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JAPANESE INDUSTRIAL STANDARD

Methods of Measurement for Spur and Helical Gears

JIS B 1752^{—1989}

Translated and Published

by

Japanese Standards Association

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Methods of Measurement for Spur and Helical Gears B 1752-1989
(Reaffirmed: 1994)

1. Scope

This Japanese Industrial Standard specifies the measuring methods and obtaining methods of errors of the pitch, tooth profile, tooth trace, radial runout and tooth thickness and the measuring method of working error of both tooth flanks of involute spur and helical gears⁽¹⁾, hereinafter referred to as the "gears".

Note (1) This Standard applies to double helical gears considering these to be the combinations of helical gears.

2. Definitions and Symbols

For the purpose of this Standard the following definitions apply, and others are in accordance with JIS B 0102, and the symbols are in accordance with JIS B 0121.

(1) working errors of both tooth flanks

- (a) in the case of single body of gear The variation of centre distance when a gear has been rotated with being engaged with a master cylindrical gear for inspection⁽²⁾ without backlash.

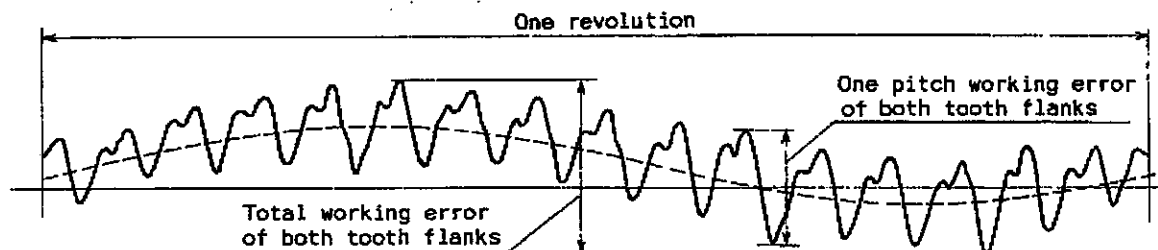
Note (2) Regarding accuracies, refer to JIS B 1751.

- (b) in the case of gear pair The variation of centre distance when two gears to be used in a pair, hereinafter referred to as the "specific gear pair", has been rotated with being engaged without backlash.

Furthermore, the working errors of both tooth flanks in the case of single body of gear and in the case of specific gear pair consist of total working error of both tooth flanks and one pitch working error of both tooth flanks.

- (2) total working error of both tooth flanks The maximum value of working error of both tooth flanks in one revolution of gear in the case of single body of gear, or one revolution or over of wheel in the case of specific gear pair (see Fig. 1).
- (3) one pitch working error of both tooth flanks The working error of both tooth flanks during working of one pitch (see Fig. 1).

Fig. 1. Example of Working Errors of Both Tooth Flanks on a Recording Diagram (In the case of Single Body of Gear)



3. Measurement of Pitch

3.1 Types of Measuring Methods for Circular Pitch The measurement of the circular pitch shall be as follows:

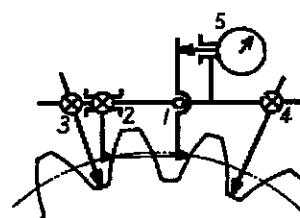
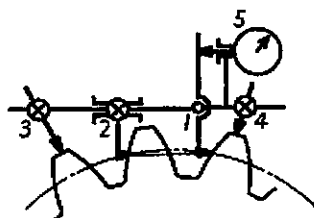
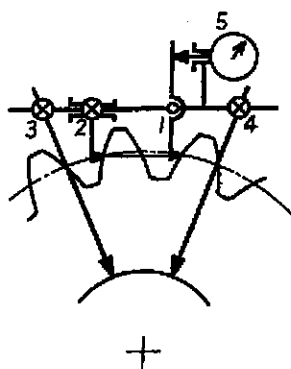
- (1) Linear Distance Measuring Method Allow the measuring contact head and fixed contactor to contact with the points on the circumference of a circle, the centre of which being the centre of rotation of a gear passing through about centre of the working depth, hereinafter referred to as the "measuring circle", corresponding to the adjoining teeth, and measure the dispersion of the distances between these points over the total circumference of the gear. For the references of measurements, there are methods using the centre of rotation of a gear, tip cylinder, root cylinder, etc. In Fig. 2, measuring methods of pitch circle in accordance with the references of these types are indicated.

Fig. 2. Methods of Circular Pitch Measurement
(Linear Distance Measuring Methods)

(a) Reference on Centre of Rotation

(b) Reference on Tip Cylinder

(c) Reference on Root Cylinder

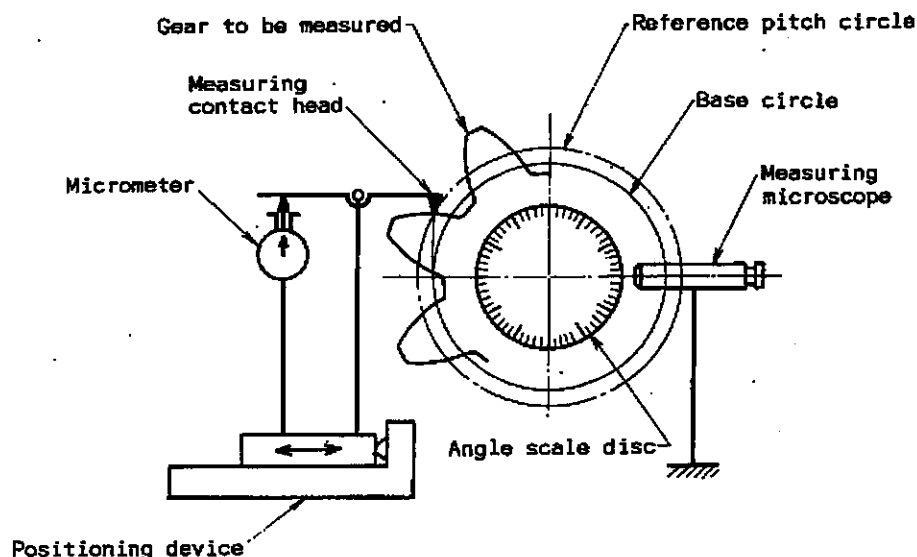


1: Measuring head 2: Fixed contactor⁽³⁾ 3,4: Positioning contactor
5: Micrometer

Note ⁽³⁾ The fixed contactor also includes the case of setting 0 position by a micrometer or the like.

- (2) Angle Measuring Method Taking the centre of rotation of a gear to be measured as the reference of measurement, measure the centre angle between the corresponding flanks on measuring circle. Carry out the measurement of angle usually according to an optical method, using an angle scale disc, optical dividing head, transit or the like. In Fig. 3, the angle measuring method by the angle scale disc is indicated. Determine the 0 position of flank by the micrometer, and compare the reading of angle scale disc and the correct centre angle corresponding to this.

Fig. 3. Circular Pitch Measuring Method
(Angle Measuring Method)



3.2 Gists of Measurement for Circular Pitch
pitch shall be in accordance with the following;

The measurement of the circular

- (1) Reference of Measurement and Mounting of Gear to be Measured Since the accuracies of the center of rotation and tip cylindrical surface or root cylindrical surface of reference gear for measurement give influence on measured values, sufficient consideration shall be taken to the accuracies.

In the case where a mounting axis is used in measurement, the permissible value of the runout of the mounting axis should preferably be in accordance with Table 1.

Table 1. Permissible Value of Runout of Mounting Axis for
Measurement of Gear Accuracies

Unit: μm

Pitch circle diameter(mm) Grade	25 to 50 incl.	Over 50 to 100 incl.	Over 100 to 200 incl.	Over 200 to 400 incl.	Over 400 to 800 incl.
Precision grade (for gears of 1 to 3 grade)	1.5	2	3	4	6
Ordinary grade (for gears of 4 to 6 grade)	3	4	6	8	12

- (2) Measuring Places Measure the circular pitches, over the total circumference of a gear, at the centre of tooth width on each pitch continuously. In the case where furthermore measurements are required, carry out measurements by adding further 2 or over places along the tooth trace.

3.3 Treatment on Measuring Results of Circular Pitch Where the angle measuring method is used, multiply the reference pitch circle radius to the centre angle, convert into the length of circular arc on the reference pitch circle, and obtain on cumulative pitch error as the difference from the theoretical value.

In the case of using the linear distance measuring method, obtain the maximum values of individual circular pitch error, pitch variation and cumulative pitch error from the measured values.

Reference: A sequence for obtaining individual circular pitch error, pitch variation and cumulative pitch error from measured values is given in Reference Table 1, and the relations are given in Reference Fig. 1.

Reference Table 1. Example of Calculation for Individual Circular Pitch Error, Pitch Variation and Cumulative Pitch Error (for number of teeth 15)

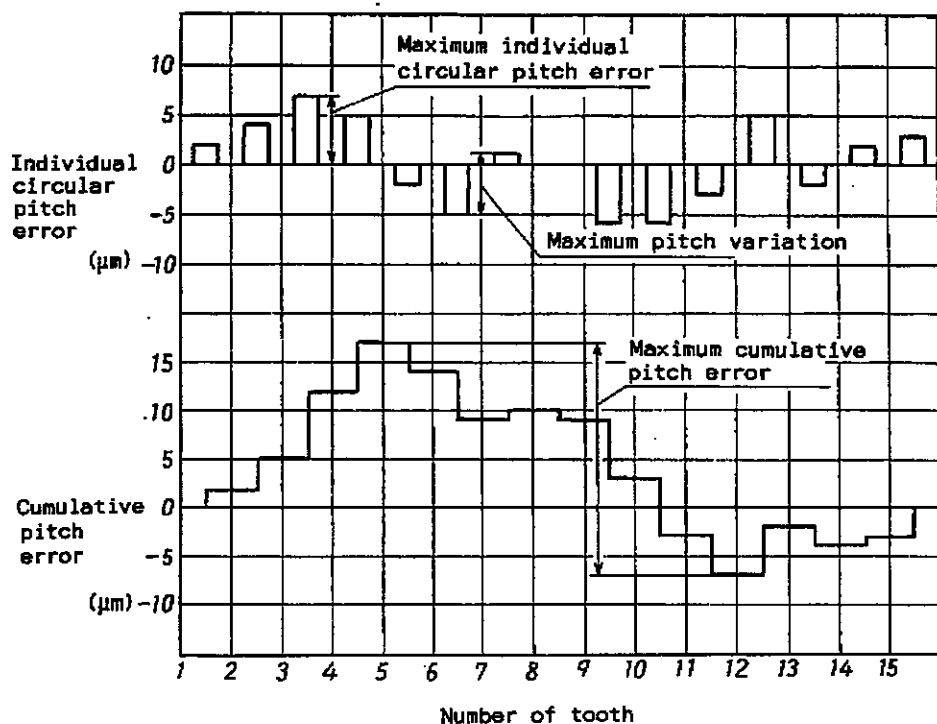
Unit: μm

Teeth	Measured value	Cumulative value of measured value	Individual circular pitch error	Pitch variation	Cumulative value of average of measured values	Cumulative pitch error
1 and 2	4	4	2	2	$2.33 \times 1 \approx 2$	2
2 and 3	6	10	4	3	$2.33 \times 2 \approx 5$	5
3 and 4	9	19	7	2	$2.33 \times 3 \approx 7$	12
4 and 5	7	26	5	7	$2.33 \times 4 \approx 9$	17
5 and 6	0	26	-2	3	$2.33 \times 5 \approx 12$	14
6 and 7	-3	23	-5	6	$2.33 \times 6 \approx 14$	9
7 and 8	3	26	1	1	$2.33 \times 7 \approx 16$	10
8 and 9	2	28	0	6	$2.33 \times 8 \approx 19$	9
9 and 10	-4	24	-6	0	$2.33 \times 9 \approx 21$	3
10 and 11	-4	20	-6	3	$2.33 \times 10 \approx 23$	-3
11 and 12	-1	19	-3	8	$2.33 \times 11 \approx 26$	-7
12 and 13	7	26	5	7	$2.33 \times 12 \approx 28$	-2
13 and 14	0	26	-2	4	$2.33 \times 13 \approx 30$	-4
14 and 15	4	30	2	1	$2.33 \times 14 \approx 33$	-3
15 and 1	5	35	3	1	$2.33 \times 15 \approx 35$	0
Average value of measured values = $\frac{\text{Cumulative value of measured values}}{\text{Number of teeth}} = \frac{35}{15} \approx 2.33 \approx 2$						

Maximum individual circular pitch error: $7 \mu\text{m}$,
Maximum pitch variation: $8 \mu\text{m}$,
Maximum cumulative pitch error: $24 \mu\text{m}$

In Reference Table 1, individual circular pitch error
= measured value - average value of measured values
cumulative pitch error
= cumulative value of measured values - cumulative
value of average of measured values

Reference Fig. 1. Pitch Error



3.4 Measuring Method of Base Pitch In the measurement of the base pitch, measure the linear distance between the 2 intersection points, allowing the measuring contactor and fixed contactor to touch the point of intersection with the tooth flank adjoining to the tangent of base circle. In a helical gear, measure the transverse base pitch. In the case where measurement of transverse base pitch is difficult, measure the normal base pitch, and convert into the transverse base pitch.

The difference between the measured value and the theoretical value shall be the base pitch error.

Measure the base pitch at least 3 pitches each continuously, at each 90° on the circumference of a gear at the centre of tooth width.

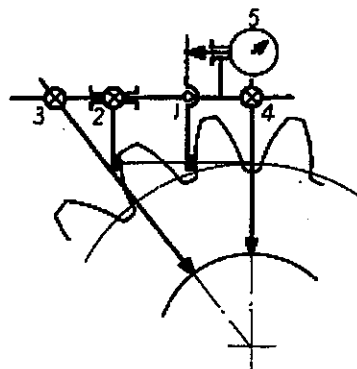
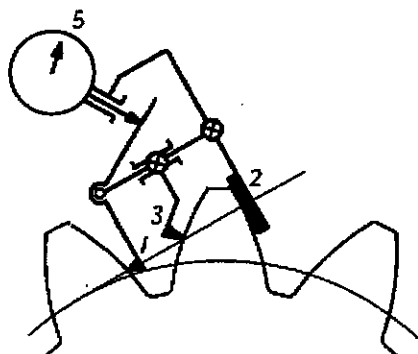
For the gear which works only at the tooth flanks of single side, only the working tooth flanks may be measured.

In Fig. 4, the methods of base pitch measurement are indicated.

Fig. 4. Measuring Methods of Base Pitch

(a) Hand-held Type

(b) Reference on Centre of Rotation



1: Measuring contact head 2: Fixed contactor

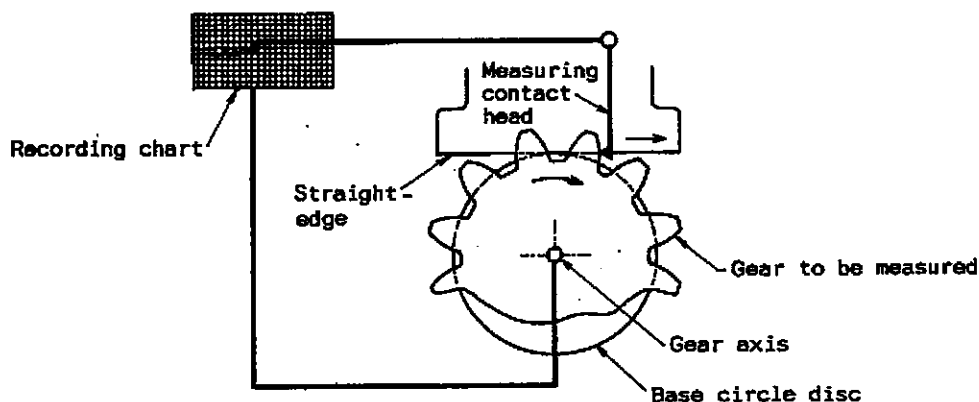
3 and 4: Positioning contactor 5: Micrometer

4. Measurement of Tooth Profile

4.1 Measuring Methods of Tooth Profile The measurement of the tooth profile shall be carried out by comparing the actual tooth profile at plane perpendicular to the axis with its correct involute curve, and shall be as given in the following.

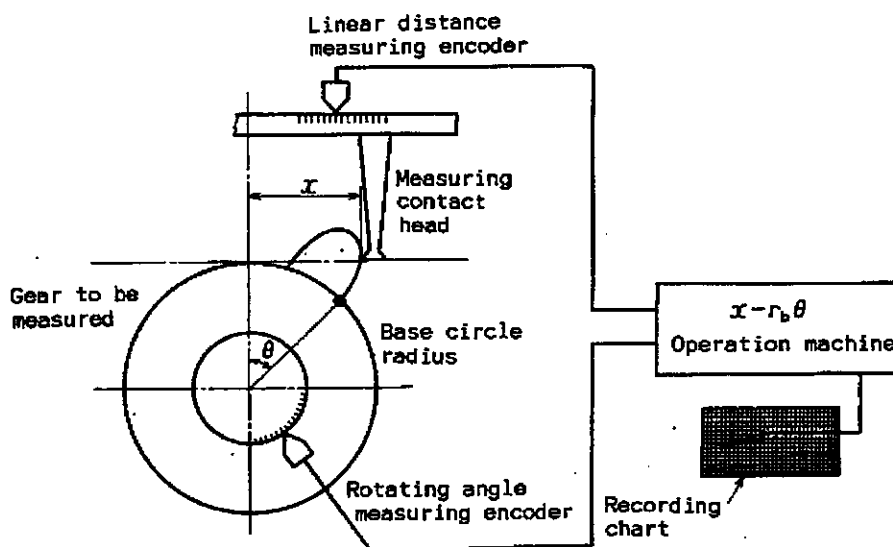
- (1) Base Disc System Allowing the measuring contact head of a micrometer fixed to the straightedge to contact with the tooth flank of the gear to be measured which has been attached to the base circle disc axis on one point on the contact face of the straightedge, measure the tooth profile error from the involute curve by the movement of tangential direction of the base circle of the measuring contact head. In the measurement, either read the movement of the measuring contact head by the micrometer, or record automatically. In the case where the movement of the measuring contact head is not contained in the plane perpendicular to the axis, convert into the plane perpendicular to the axis. In Fig. 5, the tooth profile measuring method in accordance with this method is indicated.

Fig. 5. Base Circle Disc System Measuring Method of Tooth Profile



- (2) Base Circle Adjusting System Using a defined base circle disc, by reducing or enlarging the linear motion of measuring contact head in proportion to the diameter ratio of the reference disc to the base circle of gear to be measured by an appropriate mechanism, the tooth profile measuring method of mechanism which impart the same relative motion as that using the corresponding base disc.
- (3) Operation System Measure the coordinates of the tooth profile of a gear digitally, and calculate errors by comparing this with the theoretical value of involute curve. Fig. 6 gives the method of operation system tooth profile measurement by this principle.

Fig. 6. Operation System Tooth Profile Measuring Method



4.2 Gist of Measurement The measurement of the tooth profile shall be in accordance with the following gists.

- (1) Reference of Measurement and Mounting of Gear to be Measured In the measurement of the tooth profile, the centre of rotation of the gear shall be taken as the reference of measurement. In case where the centre of rotation can not be taken as the reference, other reference of measurement in lieu of this shall be used.

In the case where it is measured by using a mounting axis, the permissible value of the runout of the mounting axis should preferably be in accordance with Table 1.

- (2) Accuracy of Base Circle Disc The accuracy of the base circle disc to be used in the base circle disc system involute tooth profile measuring machine and the permissible value of runout of the outer periphery after mounting of base circle disc should preferably be in accordance with Table 2.

Table 2. Accuracies of Base Circle Discs

Unit: μm

Diameter of base circle (mm)	Tolerances on outside diameter		Permissible value of runout of outer periphery	
	Precision grade (1 to 3 grades)	Ordinary grade (4 to 6 grades)	Precision grade (1 to 3 grades)	Ordinary grade (4 to 6 grades)
50 and under	± 3	± 5	3	5
Over 50 to 100 incl.	± 4	± 6	4	6
Over 100 to 200 incl.	± 5	± 8	5	8
Over 200 to 400 incl.	± 7	± 10	7	10
Over 400 to 800 incl.	± 9	± 13	9	13

Unit: μm

Bore (mm)	Tolerances on inside diameter	
	Precision grade (1 to 3 grades)	Ordinary grade (4 to 6 grades)
30 and under	+ 4 + 1	+ 6 + 1
Over 30 to 50 incl.	+ 5 + 2	+ 8 + 2
Over 50	+ 6 + 2	+ 9 + 2

Reference: The theoretical value of the base circle diameter d_b of spur and helical gears shall be obtained from the following formula:

$$d_b = m_t \cdot z \cdot \cos \alpha_t$$

Where m_t : transverse module
 α_t : transverse pressure angle

The transverse module m_t and transverse pressure angle α_t of normal system helical gear shall be obtained from the following formulae:

$$m_t = \frac{m_n}{\cos \beta}$$

$$\tan \alpha_t = \frac{\tan \alpha_n}{\cos \beta}$$

Where m_n : normal module
 α_n : normal pressure angle
 β : reference pitch cylinder helix angle

Example: For the normal system helical gear of normal module 4, normal pressure angle 20° , number of teeth (z) 20, reference pitch cylinder helix angle 30° .

Transverse module $m_t = \frac{4}{\cos 30^\circ} = 4.618\ 80$

Transverse pressure angle $\tan \alpha_t = \frac{\tan 20^\circ}{\cos 30^\circ} = 0.420\ 277$

$$\alpha_t = 22.795\ 9^\circ = 22^\circ 47' 45''$$

$$\cos \alpha_t = 0.921\ 891$$

Therefore, base circle diameter

$$d_b = 4.618\ 80 \times 20 \times 0.921\ 891 = 85.161\ \text{mm}$$

- (3) Measuring Places On each circumference of 90° of gear, measure the both tooth flanks of left and right of one piece of tooth at the centre of tooth width. In addition, for a gear which works at single side tooth flank only, it may be allowed to measure only the working tooth flanks.

The tooth numbers of 4 places should preferably so as given in the following according to number of teeth.

The quotient of $z/4$ is N and remainder exists, Table 3 shall be referred to.

Table 3

Remainder	1st tooth number	2nd tooth number	3rd tooth number	4th tooth number
0	1	$N+1$	$2N+1$	$3N+1$
1	1	$N+1$	$2N+1$	$3N+2$
2	1	$N+2$	$2N+1$	$3N+2$
3	1	$N+2$	$2N+2$	$3N+2$

- (3) For a machining which causes discontinuous places, for example, in the case of a gear which has been machined with gear shaping, the places concerned have been clarified in advance, and these places are to be measured.

4.3 Treatment of Measured Results In the tooth profile recording diagram, the maximum width of the protrusion and dent of the record diagram within the tooth profile inspection range shall be considered to be the tooth profile errors.

The tooth profile inspection range, in the case where tooth profile error has been recorded corresponding to the position on working line, shall be determined by the following method. Namely, assuming working pressure angle as α_w , tip radii of gear to be measured and mating gear as r_{a1} and r_{a2} , working pitch circle radii as r_{w1} and r_{w2} , and base circle radii as r_{b1} and r_{b2} , the working lengths g_a and g_r of addendum and dedendum of gear to be measured shall be obtained from the following formulae (Fig. 7).

$$g_a = \sqrt{r_{a1}^2 - r_{b1}^2} - r_{w1} \sin \alpha_w \quad (\text{The point of } g_a \text{ from the tip corresponds to a pitch point})$$

$$g_r = \sqrt{r_{a2}^2 - r_{b2}^2} - r_{w2} \sin \alpha_w$$

The range of $g_a + g_r$ shall be the tooth profile inspection range when no tooth profile modification is carried out (see Fig. 8).

Fig. 7. Working Length

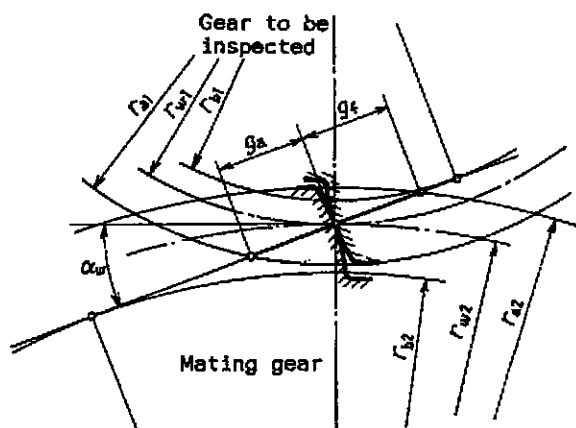
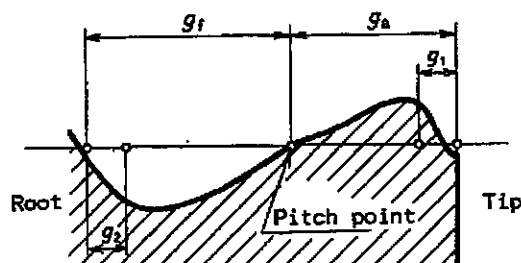


Fig. 8. Tooth Profile Inspection Range on Record Diagram



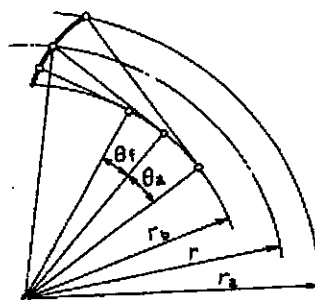
In the case where mating gear is not known, when assuming that the reference pitch circle radius of gear to be measured as r , the transverse pressure angle on reference pitch circle as α , the addendum as h_a , and the working depth as h_w , the tooth profile inspection range shall be obtained as follows:

$$g_a = \sqrt{r_{a1}^2 - r_{b1}^2} - r_1 \sin \alpha_t$$

$$g_f = \frac{h_w - h_a}{\sin \alpha_t}$$

In addition, in the case where to measure the tooth profile by using the base circle disc system gear measuring machine with rotation angle indication, the tooth profile inspection range shall be expressed by the rotation angle θ_a and θ_f on the base circle which is obtained as follows from g_a and g_f mentioned above (Fig. 9).

Fig. 9. Rotation Angle Representation



$$\theta_a = \frac{g_a}{r_b} \frac{180}{\pi} \text{ (degree)}$$

$$\theta_f = \frac{g_f}{r_b} \frac{180}{\pi} \text{ (degree)}$$

Example 1: In the case where the full depth standard gear of module 4, reference pressure angle 20° , and number of teeth 20 engages with the full depth tooth standard gear of number of teeth 40 at the standard centre distance, since,

$$\alpha = 20^\circ, r_{a1} = 44 \text{ mm}, r_{a2} = 84 \text{ mm}, r_{w1} = 40 \text{ mm}, r_{w2} = 80 \text{ mm}$$

therefore $r_{b1} = 40 \cos 20^\circ = 37.59 \text{ mm}, r_{b2} = 80 \cos 20^\circ = 75.18 \text{ mm}$

$$g_a = \sqrt{44^2 - 37.59^2} - 40 \sin 20^\circ = 9.19 \text{ mm}$$

$$g_f = \sqrt{84^2 - 75.18^2} - 80 \sin 20^\circ = 10.11 \text{ mm}$$

$$g_a + g_f = 9.19 + 10.11 = 19.30 \text{ mm}$$

In addition, in the case where mating gear is unknown, since,

$$h_a = 8 \text{ mm}, h_{a1} = 4 \text{ mm}$$

$$g_a = \sqrt{44^2 - 37.59^2} - 40 \sin 20^\circ = 9.19 \text{ mm}$$

$$g_f = \frac{8 - 4}{\sin 20^\circ} = 11.70 \text{ mm}$$

$$g_a + g_f = 9.19 + 11.70 = 20.89 \text{ mm}$$

Example 2: In the case where the full depth standard helical gear of normal module 4, normal pressure angle 20° , number of teeth 20, and reference cylinder helic angle 30° engages with the full depth standard helical gear of number of teeth 40 at the standard centre distance, the working pressure angle α_w is equal to the transverse pressure angle α_t .

$$\tan \alpha_t = \frac{\tan 20^\circ}{\cos 30^\circ} = 0.420277, \alpha_w = \alpha_t = 22.7959^\circ = 22^\circ 47' 45''$$

$$r_{w1} = \frac{40}{\cos 30^\circ} = 46.19 \text{ mm}, r_{w2} = \frac{80}{\cos 30^\circ} = 92.38 \text{ mm}$$

$$r_{a1} = 46.19 + 4 = 50.19 \text{ mm}, r_{a2} = 92.38 + 4 = 96.38 \text{ mm}$$

$$r_{b1} = 46.19 \cos 22^\circ 47' 45'' = 42.58 \text{ mm}, r_{b2} = 92.38 \cos 22^\circ 47' 45'' = 85.16 \text{ mm}$$

$$g_a = \sqrt{50.19^2 - 42.58^2} - 46.19 \sin 22^\circ 47' 45'' = 8.67 \text{ mm}$$

$$g_f = \sqrt{96.38^2 - 85.16^2} - 92.38 \sin 22^\circ 47' 45'' = 9.33 \text{ mm}$$

$$g_a + g_f = 8.67 + 9.33 = 18.00 \text{ mm}$$

Example 3: In the case where the spur gears of the module 4, reference pressure angle 20° , number of teeth 20, addendum modification coefficient 0.24 and tip circle radius 24.96 mm engages without backlash.

$$\text{inv} \alpha_w = 2 \tan 20^\circ \times \left(\frac{0.24 + 0.24}{10 + 10} \right) + \text{inv} 20^\circ = 0.032375$$

$$\alpha_w = 25.6148^\circ = 25^\circ 36' 53''$$

$$r_b = 20 \cos 20^\circ = 18.79 \text{ mm}, r = \frac{18.79}{\cos 25^\circ 36' 53''} = 20.84 \text{ mm}$$

$$g_a = g_f = \sqrt{24.96^2 - 18.79^2} - 20.84 \sin 25^\circ 37' = 7.42 \text{ mm}$$

$$g_a + g_f = 7.42 + 7.42 = 14.84 \text{ mm}$$

Whether the tooth profile modification range is to be included or not in the tooth profile error of gear which has been carried out with tooth profile modification shall be clearly stated in the inspection reference document or drawings. If possible; it should preferable to indicate the permissible range on the drawings.

The tooth profile inspection range, in the case where the tooth profiles of addendum and dedendum have been modified, shall be determined as the following: Namely, assuming that the pressure angle on reference pitch circle as α , the pitch circle radius of gear to be measured as r , the addendum and dedendum from the gear cutting pitch line of gear cutting tool to the starting point of modification respectively as h_a and h_b (Fig. 10), the imaginary working lengths g_1 and g_2 corresponding to the modified parts of addendum and dedendum of tooth profile shall be obtained from the following formulae approximately.

$$g_1 = \sqrt{r_a^2 - r_b^2} - r \sin \alpha_t - \frac{h_a}{\sin \alpha_t}$$

$$g_2 = g_f - \frac{h_b}{\sin \alpha_t}$$

The length of tooth profile inspection range, in the case where the tooth profile modification range is included,

$$g_a = g_a + g_f,$$

and in the case where the tooth profile modification is not included,

$$g_a' = g_a + g_f - g_1 - g_2$$

Example: In the case where the full depth standard gear of module 4, reference pressure angle 20° and number of teeth 20 has been generated by using a rack shape gear cutting tool of which tooth tip has been tooth-profile-modified, assuming that $h_a = 2$ mm

$$g_1 = \sqrt{44^2 - 37.59^2} - 40 \sin 20^\circ - \frac{2}{\sin 20^\circ} = 3.34 \text{ mm}$$

assuming that the number of teeth of the mating gear as 40, where the modification range is included, the length g_a of the tooth profile inspection range shall be

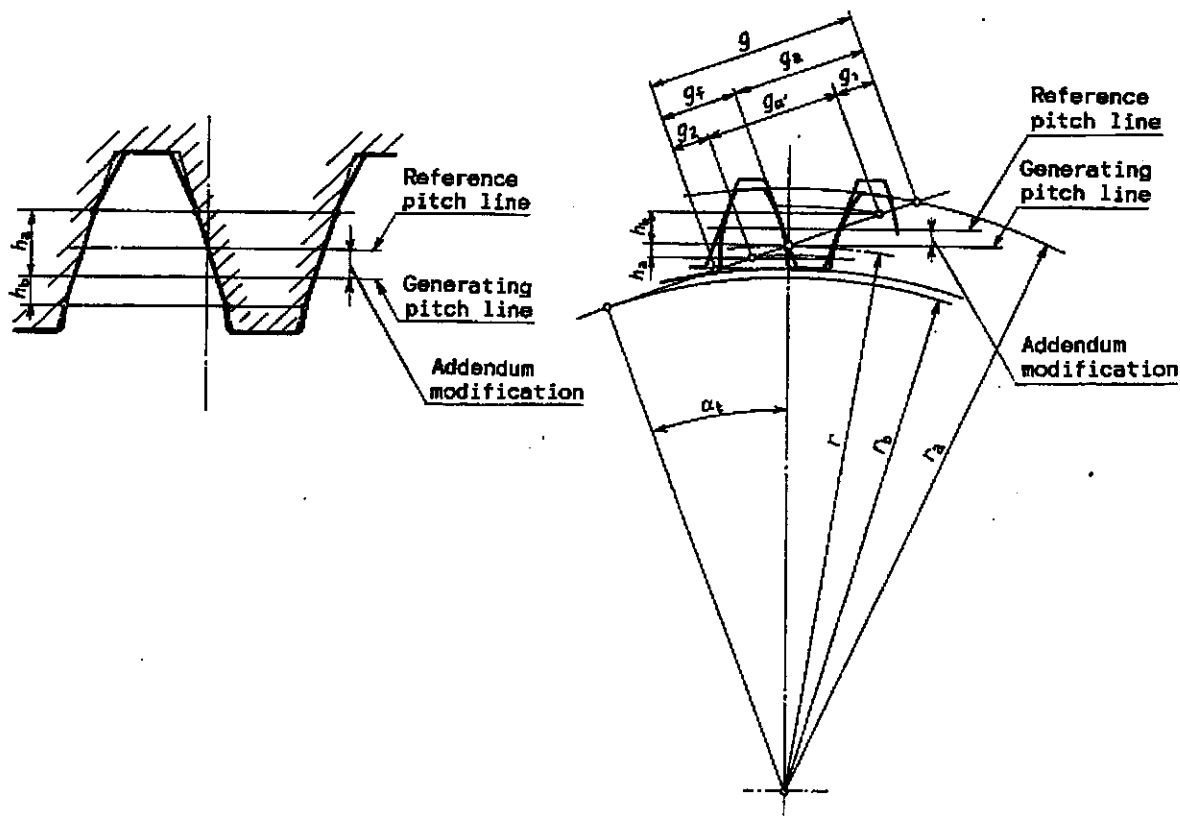
$$g_a = g_a + g_f = 9.19 + 10.11 = 19.30 \text{ mm}$$

and, where the modification range is not included, the length g_a' of the tooth profile inspection range shall be

$$g_a' = g_a + g_f - g_1 - g_2 = 9.19 + 10.11 - 3.34 - 0 = 15.96 \text{ mm}$$

Fig. 10. Tooth Profile Modification

- (a) Tool Profile Modification of Rack Shape Gear Cutting Tool (b) Imaginary Working Length Corresponding to Modified Part



5. Measurement of Tooth Trace

5.1 Measuring Method of Tooth Trace Measurement shall be carried out by comparing the theoretical tooth trace on the concentric measuring cylindrical surface with the gear which passes through approximately centre of tooth depth of the gear with the actual tooth trace as given in the following:

- (1) Tooth Trace Generating Method In the case of a spur gear, place a measuring contact head on the measuring cylinder of the gear to be measured, and measure by travelling the gear or the measuring contact head in axial direction.

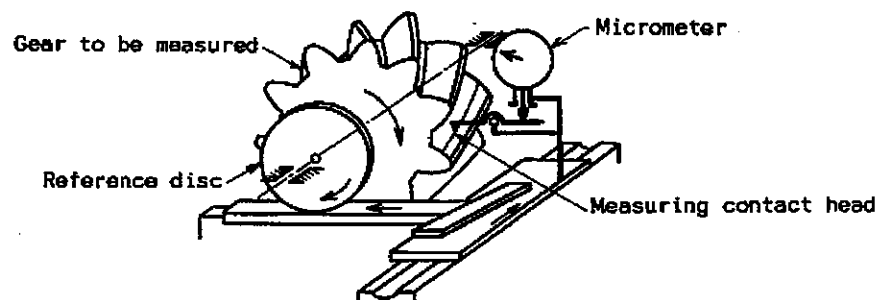
In the case of a helical gear, rotate the gear being mounted on the measuring machine, and measure by travelling the gear or measuring contact head in axial direction by the equivalent distance in axial direction of theoretical tooth trace on measuring cylinder. In this case, the axial direction amount of travel equivalent to the angle of rotation θ of the gear shall be $\frac{p_x \theta}{2\pi}$ when assuming the lead as p_x . Where the lead p_x

shall be in the relation of $p_x = 2\pi r \cdot \cot \beta$, assuming that the reference pitch cylinder radius as r , and the reference pitch cylinder helix angle as β .

In the measurement, the movement of the measuring contact head in a perpendicular plane to the axis is read out by means of a micrometer or recorded automatically, however in this case, since it is difficult to express the whole aspect by digits only, it should be preferable to express by error diagram.

In Fig. 11, the method of reference disc system tooth trace measurement is indicated.

Fig. 11. Measuring Method of Reference Disc System Tooth Trace



Reference: In the case where the reference disc of which radius is different from the reference pitch circle is used, the helix angle β_x on the cylinder of its radius r_x shall be obtained from the following formula:

$$\tan \beta_x = \frac{r_x}{r} \tan \beta$$

In general, this type of tooth trace measuring machine is mostly used in combination with the tooth profile measuring machine, in this case a base circle disc is used as a reference disc. In this case, the lead p_x , when assuming the base circle radius as r_b and the helix angle on the basic cylinder as β_b , shall be as follows:

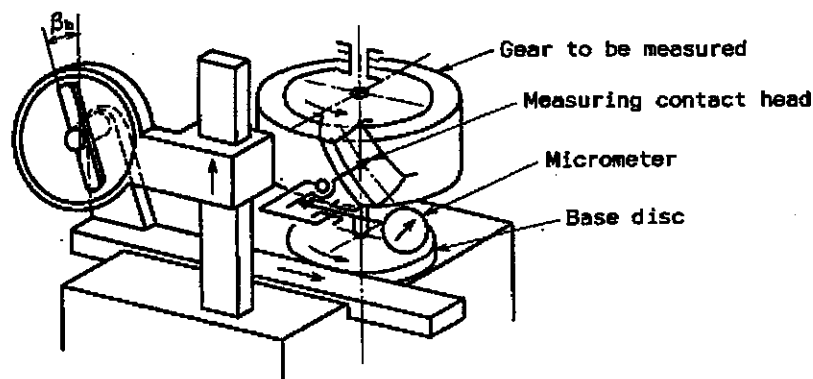
$$p_x = 2 \pi r_b \cdot \cot \beta_b$$

In addition, when assuming the normal pressure angle as α_n and the helix angle on reference pitch cylinder as β , these shall be in a relation as follows:

$$\beta_b = \sin^{-1} (\cos \alpha_n \cdot \sin \beta)$$

In Fig. 12, the method of base disc system tooth trace measurement is indicated.

Fig. 12. Basic Circle Disc System Measuring Method of Tooth Trace



- (2) Operation System A method to calculate errors by comparing with the theoretical tooth trace, by measuring the coordinates of the tooth trace of a gear.

5.2 Measuring Gist The measuring of the tooth trace shall be in accordance with the following gist.

- (1) Reference of Measuring and Mounting of Gear In the measuring of the tooth trace, the centre of rotation of the gear shall be taken as the reference of measurement. In the case where centre of rotation can not be taken as reference in measurement, other reference in lieu of this may be used.

In the case of measurement by using the mounting axis, the permissible value of the runout of the mounting axis should preferably be in accordance with the value of Table 1.

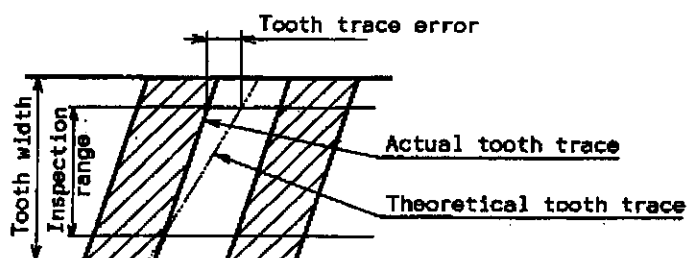
- (2) Measuring Places Both tooth flanks of the left and right of one piece of tooth at each 90° on the circumference of the measuring circle of gear shall be measured. For a gear which engages only with single tooth flank, it may be measured on the engaging tooth flank.

The measuring tooth number should preferably be referred to 4.2 (3) of the item of tooth profile of 4.2 (3).

For a gear which has been so machined as to cause discontinuous place, the place shall have been clarified, and this place shall be measured.

5.3 Treatment of Measuring Results The tooth trace error, which is the difference between the measured tooth trace curve corresponding to the tooth width within inspection range and the theoretical tooth trace curve, shall be expressed by the dimension on the circumference of measuring circle (see Fig. 13).

Fig. 13. Tooth Trace Error



In the case where the tooth trace waves as given in Fig. 14, the distance on the measuring circle of the theoretical tooth trace line which touches with the tooth trace curve at both sides shall be considered to be the tooth trace error. The tooth trace error of the tooth which has been crowning processed shall be determined as given in Fig. 15.

Furthermore, the protrusion and dent of the tooth trace curve due to tooth flank roughness shall not be considered to be the error.

Fig. 14. Tooth Trace Error (Waved Tooth)

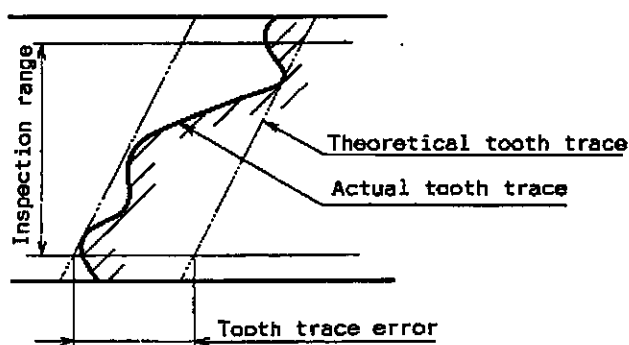
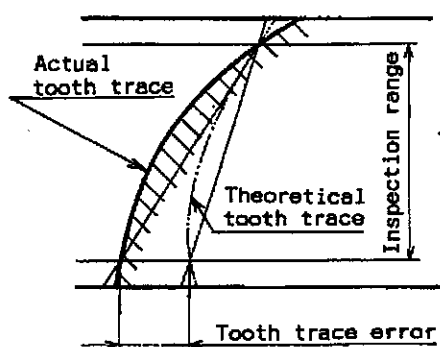


Fig. 15. Tooth Trace Error (Crowned Tooth)

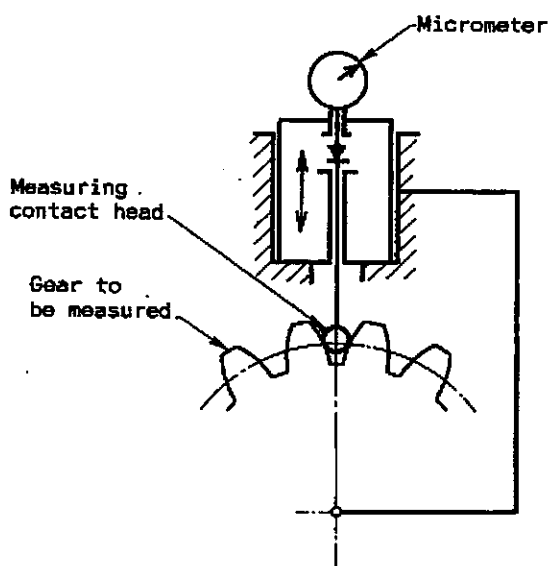


6. Measurement of Runout of Tooth Space

6.1 Measuring Method of Runout of Tooth Space The measurement of the runout of tooth space shall be as follows:

- (1) Measurement by Ball or Pin Insert the measuring contact head of a ball or pin so that it contacts with the both sides tooth flanks of tooth space over the entire periphery, and take reading of the variation of positions in radial direction of the measuring contact head, or record automatically. Consider the difference between the maximum value and the minimum value of the readings to be the runout of the tooth space. In Fig. 16, the measuring principle of the runout of tooth space is indicated.

Fig. 16. Measuring Method of Runout of Tooth Space



- (2) Measurement by Pitch Measurement Obtain the runout by the accumulative pitch error of respective both tooth flanks in the left and right by the calculation. The difference between the maximum value and the minimum value of this calculation result shall be the runout of the tooth space.

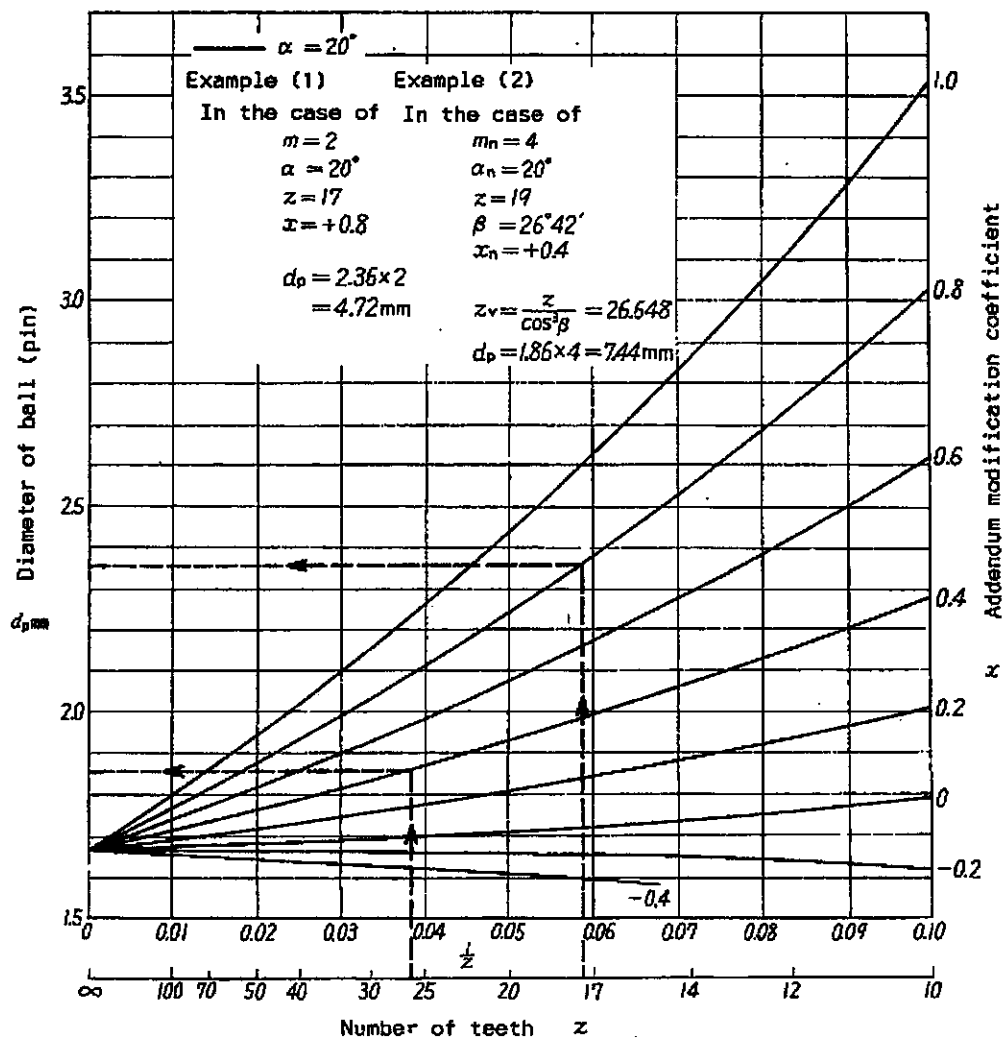
6.2 Gist in Measurement The measurement of the runout of tooth space shall be in accordance with the following gists.

- (1) Reference of Measurement and Mounting of Gear In the measurement of the runout of tooth space, the centre of rotation of the gear shall be taken as the reference of measurement. In the case where it is not capable of being measured by taking the centre of rotation as the reference of measurement, other reference of measurement in lieu of this shall be used.

In the case of measurement using a mounting axis, the permissible value of the runout of the mounting axis should be in accordance with Table 1.

- (2) Selection of Ball (Pin) The diameter of the ball (pin) shall be selected so that the ball generally contacts at nearly the centre of the working depth of gear to be measured. The diameter of the ball (pin) should preferably be in accordance with Fig. 17.
- (3) Measuring Places Measure at the centre of tooth width over the entire periphery of a gear.

Fig. 17. Diagram Obtaining Diameter of Ball (Pin)
(For module $m_n = 1$)



7. Measurement of Tooth Thickness

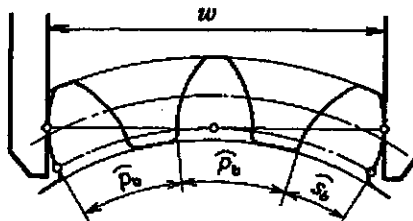
7.1 Measuring Methods of Tooth Thickness
The measurement of the tooth thickness shall be as follows:

The measurement of the tooth

- (1) **Base Tangent Length Method** Measure by straddling plural number of teeth (z_m sheets) with parallel planes. In the case of the spur gear, the base tangent length of which shall be the sum of base circle arc tooth thickness s_b and $(z_m - 1) \times$ (normal pitch p_b).

In Fig. 18, the measuring method of base tangent length by means of a tooth thickness micrometer or the like is indicated.

Fig. 18. Measuring Method of Tooth Thickness
(Base Tangent Length Method)



Assuming that base tangent length as w , and straddled number of teeth as z_m , in a spur gear, when module is m , reference pressure angle is α , number of teeth z , and addendum modification coefficient x , the base tangent length shall calculate by

$$w = m \cos \alpha \cdot [\pi (z_m - 0.5) + z \operatorname{inv} \alpha] + 2 x m \sin \alpha$$

and, compared with the measured value.

The values of the base tangent length of the standard spur gear (addendum modification coefficient $x = 0$) of module $m = 1$, and reference pressure angle $\alpha = 20^\circ$ are given in Table 4.

For the standard gears other than those of $m = 1$, obtain by multiplying module m to the value of Table.

Table 4. Values of Base Tangent Length w
($m=1$, $x=0$, $\alpha=20^\circ$)

Unit: mm

z	z_m	w	z	z_m	w	z	z_m	w	z	z_m	w
6	2	4.512 2	43	5	13.886 8	79	9	26.199 6	115	13	38.512 3
7	2	4.526 2	44	5	13.900 8	80	9	26.213 6	116	13	38.526 3
8	2	4.540 2	45	6	16.867 0	81	10	29.179 7	117	14	41.492 4
9	2	4.554 2	46	6	16.881 0	82	10	29.193 7	118	14	41.506 1
10	2	4.568 3	47	6	16.895 0	83	10	29.207 7	119	14	41.520 4
11	2	4.582 3	48	6	16.909 0	84	10	29.221 7	120	14	41.534 4
12	2	4.596 3	49	6	16.923 0	85	10	29.235 7	121	14	41.548 4
13	2	4.610 3	50	6	16.937 0	86	10	29.249 7	122	14	41.562 4
14	2	4.624 3	51	6	16.951 0	87	10	29.263 7	123	14	41.576 5
15	2	4.638 3	52	6	16.965 0	88	10	29.277 7	124	14	41.590 5
16	2	4.652 3	53	6	16.979 0	89	10	29.291 7	125	14	41.604 5
17	2	4.666 3	54	7	19.945 2	90	11	32.257 9	126	15	44.570 6
18	3	7.632 4	55	7	19.959 2	91	11	32.271 9	127	15	44.581 6
19	3	7.646 4	56	7	19.973 2	92	11	32.285 9	128	15	44.598 6
20	3	7.660 4	57	7	19.987 2	93	11	32.299 9	129	15	44.612 6
21	3	7.674 4	58	7	20.001 2	94	11	32.313 9	130	15	44.626 6
22	3	7.688 4	59	7	20.015 2	95	11	32.327 9	131	15	44.640 6
23	3	7.702 5	60	7	20.029 2	96	11	32.341 9	132	15	44.654 6
24	3	7.716 5	61	7	20.043 2	97	11	32.355 9	133	15	44.668 6
25	3	7.730 5	62	7	20.057 2	98	11	32.369 9	134	15	44.682 6
26	3	7.744 5	63	8	23.023 3	99	12	35.336 1	135	16	47.648 8
27	4	10.710 6	64	8	23.037 3	100	12	35.350 1	136	16	47.662 8
28	4	10.724 6	65	8	23.051 3	101	12	35.364 1	137	16	47.676 8
29	4	10.738 6	66	8	23.065 3	102	12	35.378 1	138	16	47.690 8
30	4	10.752 6	67	8	23.079 4	103	12	35.392 1	139	16	47.704 8
31	4	10.766 6	68	8	23.093 4	104	12	35.406 1	140	16	47.718 8
32	4	10.780 6	69	8	23.107 4	105	12	35.420 1	141	16	47.732 8
33	4	10.794 6	70	8	23.121 4	106	12	35.434 1	142	16	47.746 8
34	4	10.808 6	71	8	23.135 4	107	12	35.448 1	143	16	47.760 8
35	4	10.822 7	72	9	26.101 5	108	13	38.414 2	144	17	50.727 0
36	5	13.788 8	73	9	26.115 5	109	13	38.428 2	145	17	50.741 0
37	5	13.802 8	74	9	26.129 5	110	13	38.442 2	146	17	50.755 0
38	5	13.816 8	75	9	26.143 5	111	13	38.456 3	147	17	50.769 0
39	5	13.830 8	76	9	26.157 5	112	13	38.470 3	148	17	50.783 0
40	5	13.844 8	77	9	26.171 5	113	13	38.484 3	149	17	50.797 0
41	5	13.858 8	78	9	26.185 5	114	13	38.498 3	150	17	50.811 0
42	5	13.872 8									

In the spur gears, carry out measurement in a vertical direction to the tooth flank, calculate according to

$$w = m_n \cos \alpha_n \cdot [\pi (z_m - 0.5) + z \operatorname{inv} \alpha_z] + 2 x_n m_n \sin \alpha_n$$

when normal module is m_n , normal pressure angle, α_n , transverse pressure angle, α_z , and normal addendum modification coefficient, x_n , and compare with the measured value.

Example: Where normal module is 4, normal pressure angle, 20° , number of teeth, 19, reference pitch cylinder helix angle, $26^\circ 42'$, normal addendum modification coefficient, 0.4.

Straddling number of teeth $z_n=4$ (see Fig. 21)

$$\alpha_t = \tan^{-1} \left(\frac{\tan 20^\circ}{\cos 26^\circ 42'} \right) = \tan^{-1} 0.407412 = 22.1666^\circ$$

$$w = 4 \times \cos 20^\circ \cdot [\pi (4 - 0.5) + 19 \operatorname{inv} 22.1666^\circ] + 2 \times 0.4 \times 4 \times \sin 20^\circ = 43.891 \text{ mm}$$

The base tangent length, where backlash is given by giving the arc tooth thickness reducing amount δ_s on reference pitch circle, shall be

For spur gear

$$w = m \cos \alpha \cdot [\pi (z_n - 0.5) + z \operatorname{inv} \alpha] + 2 x m \sin \alpha - \delta_s \cos \alpha$$

for helical gear

$$w = m_n \cos \alpha_n \cdot [\pi (z_n - 0.5) + z \operatorname{inv} \alpha_t] + 2 x_n m_n \sin \alpha_n - \delta_s \cos \beta \cos \alpha_n$$

and the variation amount δw of base tangent length w in respect to δ_s shall be

for spur gear

$$\delta w = -\cos \alpha \cdot \delta_s$$

for helical gear

$$\delta w = -\cos \beta \cos \alpha \cdot \delta_s$$

- (2) Over Pin (Ball) Method In the case of the spur gear, insert 2 pins (balls) in the confronting tooth spaces on diameter for a gear of even number of teeth and in tooth spaces of deviated by $\frac{\pi}{z}$ for a gear of odd number of teeth, measure the outside dimension of two pins (balls) for external gear and the inside dimension of 2 pins (balls) for internal gear, and obtain the tooth thickness.

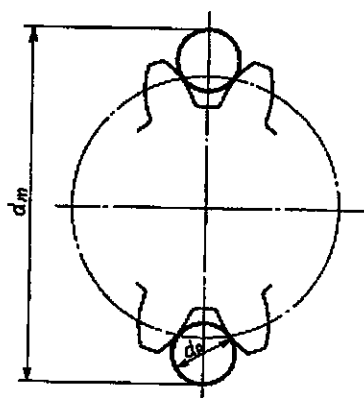
In addition, measure the outside dimension of balls for the external helical gear and the inside dimension of balls for the internal helical gear. In Fig. 19, the method of measurement by the over pin (ball) method is indicated.

Furthermore, the diameter d_p of ball (pin) should preferably be obtained in accordance with Fig. 17.

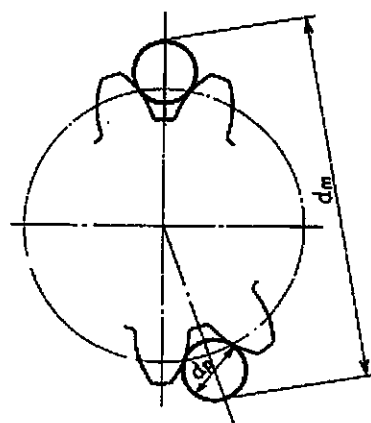
Fig. 19. Measurement of Tooth Thickness
(over Pin (Ball) Method)

External Gear

In the Case of Even Number of
teeth

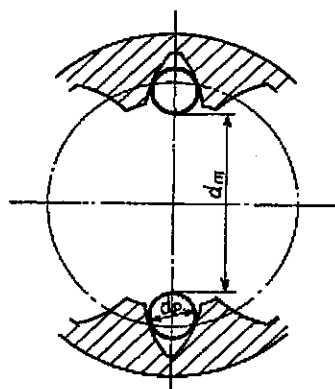


In the Case of Odd Number of
Teeth

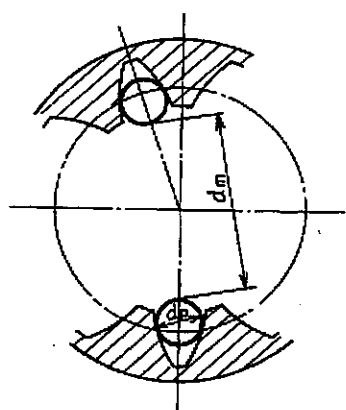


Internal Gear

In the Case of Even Number of
Teeth



In the Case of Odd Number of
Teeth



When assuming over pin (ball) dimension as d_m and the diameter of
pin (ball) as d_p ,

For spur gears:

In the case of even number of teeth $d_m = \frac{2m \cos \alpha}{\cos \phi} + d_p$

In the case of odd number of teeth

$$d_m = \frac{zm \cos \alpha}{\cos \phi} \cos \frac{90^\circ}{z} + d_p$$

However,

$$\text{inv} \phi = \frac{d_p}{zm \cos \alpha} - \left(\frac{\pi}{2z} - \text{inv} \alpha \right) + \frac{2x \tan \alpha}{z}$$

For helical gears:

In the case of even number of teeth

$$d_m = \frac{zm_t \cos \alpha_t}{\cos \phi} + d_p = \frac{zm_n \cos \alpha_n}{\cos \phi \sqrt{1 - \cos^2 \alpha_n \sin^2 \beta}} + d_p$$

In the case of odd number of teeth

$$d_m = \frac{zm_t \cos \alpha_t}{\cos \phi} \cos \frac{90^\circ}{z} + d_p = \frac{zm_n \cos \alpha_n}{\cos \phi \sqrt{1 - \cos^2 \alpha_n \sin^2 \beta}} \cos \frac{90^\circ}{z} + d_p$$

However,

$$\text{inv} \phi = \frac{d_p}{zm_n \cos \alpha_n} - \left(\frac{\pi}{2z} - \text{inv} \alpha_t \right) + \frac{2x_n \tan \alpha_n}{z}$$

For internal spur gears:

In the case of even number of teeth

$$d_m = \frac{zm \cos \alpha}{\cos \phi} - d_p$$

In the case of odd number of teeth

$$d_m = \frac{zm \cos \alpha}{\cos \phi} \cos \frac{90^\circ}{z} - d_p$$

However,

$$\text{inv} \phi = \left(\frac{\pi}{2z} + \text{inv} \alpha \right) + \frac{2x \tan \alpha}{z} - \frac{d_p}{zm \cos \alpha}$$

For internal spur gears:

In the case of even number of teeth

$$d_m = \frac{zm_t \cos \alpha_t}{\cos \phi} - d_p = \frac{zm_n \cos \alpha_n}{\cos \phi \sqrt{1 - \cos^2 \alpha_n \sin^2 \beta}} - d_p$$

In the case of odd number of teeth

$$d_m = \frac{zm_t \cos \alpha_t}{\cos \phi} \cos \frac{90^\circ}{z} - d_p = \frac{zm_n \cos \alpha_n}{\cos \phi \sqrt{1 - \cos^2 \alpha_n \sin^2 \beta}} \cos \frac{90^\circ}{z} - d_p$$

However,

$$\text{inv } \phi = \left(\frac{\pi}{2z} + \text{inv } \alpha_t \right) + \frac{2x_n \tan \alpha_n}{z} + \frac{d_p}{zm_n \cos \alpha_n}$$

In addition,

$$\alpha_t = \tan^{-1} \left(\frac{\tan \alpha_n}{\cos \beta} \right)$$

Example: In the case of normal module 4, normal pressure angle 20° , number of teeth 19, reference pitch cylinder helix angle $26^\circ 42'$, normal addendum modification coefficient 0.4.

$$z_v = \frac{19}{\cos^3 26^\circ 42'} = 26.648$$

From Fig. 17, diameter of ball $d_p = 4 \times 1.86 = 7.44 \text{ mm}$

When a ball of 7.500 mm, which is similar to this dimension practically, is used, $d_p = 7.500 \text{ mm}$

$$\alpha_t = \tan^{-1} \left(\frac{\tan 20^\circ}{\cos 26^\circ 42'} \right) = \tan^{-1} 0.407412 = 22.1666^\circ = 22^\circ 10'$$

$$\text{inv } \phi = \frac{7.500}{19 \times 4 \times \cos 20^\circ} - \left(\frac{\pi}{2 \times 19} - \text{inv } 22.1666^\circ \right) + \frac{2 \times 0.4 \times \tan 20^\circ}{19} = 0.0582017$$

$$\phi = 30.742389^\circ = 30^\circ 44' 33''$$

$$m_n = 4 / \cos 26^\circ 42' = 4.47742 \text{ mm}$$

$$d_m = \frac{19 \times 4.47742 \times \cos 22.1666^\circ}{\cos 30.7424^\circ} \times \cos \frac{90^\circ}{19} + 7.500 = 98.852 \text{ mm}$$

The variation amount of δd_m of over pin (ball) dimension d_m in respect to δ_s in the case where backlash is given by giving the reducing amount of arc tooth thickness δ_s on the reference pitch circle,

For spur gears,

In the case of even number of teeth

$$\delta d_m = \mp \frac{\cos \alpha}{\sin \phi} \delta_s$$

In the case of odd number of teeth

$$\delta d_m = \mp \frac{\cos \alpha}{\sin \phi} \cos \frac{90^\circ}{z} \delta_s$$

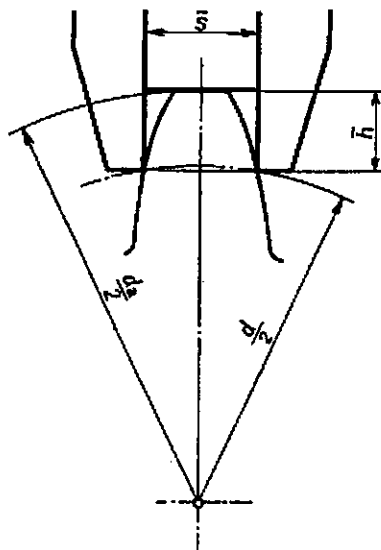
Provided that (-) of double signs shall be for the external gears and (+) for the internal gears.

254
140

In addition, for the helical gears, α_n shall be used in lieu of α .

- (3) **Chordal Tooth Thickness Method** Measure the length of a chord in the measuring plane between the intersections of the left tooth flank and right tooth flank of one tooth and the reference pitch cylinder, usually take a tip circle as the reference of measurement. In Fig. 20, the chordal tooth thickness measuring method by using a tooth thickness calipers is indicated.

Fig. 20. Measuring Method of Tooth Thickness
(Chordal Tooth Thickness Method)



Assuming chordal height as $\bar{h}$, chordal tooth thickness as $\bar{s}$, module as m , number of teeth as z , reference pressure angle as α , addendum modification coefficient as x , tip circle diameter as d_a , and reference pitch circle diameter as d , in the spur gears it shall be calculated as follows:

$$\bar{h} = \frac{mz}{2} \left[1 - \cos \left(\frac{\pi}{2z} + \frac{2x \tan \alpha}{z} \right) \right] + \frac{d_a - d}{2}$$

$$\bar{s} = mz \sin \left(\frac{\pi}{2z} + \frac{2x \tan \alpha}{z} \right)$$

and be compared with the value of $\bar{s}$ measured at the distance of $\bar{h}$ from the tip.

Generally, the values of chordal height $\bar{h}$ and chordal tooth thickness $\bar{s}$ are obtained from the above formulae, however, the values of the standard spur gears (addendum modification coefficient $x = 0$) of module $m = 1$ are given in Table 5. For the gears other than $m = 1$, these may be obtained by multiplying module m to the values of Table.

Table 5. Values of $\bar{h}$ and $\bar{s}$
(In the case of $x = 0$ and module 1)

z	$\bar{h}$ mm	$\bar{s}$ mm	z	$\bar{h}$ mm	$\bar{s}$ mm
12	1.0513	1.5663	35	1.0176	1.5703
13	1.0474	1.5670	40	1.0154	1.5704
14	1.0440	1.5675	45	1.0137	1.5705
15	1.0411	1.5679	50	1.0123	1.5705
16	1.0385	1.5683	60	1.0103	1.5706
17	1.0363	1.5686	70	1.0088	1.5707
18	1.0342	1.5688	80	1.0077	1.5707
19	1.0324	1.5690	90	1.0069	1.5707
20	1.0308	1.5692	100	1.0062	1.5707
22	1.0280	1.5695	120	1.0051	1.5708
24	1.0257	1.5697	150	1.0041	1.5708
26	1.0237	1.5698	200	1.0031	1.5708
28	1.0219	1.5700	∞	1.0000	1.5708
30	1.0206	1.5701			

In the case of x -gear of which tip circle diameter is assumed as $d_a = (z+2+2x)$ it shall be calculated according to

$$\bar{h} = \frac{mz}{2} \left[1 - \cos \left(\frac{\pi}{2z} + \frac{2x \tan \alpha}{z} \right) \right] + (1+x)m$$

In the case where backlash is given by giving the reduction amount δ_s of the arc tooth thickness of the reference pitch circle, the chordal tooth thickness $\bar{s}$ is given according to

$$\bar{s} = mz \sin \left(\frac{\pi}{2z} - \frac{\delta_s}{m_z} + \frac{2x \tan \alpha}{z} \right)$$

and the variation amount $\delta_{\bar{s}}$ of chordal thickness $\bar{s}$ in respect to δ_s is given according to

$$\delta_{\bar{s}} = -\cos \left(\frac{\pi}{2z} + \frac{2x \tan \alpha}{z} \right) \cdot \delta_s$$

however, it is sufficient to be calculated practically as

$$\delta_{\bar{s}} = -\delta_s$$

For the helical gear, carry out measurement in a normal plane, and calculate by substituting the respective normal values for the values of m , α , and x of above formulae. However, the equivalent spur gear number of teeth z_v ,

$$z_v = \frac{z}{\cos^3 \beta}$$

shall be used as z .

Example: In the case of normal module 4, normal pressure angle 20° , number of teeth 19, reference pitch cylinder helix angle $26^\circ 42'$, and normal addendum modification coefficient 0.4.

$$z_v = \frac{19}{\cos^3 26^\circ 42'} = 26.648$$

$$h = \frac{4 \times 26.648}{2} \left[1 - \cos \left(\frac{\pi}{2 \times 26.648} + \frac{2 \times 0.4 \times \tan 20^\circ}{26.648} \right) \right] + (1 + 0.4) \times 4 = 5.730 \text{ mm}$$

$$s = 4 \times 26.648 \times \sin \left(\frac{\pi}{2 \times 26.648} + \frac{2 \times 0.4 \times \tan 20^\circ}{26.648} \right) = 7.442 \text{ mm}$$

7.2 Gist on Measurement The measurement of tooth thickness shall be in accordance with the following gists.

- (1) Base Tangent Length Method The straddling number of teeth shall generally be selected so that the measuring contact heads contact with the tooth profile at approximately the centre of working depth.

The straddling number of teeth shall be obtained from Fig. 21 (for spur gear) and Fig. 22 (for helical gear).

In addition, the measurable minimum tooth width of the helical gear shall be obtained from Fig. 22.

- (2) Over Pin (Ball) Method Measurement shall be carried out correctly on a normal section.

The diameter of the ball (pin) should preferably be in accordance with Fig. 17.

- (3) Chordal Tooth Thickness Method The contact ends of the measuring contact head shall be on the reference pitch circle. Therefore, in the case where the tip circle is taken for the reference of measurement, it is necessary to correct the chordal height according to the actual dimension of outside diameter.

- (4) Measuring Place In the chordal tooth thickness method and the base tangent length method, measure at the centre of tooth width at each about 90° on the circumference of gear.

In the over pin (ball) method, measure at the centre of tooth width on the two diameters intersecting at right angles approximately.

Fig. 21. Straddled Number of Teeth of Spur Gear ($\alpha=20^\circ$)

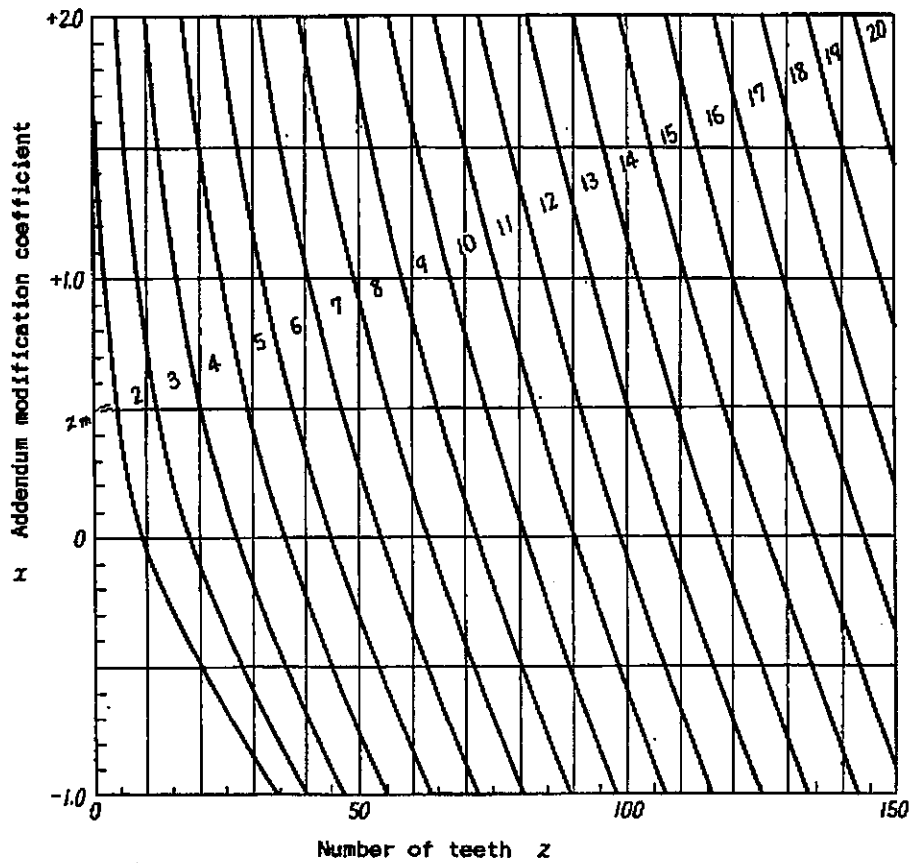
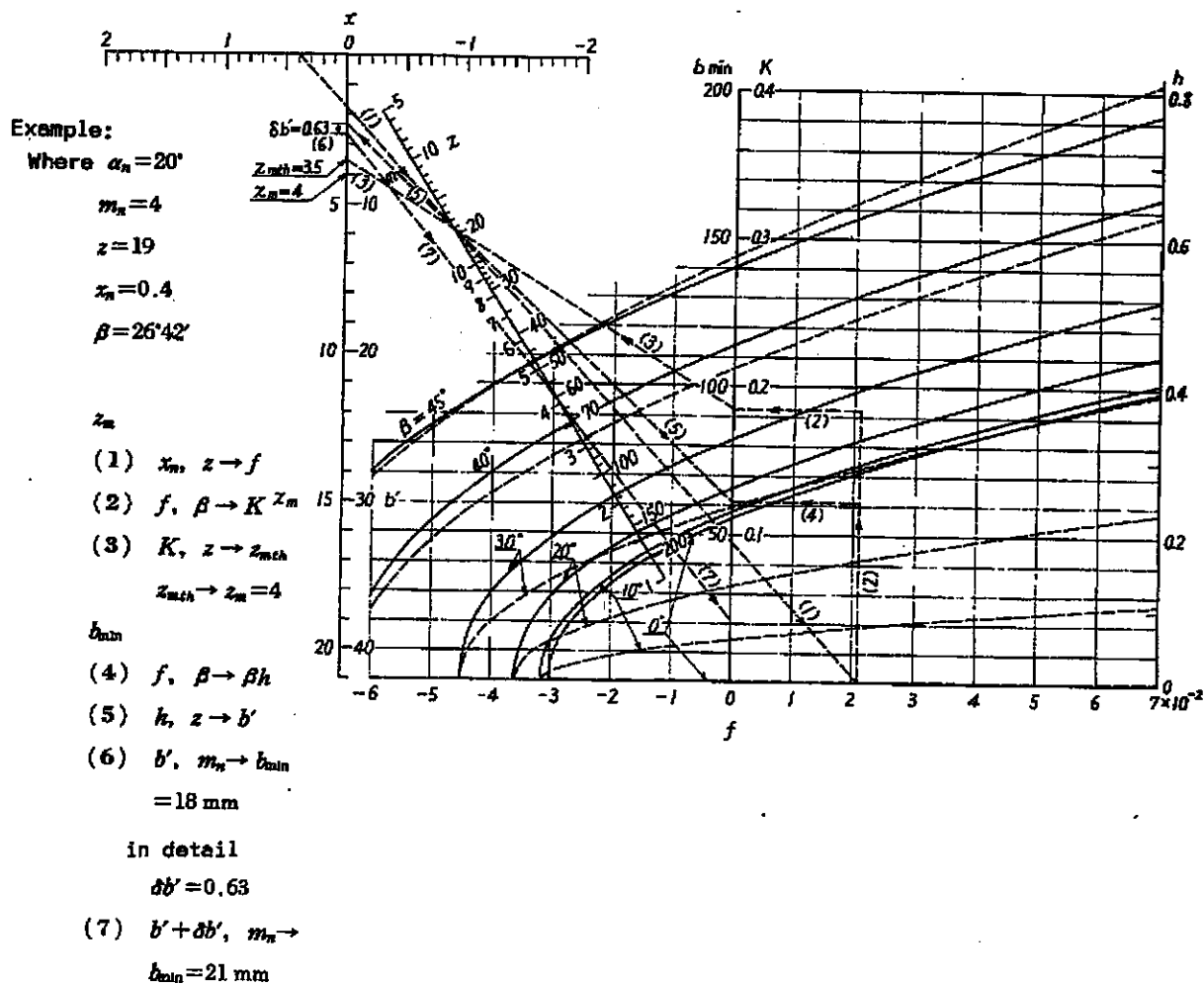


Fig. 22. Straddled Number of Teeth of Helical Gear ($\alpha = 20^\circ$)



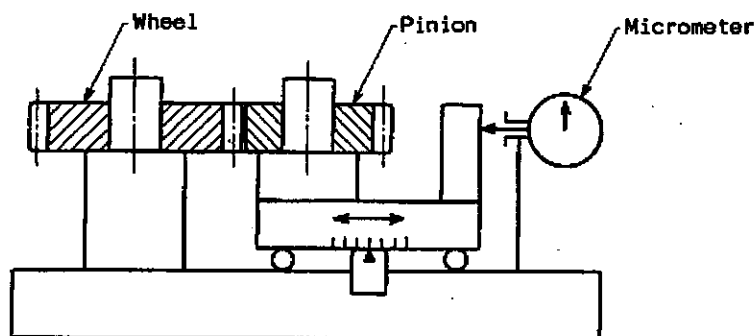
8. Measurement of Both Tooth Flank Working Error

8.1 Measuring Method of Both Tooth Flank Working Error Read the variation of centre distance with a micrometer when a gear to be measured and a master cylindrical gear for inspection, hereinafter referred to as the "master gear", or a gear pair have been rotated in engagement under the condition of both tooth flanks in engagement, or record automatically.

In addition, the recorded diagram obtained above shall be called as the working error record diagram, hereinafter referred to as the "error diagram".

The value of variation indicated in this record diagram shall be that has been integrated individual errors of both gears. In Fig. 23, the principle of measurement on both tooth flank working errors is indicated.

Fig. 23. Measuring Method of Both Tooth Flank Working Errors



8.2 Gist on Measurement The measurement of the both tooth flank working error shall be in accordance with the following:

- (1) Measurement shall be carried out so that the following relations are maintained by a testing machine having construction permitting the variation of the centre distance of a pair of gears and mechanism which is capable of measuring this variation correctly.
 - (a) The parallelism error, eccentricity error, face runout error, etc. of the both rotating centre axes shall be sufficiently smaller than the both tooth flank working error of the gear to be measured.
 - (b) Both gears shall rotate smoothly respectively.
 - (c) The measuring pressure shall be constant within measuring range.

The measuring pressure should preferably be in accordance with Table 6.

Table 6. Upper Limit Values of Measuring Pressures per
Tooth Width 10 mm

Unit: N

Material	Module					
	0.2 to 0.3 incl.	Over 0.3 to 0.6 incl.	Over 0.6 to 1.25 incl.	Over 1.25 to 2.5 incl.	Over 2.5 to 5 incl.	Over 5 to 10 incl.
Thermally refined steel (HB 160)	11	24	47	99	200	390
Brass C 2600	4.2	8.4	17	35	70	140
Aluminium alloy A2017, Temper T 4	5.8	12	23	48	97	190
Injection moulding plastic POMPA	4.2	4.8	5.4			

The measuring pressure shall be determined in proportion to the tooth width of the gear to be measured.

In the case of measurement by using a mounting axis, the permissible value of the runout of the mounting axis should preferably be in accordance with Table 1.

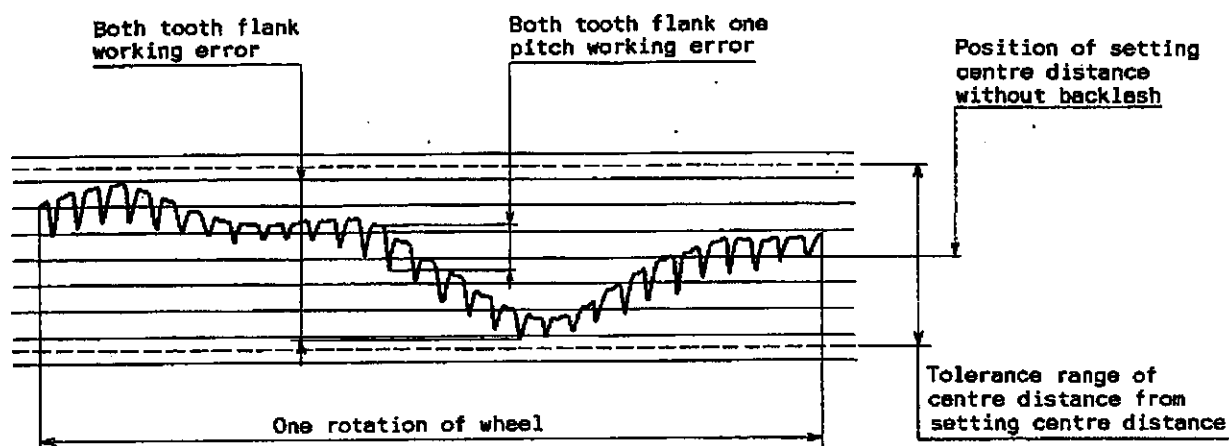
- (2) In the case of measurement by using a master gear, the accuracy grade of the master gear shall be determined, with considering the accuracy of the gear to be measured.

In addition, in the case where general gear is used in lieu of a master gear, it may be employed by grasping the error of the gear to eliminate the influence of that error from the measured value of the gear to be measured.

- (3) It shall be that of capable of measuring the centre distance between the master gear and the gear to be measured or the centre distance between the gear pair to be measured on the measuring machine at the accuracy of the required accuracy or better than the gear to be measured, and that the position of the indicator of the micrometer or recorder under measuring condition shall be capable of being indicated on the error diagram.
- (4) Regarding the injection moulding plastic gear, since its tooth profile error is generally larger and the elastic deformation of tooth flank due to engagement is also larger, it is liable to cause indeterminated larger error in the measurement by the gear. Therefore, it should preferable be to use a steel gear for the mating gear.

8.3 Treatment of Measuring Results From the both tooth flank working error diagram of Fig. 24, obtain the bias from the position of the centre distance for the instrumentation of both tooth flank total working error, both tooth flank one pitch working error and without backlash.

Fig. 24. Example of Both Tooth Flank Working Error Diagram
(In the Case of Specific Gear Pair)



- Remarks 1. The centre distance variation due to virtual difference of tooth thickness dimension becomes the bias from the position of centre distance for the instrumentation without backlash on the error diagram, and the position of fluctuation of the variation appears in the both tooth flank working error and both tooth flank one pitch working error. The virtual tooth thickness mentioned herein means that it also includes the influence of tooth profile error and tooth trace error other than the influence of the actual tooth thickness.
2. Since the both tooth flank working error is that error which has been measured as the integrated amount of the influence of the individual errors of both gears and the dimensional error of tooth thickness, generally it can not be obtained by separating the individual error of each gear or the dimensional difference of tooth thickness from the error diagram.
 3. In the injection moulding plastic gears, it is necessary to devise so that the influence of the deformation of the rotation supporting part will not appear in the error diagram, particularly considering the elastic deformation of the mounting axis and supporting part of the gear to be measured.

Applicable Standards:

JIS B 0102-Glossary of Gear Terms

JIS B 0121-Gear Notation-Symbols for Geometrical Data

JIS B 1751-Master Cylindrical Gears

Reference Standard:

JIS B 1702-Accuracy for Spur and Helical Gears

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