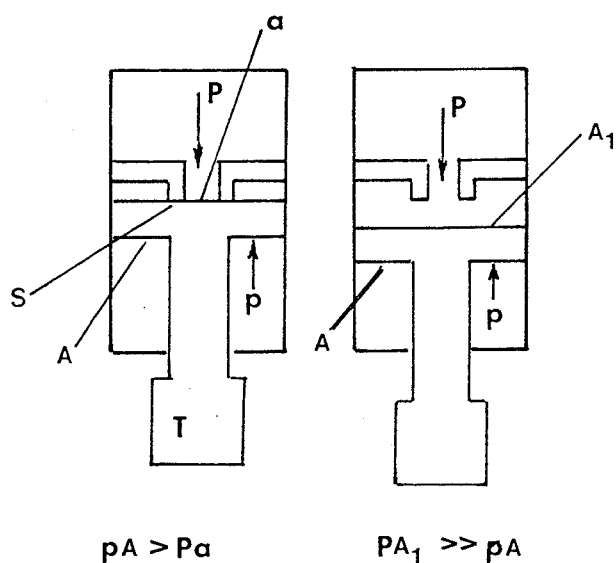


FIG. 18.1

The high gas pressures used were about 10 to 15 N/mm² and led to impact speeds in the range 5000 to 20 000 mm/second with corresponding blow energies varying from about 10 to over 20 000 kgm.

Because relatively small machines delivered such a high blow energy they were not designed as double-acting hammers mounted on a massive foundation but as counter-blow machines. Some machines such as the US Industries design operated with top and bottom tups of equal mass driven towards each other with equal velocity. In other designs such as that used in the Dynapak version the frame of the machine was a floating assembly held in position and stabilised through bellows-type air cushions. During a forging blow the tup was driven downwards at a high velocity whilst the massive frame moved upwards with a much lower velocity but the same momentum as the tup. This counterblow arrangement meant massive foundations were not required.

Another method of providing the tup energy was used at Birmingham University in England where the Petroforge machine was developed. In this design petrol was ignited in the cavity above the piston to provide the motive power although in later versions gas was used instead of petrol.

When HERF was first introduced a number of exaggerated claims were made regarding the capability of the machines to produce forgings.

It was claimed that under high rates of deformation metals would exhibit enhanced ductility and would flow like a fluid to fill narrow, intricate die cavities. In addition it was claimed that the process was ideally suited to the production of flashless forgings.

It was indeed true that impressive forgings could be made in a single blow as the illustrations in figure 18.2 indicate. These examples are taken from a US Industries' publicity brochure.

Growing experience of HERF showed that the ability to produce thin webs and fill narrow ribs was in fact due to the very short contact time between billet and die during the forging blow. This minimised chilling of the forging and in many cases any heat loss was more than compensated by the temperature increase generated by the working of the billet.

As user experience of HERF developed certain drawbacks became apparent. Although contact times during the forging blow itself were very short the component and the die remained in intimate contact for a relatively long period after the blow before the dies were separated. This led to excessive heating of the dies and poor die life resulted. This effect was exacerbated by the inability to use moulding impressions as is common practice in hammer and crank press forging.

Additionally in some cases the use of a single die impression led to unsatisfactory grain flow and the formation of folds in forgings.

Thus in spite of the early promise of HERF the machines have never become widely accepted in the general forging industry but have found a strictly limited application for the production of special forgings.

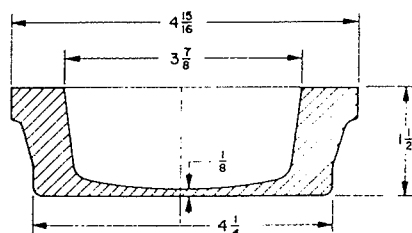


FIG. 18.2

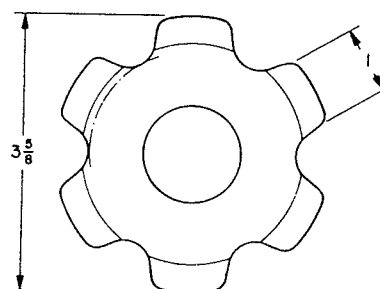
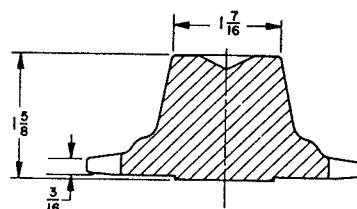
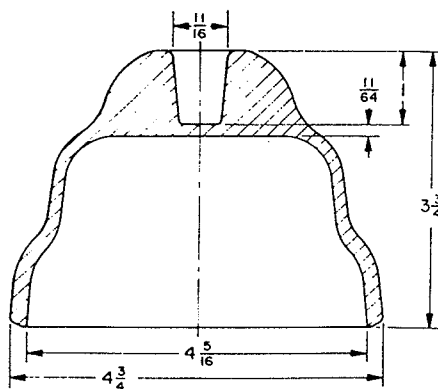
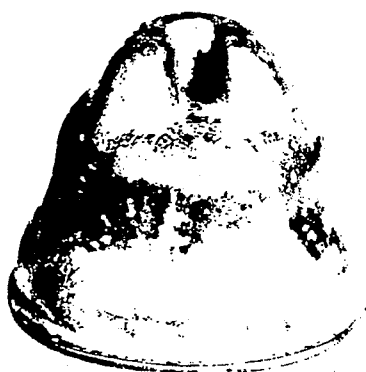
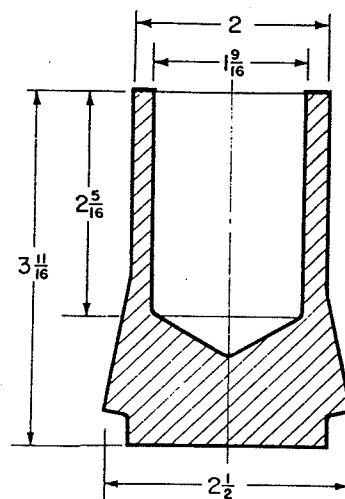
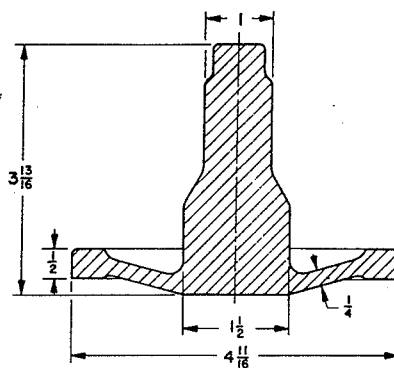
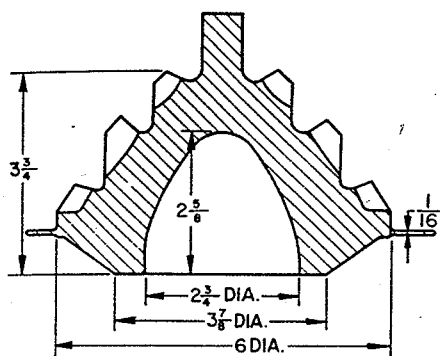
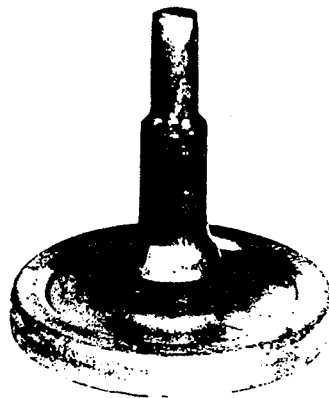
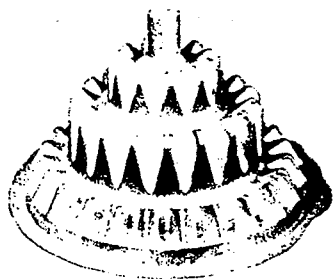


Fig. 18.2

19 PLANT REPAIR

Previous sections of this Handbook have attempted to give the reader an understanding of how forging plant works and how it should be used to avoid premature failure.

Inevitably however plant will wear out or failures of components will occur. A number of methods have been used to deal with cracks including drilling holes at the end of a crack to arrest its progress, localised welding, metal stitching, bolting or welding plate across the crack and even using tie bars to hold halves of a member together.

If however cracking was extensive or complete fracture of a part had occurred none of the above methods offered a solution and there was no alternative except expensive replacement by a machined forging or casting.

Recent progress in welding however has resulted in the development of a process which allows major repairs of large plant and forging dies to be carried out. The original developments were done in America but one version of the welding process is now commercially available in the United Kingdom, where it is known as the Floodmold Process.

The Floodmold Process

The first procedure in the Floodmold process is to assess the extent of cracking using ultrasonic or Magnaflux testing. Even where a component is broken in two crack detecting may be necessary to locate secondary cracks which exist in addition to the main fracture path.

Metal is then removed from the damaged area to remove all cracks by "scarfing", ie melting away metal using high pressure oxy-acetylene burners or in the case of austenitic materials, arc-air equipment.

At this stage preheating is only necessary when scarfing high carbon or high alloy steels and the process leaves a clean metal surface onto which weld metal can be deposited without further treatment. After scarfing further crack detecting is carried out to ensure complete removal before welding commences.

The component is then preheated to 200-500°C depending on composition and the weld metal is deposited as described below.

The scarfed portion is inclined at about 30° to the horizontal and if the channel is open ended at the bottom end a heavy gauge copper plate is used to close the end and form a dam.

Weld metal is then deposited using large flux-coated electrodes held in a manipulator. Depending on the extent of the repair the electrode core size varies up to a maximum of 19 mm diameter.

The weld pool remains molten long enough to allow the slag formed from the rod to rise to the surface and flow over the dam. As the weld pool is moved up the inclined cavity the first metal deposited solidifies with a slag covering which acts as a heat shield.

After welding is completed the part is stress relieved at 500-600°C and slowly cooled. The weld is then cleaned by oxy-acetylene cutting and finally heat treated to ensure the development of compatible properties between the parent metal and the deposit before final machining.

Applications

The potential of the process is perhaps best illustrated by briefly describing some applications.

Figure 19.1 shows a broken ram from a double acting hammer. A crack had been repaired using an austenitic electrode but complete fracture occurred soon after the repair.

The two halves were axially located by inserting a mild steel slug into the bored out holes shown. Radial location was ensured by matching the fracture faces and heavy tack welding.

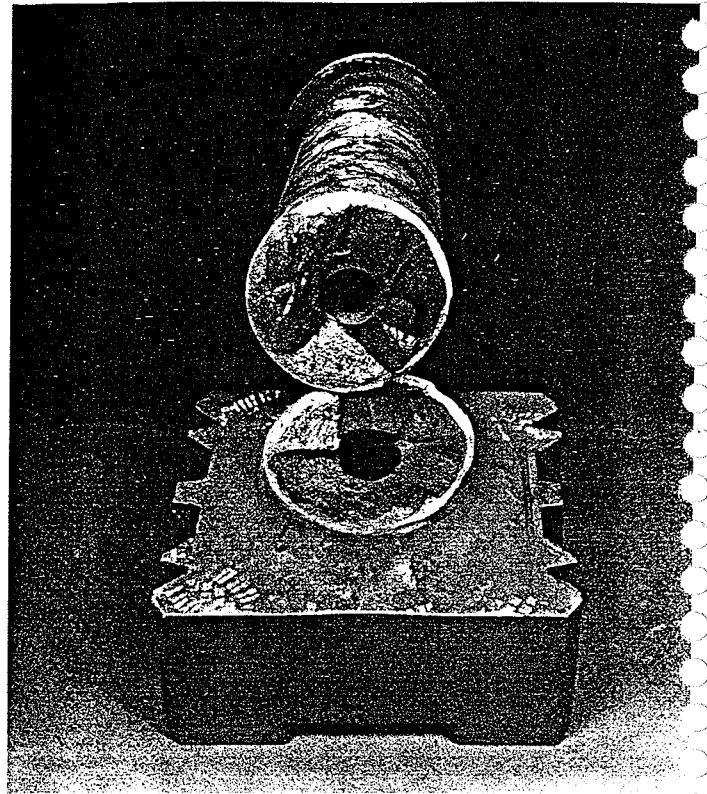


Fig. 19.1

The assembly was then scarfed to produce a cavity 130 mm wide at the top by 50 mm at the bottom as shown in figure 19.2. Two further scarfing and welding operations were then carried out to complete the repair as shown in figure 19.3. Figure 19.4 shows the ram after final machining.

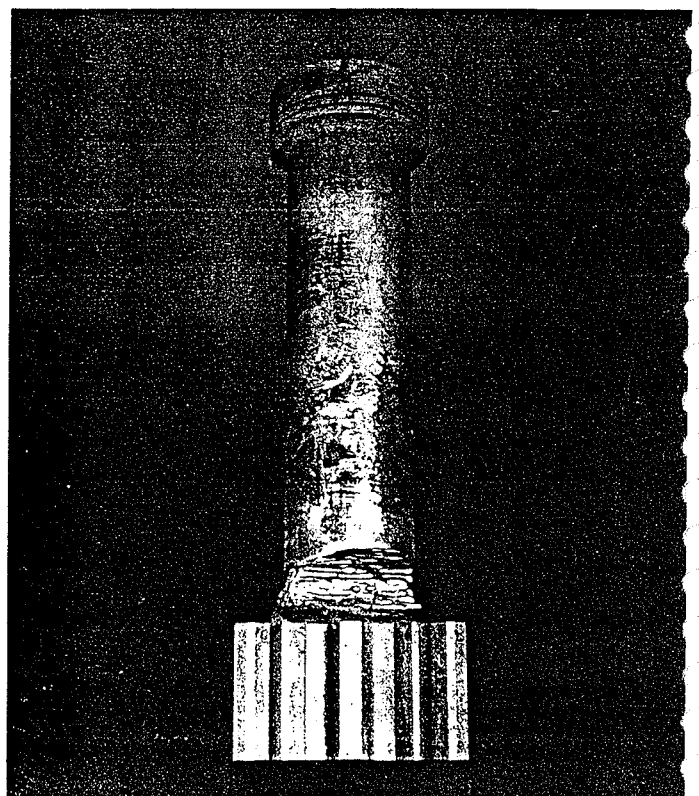
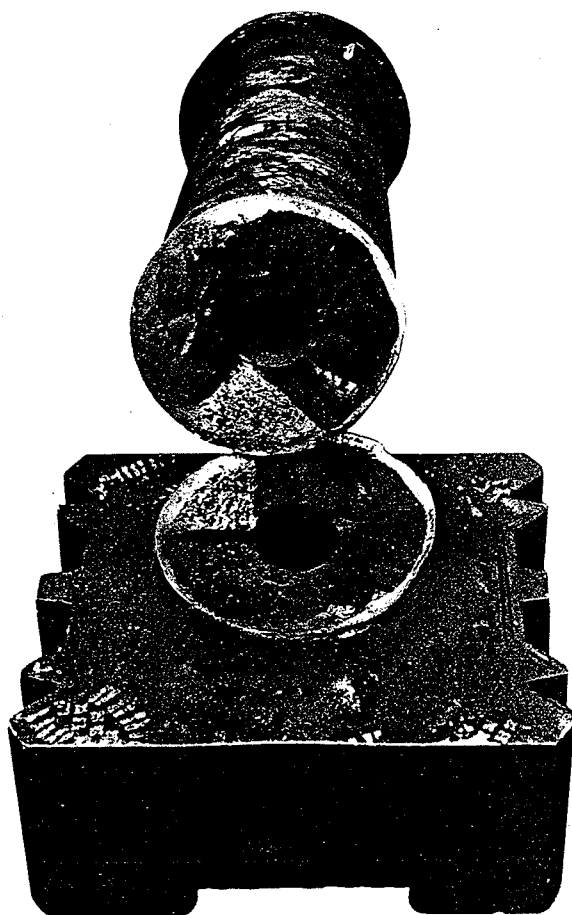


FIG. 19.2

Hunt Bros. Oldbury Ltd

Registered Office: WEST BROMWICH STREET • OLDBURY
WARLEY • WEST MIDLANDS B69 3AT

SAVE MONEY ***FLOODMOLD REPAIR SERVICE***



A typical component as
received.



Machining completed—the
item is now restored to
the condition when it was first
manufactured.

SAVE TIME

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with 'Floodmold' you save all ways.

The composition of the ram and weld metal are compared in table 19.1 together with mechanical properties achieved after heat treatment.

Table 19.1

	C	Si	Mn	Ni	Cr	Mo	UTS kg/mm ²	Elong- ation %
Ram	.35	.3	.7	1.6	1.2	.35	95/110	17
Electrode	.1	.1	.8	1.7	1.1	.6	95/102	20

The repair was completed in two weeks at one third the cost of a new ram.

Figure 19.5 shows the connecting rod from a 4000 tonne crank press being crack detected. Multiple cracking of the small end had occurred.

To effect the repair the whole of the small end was scarfed away (figure 19.6) and a new forging was welded on. Figure 19.7 shows the preliminary positioning of the two parts whilst figure 19.8 shows the welding taking place and figure 19.9 the completed repair.

The composition and final properties of the original connecting rod, the small end forging and the welding electrode are compared in table 19.2.

Table 19.2

	C	Si	Mn	Ni	Cr	Mo	UTS kg/mm ²	Elong- ation %
Original con-rod	.3	.25	.7	—	—	—	71	23
Small end forging	.1	.25	.5	1.3	.8	—	79	17
Electrode	.1	.3	.8	1.7	1.1	.6	79	23

The repair time was one month and the cost one fifth of the replacement cost.

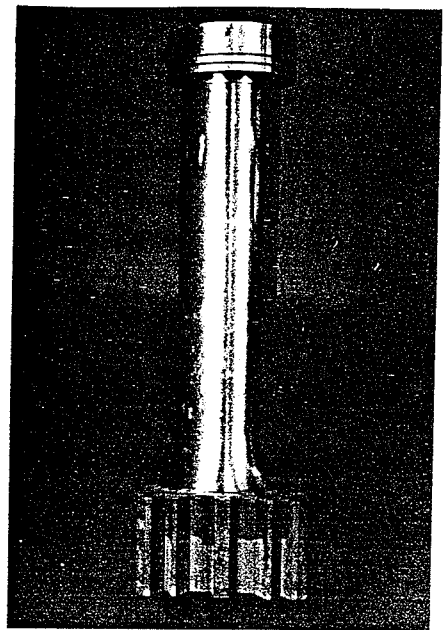


FIG. 19.4

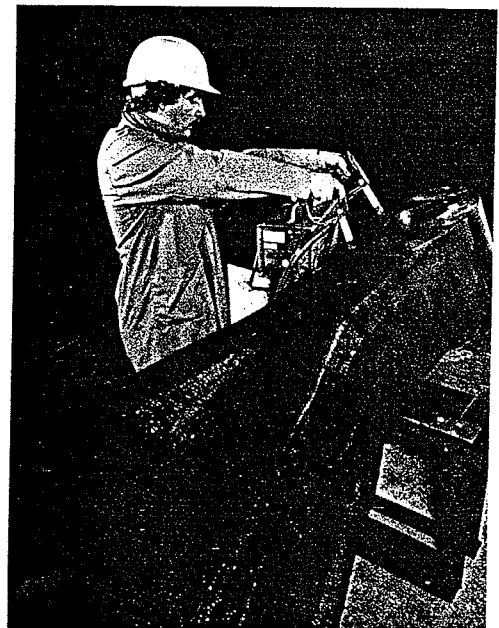


FIG. 19.5

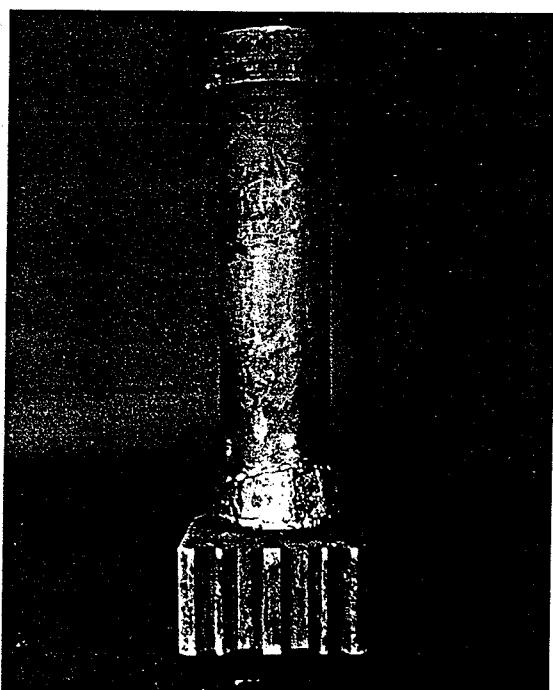


FIG. 19.3

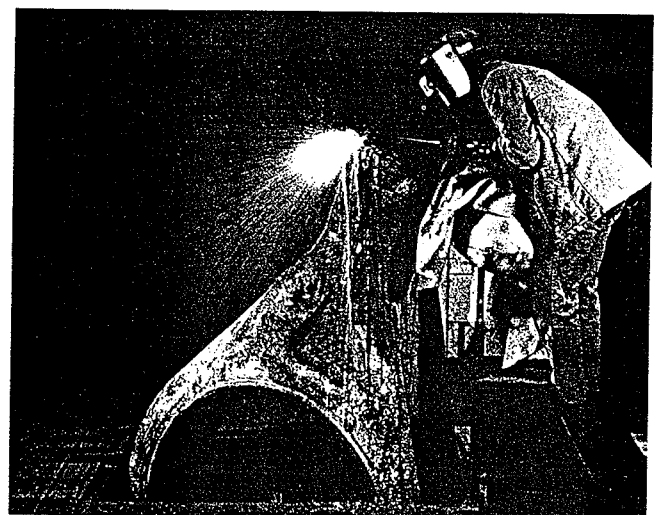


FIG. 19.6

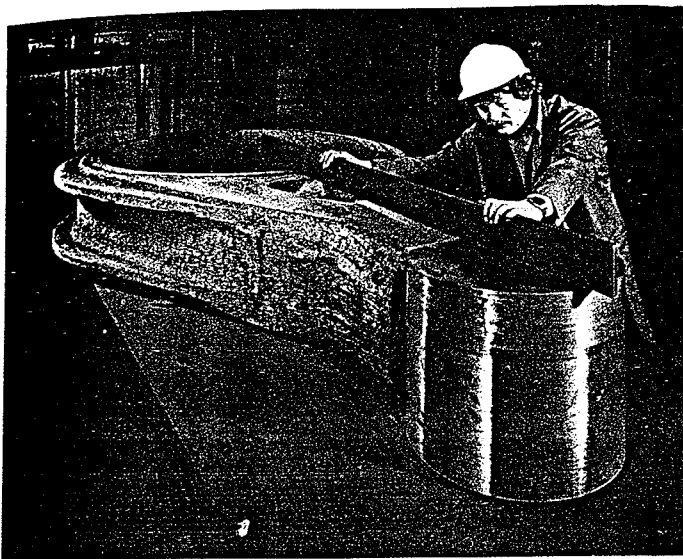


FIG. 19.7

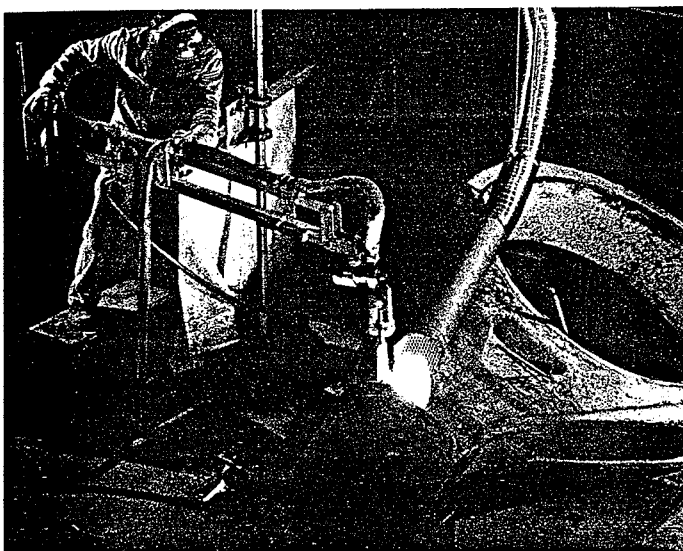


FIG. 19.8

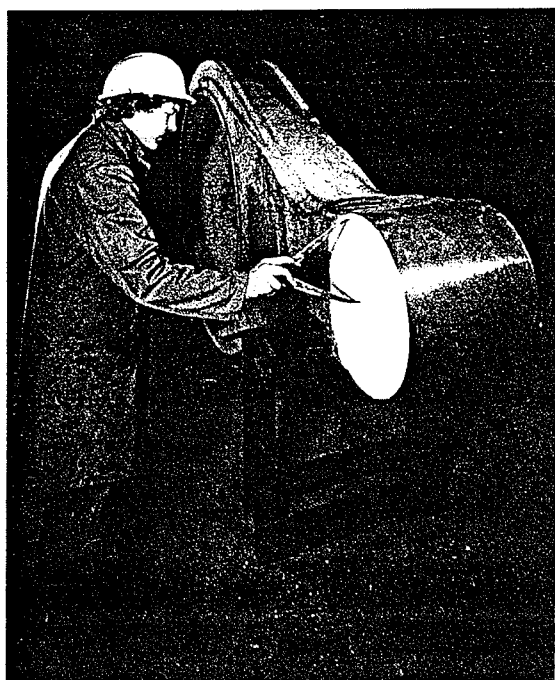


FIG. 19.9

20 SELECTION AND APPLICATION OF FORGING PLANT

Plant selection in the drop forge usually falls into one of three categories.

- (1) deciding which piece of existing plant to use for the production of a given forging.
- (2) deciding whether a potential forging order can be produced economically on existing plant. The most common occurrence in this category is deciding whether the largest available piece of plant will make the forging.
- (3) deciding what size of plant to buy when existing equipment is to be replaced. This problem often arises when old hammers are to be replaced by more modern ones or by crank or screw presses. These latter cases invariably lead to a debate on which size of press is equivalent to a given size of hammer.

Before discussing these three categories in more detail it is useful to recall some fundamental principles of forging and machine characteristics.

It has been shown that for any forging there is a characteristic load-displacement diagram which indicates the maximum load and energy requirement needed to produce the forging.

To produce a forging on a crank press the load and energy requirements of the forging must be fulfilled in one single forging blow and furthermore the load-displacement curve for the forging must at all times be below the characteristic load-displacement curve for the press.

In most forging applications if a crank press has sufficient load capacity to produce a forging it will also have sufficient energy capacity. The exception to this generalisation is most likely to be in extrusion type operations where a maximum load demand builds up early in the deformation process.

Thus the main characteristic of the forging press is a large energy capacity for a given load rating.

At the other end of the scale of forging plant is the hammer which has quite the opposite characteristics to the forging press. Hammers are capable of generating very high loads but for a given load capacity they have very little energy content per blow. This deficiency in energy can of course be compensated to some extent by the use of multiple blows.

The characteristics indicated so far suggest that the shape of the forging will in some cases indicate the type of forging plant most likely to be suitable for economic production.

Thus thin, flat forgings which because of their shape require high forging loads but little energy due to the small displacement will be most suited to hammer forging. The low energy requirement for such forgings leads to the need for only a small number of hammer blows and thus a high production rate.

If such forgings were made on a press the capital cost would be high due to the high load requirement and would be unlikely to be compensated by a much higher production rate since that on the hammer is already high.

This reasoning usually applies irrespective of the order quantities involved thus dispelling the widely held conception that press forging can always be justified provided orders are sufficiently large.

A detailed study in Germany of 21 forgings showed that in 12 cases hammer forging was more economic than press forging irrespective of run size whilst the reverse was true in one instance. For the remaining eight forgings press forging became more economic than hammer forging as the run size increased.

Typical forgings falling into this high load, low energy category are spanners, hand tools and cutlery.

Another type of forging most suited to hammers is one where deep bosses or ribs have to be filled, typical examples of such forgings would be a weld neck flange or a stub axle.

In this instance a restrictive flash has to be used to ensure die filling and this again leads to a high load requirement.

Recent tooling developments however allow forgings such as the stub axle to be made on presses by incorporating a virtually closed die extrusion station in the tooling. Generally though the cost of tool development and production is such that long runs are needed to make press forging attractive.

Whilst these general principles regarding plant selection are reasonably clear it is of course very difficult to present them in quantitative terms. Figure 20.1 may however be used as a rough indication of whether a forging is likely to be suitable for consideration as a press forging.

If the forging load and hammer size for a given forging are determined in the manner already described they can be used to define a point on figure 20.1. those points falling below the curve indicate that press forging may be economic whilst those lying above the curve indicate the use of hammer forging.

The further points lie below or above the curve the clearer the choice is likely to be. It must however be stressed that this figure is only meant to be a general guide.

There are of course other considerations apart from those discussed above which will influence the choice of plant. Hammer forging is extremely versatile and particularly suited to small to medium runs of elongate forgings where preforming can be done on the hammer dies using fullering and rolling tools.

Only when production runs for elongate forgings are large is the use of press forging justified. This is because of the need to use auxilliary equipment, usually forging rolls, for preforming operations.

In general therefore press forging is most widely used for axisymmetric forgings where preforming is confined to a scale breaking upset and forging in a moulding impression.

In addition to a high production rate the crank press offers other advantages compared with hammer forging. The use of ejectors on presses allows draft on forgings to be reduced which is a particularly attractive feature on large forgings such as crankshafts since it leads to lower weight and reducing machining. Control of offset is also better on presses since pillared tool sets are commonly used and ram guidance is much better than the tup guidance on hammers.

Generally thickness control on press forgings is limited because the dies cannot be allowed to meet as in other forging processes. In addition any variations in forging load due to billet temperature differences will lead to variable press spring and thus thickness deviations.

Thickness variations in press forging also occur due to expansion effects as the die and bolster heat up during a production run and periodic corrections are commonly made by adjusting the bottom bolster position.

The general role of fraction screw presses in forging appears to be even less clearly defined than that of hammers or crank presses.

Like the latter they are not suitable for extensive preforming so that if used for elongate forgings of varying cross-section they must be accompanied by ancillary pre-forming equipment.

For many years screw presses have been used predominantly for the forging of turbine blades. Their suitability for such forgings stems from the fact that screw presses combine some of the advantageous features of both hammers and presses.

As in the press there is good guidance and since pillared tool sets can also be used control of offset is very good. In addition because the dies can meet on clashing faces good thickness control is possible. The screw press is therefore the preferred machine for precision forgings such as blades.

The developments in machine design, particularly the slipping clutch, have resulted in the rapid development over the last decade of very large friction screw presses and machines with capacities up to 16000 tonne exist.

In sizes of 6000 tonne upwards there appears to be a trend for the screw press to be preferred to the mechanical press.

Apart from such very large developments the general area of application of small to medium sized screw presses is more similar to that for crank presses than for hammers. The screw press is however less amenable to offset loading than the crank press and so it is not possible to accommodate so many forging stations.

One of the main attractions of a screw press compared with a crank press is the lower cost. Table 20.1 is based on figures given in a Hasenclever publication and makes an approximate cost comparison of the two machines.

In the table the comparison is not made between machines of the same rated tonnage but rather between machines able to produce an identical workpiece.

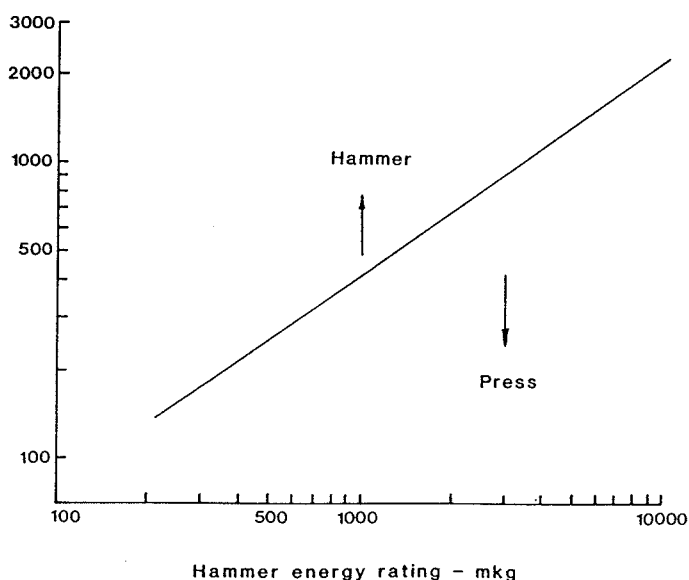
Table 20.1

Load required for forging tonnef

	600	950	1500	1950	3000	4000
Mechanical press cost %	100	100	100	100	100	100
Screw press cost %	59	64	66	71	73	75

Having underlined the characteristics of the major types of forging plant the original questions posed at the beginning of this section can be considered.

Questions 1 and 2 regarding the size of plant needed have already been dealt with since methods for calculating



NB This is not total forging energy required

FIG. 20.1

required forging loads and energies have been presented and a simple graphical method of selecting hammer size has been given.

The remaining question concerns the equivalent sizes of hammers and presses. The true answer to this question is that there is in fact no general relationship and that the equivalent size depends on the particular forging being made.

Table 20.2 summarises the equivalent machine sizes as suggested in the literature.

Table 20.2

Equivalent sizes of forging plant

H/CP = hammer energy—mkg/press rating—tonnef

H/FSP = hammer energy—mkg/screw press rating—tonnef

	Small machines	Large machines	Unspecified m/c size	Average value	Literature source
H/CP	1.6	3.15	—	2.5	German
			3.08-3.76	3.5	USA
			1.5 -2.5	2.0	UK
H/FSP				3.15	German

For reasons already discussed above it is not surprising that there is no general agreement on equivalent plant sizes. The range of values given is certainly too wide to allow a rational economic decision to be taken on equivalent press sizes to replace hammers.

Information given in previous sections of this Handbook allows reasonable estimates of load and energy requirements for forgings to be made. This approach should certainly be used when considering a large capital investment in new plant.

The effort involved is minimal in relation to the cost of the plant to be installed.

