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JAPANESE INDUSTRIAL STANDARD

Methods of Measurement for Spur and Helical Gears

JIS B 1752—1989

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**In the event of any doubt arising,
the original Standard in Japanese is to be final authority**

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Errata are also provided to subscribers of JIS (English edition) in *Monthly Information*.

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.

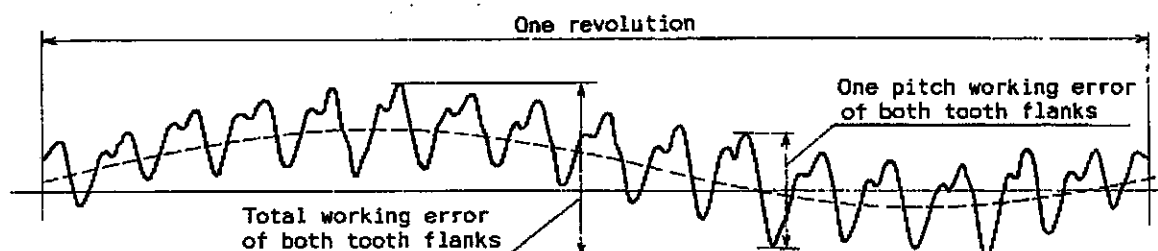
Note (2) Regarding accuracies, refer to JIS B 1751.

- (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)



Applicable Standards and Reference Standard: See page 34.

3. Measurement of Pitch

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

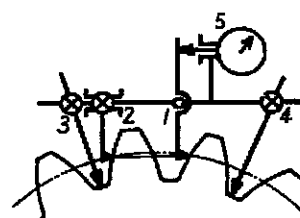
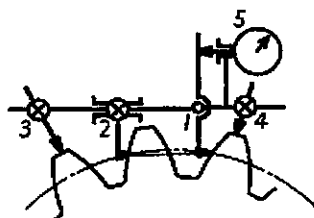
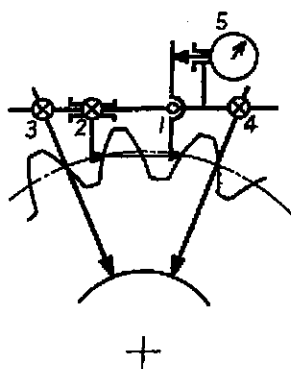
- (1) Linear Distance Measuring Method Allow the measuring contact head and fixed contactor to contact with the points on the circumference of a circle, the centre of which being the centre of rotation of a gear passing through about centre of the working depth, hereinafter referred to as the "measuring 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

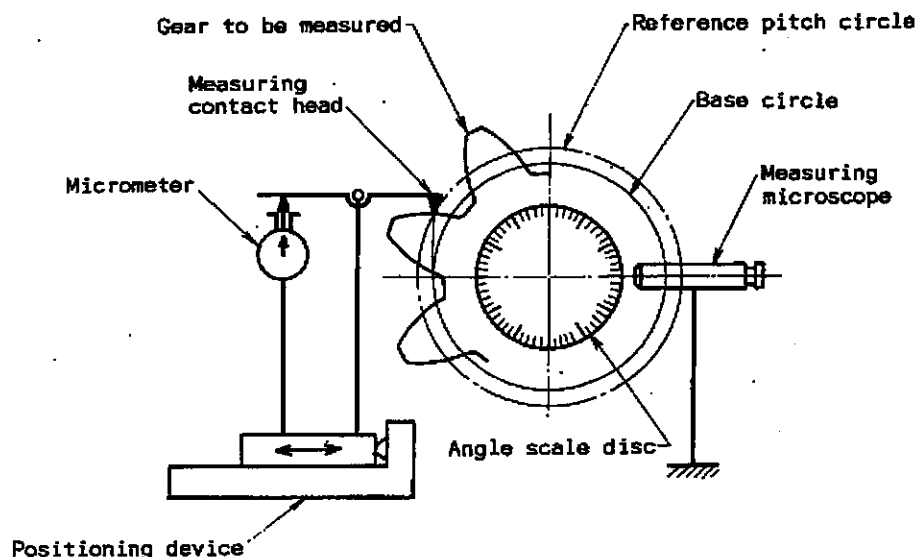


1: Measuring head 2: Fixed contactor⁽³⁾ 3,4: Positioning contactor
5: Micrometer

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

The measurement of the circular 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)

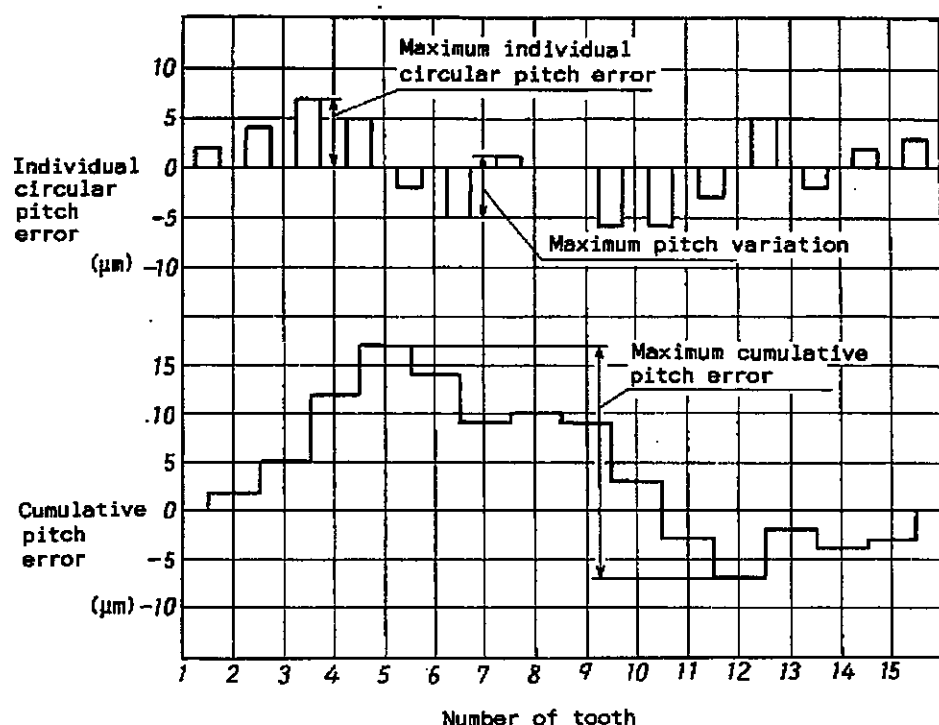
Unit: μm

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.

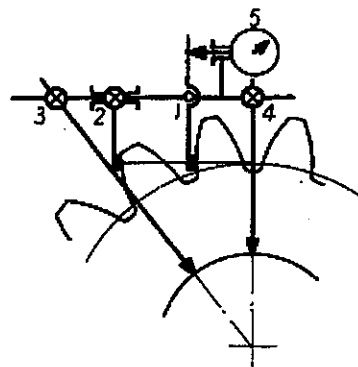
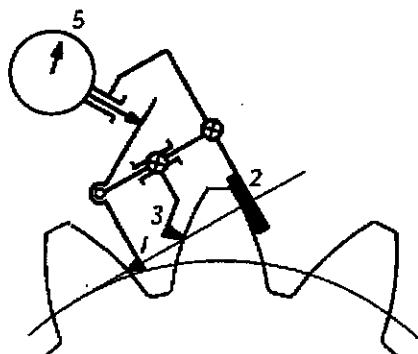
For the gear which works only at the tooth flanks of single side, only the working tooth flanks may be measured.

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

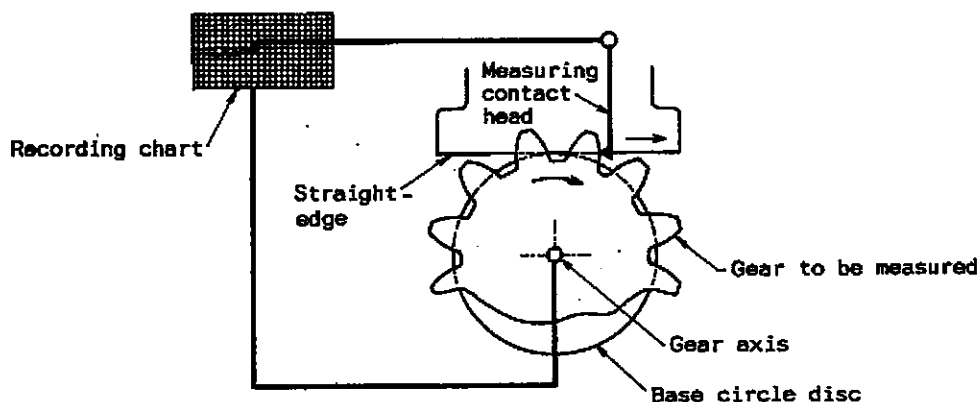
3 and 4: Positioning contactor 5: Micrometer

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.

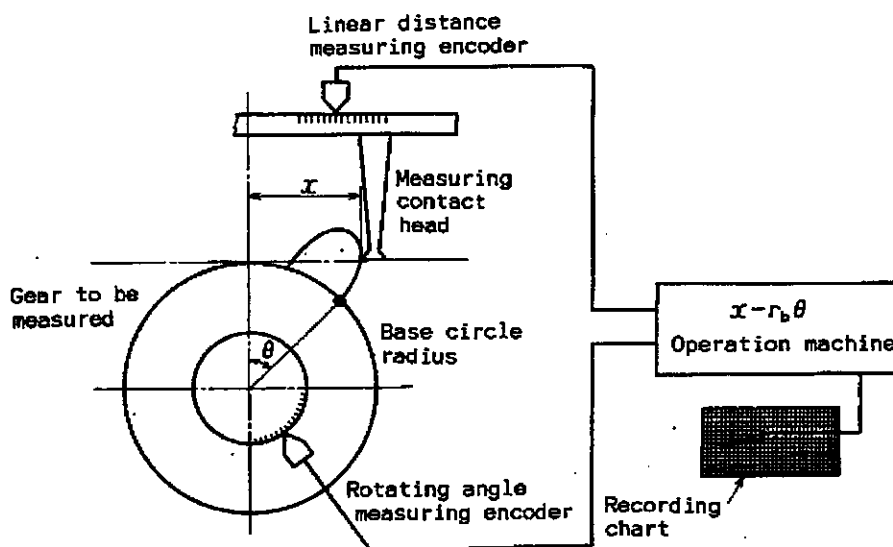
- (1) Base Disc System Allowing the measuring contact head of a micrometer fixed to the straightedge to contact with the tooth flank of the gear to be measured which has been attached to the base circle disc axis on one point on the contact face of the straightedge, measure the tooth profile error from 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

