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Straight cylindrical involute splines—side fit—Generalities, dimensions and inspection

ICS 21.200

Descriptors : involute splines, gear drives

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of International Trade and Industry through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law:

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Straight cylindrical involute splines—side fit—Generalities, dimensions and inspection

Forward for Japanese Industrial Standard

This Japanese Industrial Standard has been prepared based on the first edition of **ISO 4156** *Straight cylindrical involute splines—Metric module, side fit—Generalities, dimensions and inspection* published in 1981 without modifying the technical contents. Addition the specification contents of the conventional **JIS D 2001**, which have been applied, are stated in a compact form in the annex to this Standard.

The portions indicated with dotted lines are the matters not stated in the original International Standard.

Section one : Generalities

1 Scope and field of application This Standard provides data and guidance for the design, manufacture and inspection of straight (non-helical) cylindrical involute splines with side fit (hereafter referred to as "splines"). It establishes a specification based on the module within the range 0.25 to 10 inclusive, relating to nominal pressure angles of 30°, 37.5° and 45°. (For electronic data processing purposes, the form of expression "37.5°" has been adopted instead of 37° 30′.)

Limiting dimensions, tolerances, manufacturing errors and their effects on the fit between connecting co-axial spline elements are defined and tabulated. Linear dimensions are expressed in millimetres and angular dimensions in degrees.

Informative references: The corresponding standards to this Standard are as follows.

ISO 3 *Preferred numbers—Series of preferred numbers*

JIS Z 8601-1954 *Preferred numbers* is equivalent to the said standard.

ISO/R286 *ISO system of limits and fits—Part 1 : General, tolerances and deviations*

JIS B 0401-1986 *ISO system of limits and fits* is equivalent to the said standard.

ISO 286 *ISO system of limits and fits*

JIS B 0401-1986 *ISO system of limits and fits* is equivalent to the said standard.

ISO 1328 *Parallel involute gears—ISO system of accuracy*

ISO/R1938 *ISO system of limits and fits—Part 2 : Inspection of plain workpieces*

ISO 3670 *Blanks for plug gauges and handles (taper lock and trilock) and ring gauges—Design and general dimensions*

2 Terms and definitions relating to splines

2.1 spline joint : Connecting, co-axial elements that transmit torque through the simultaneous engagement of equally spaced teeth situated around the periphery of a cylindrical external member with similar spaced mating spaces situated around the inner surface of the related cylindrical internal member.

2.2 involute spline : One member of spline joint having teeth or spaces that have involute flank profiles.

2.3 internal spline : A spline formed on the inner surface of a cylinder.

2.4 external spline : A spline formed on the outer surface of a cylinder.

2.5 fillet : The concave surface of the tooth or space connecting the involute flank and the root circle. This curved surface as generated varies and cannot be properly specified by a radius of any given value (see figure 12).

2.6 fillet root spline : A spline having a tooth or space profile in which the opposing involute flanks are connected to the root circle (D_{ei} or D_{ie} diameter) by a single fillet (see figure 13).

2.7 flat root spline : A spline having a tooth or space profile in which each of the opposing involute flanks are connected to the root circle (D_{ei} or D_{ie} diameter) by a fillet (see figure 12).

2.8 module, *m* : The ratio of the circular pitch, expressed in millimetres, to the number π (or the ratio of the pitch diameter, expressed in millimetres, to the number of teeth).

2.9 pitch circle : The reference circle from which all normal spline dimensions are derived, and the circle on which the specified pressure angle has its nominal value.

2.10 pitch diameter, *D* : The diameter of the pitch circle, in millimetres, equal to the number of teeth multiplied by the module (see figure 12).

2.11 pitch point : The intersection of the spline tooth profile with the pitch circle (see reference figure 1).

2.12 circular pitch, *p* : A length of arc of the pitch circle between two consecutive pitch points of left- (or right-) hand flanks, which has a normal value of the number π multiplied by the module (see figure 12).

2.13 pressure angle, α : The acute angle between a radial line passing through any point on a tooth flank and the tangent plane to the flank at that point.

2.14 standard pressure angle, α_D : The pressure angle at the specified pitch point (see reference figure 1).

2.15 base circle : The circle from which involute spline tooth profiles are generated.

2.16 base diameter, D_b : The diameter of the base circle.

2.17 base pitch, P_b : The arc length of the base circle between two consecutive corresponding flanks.

2.18 major circle : The circle formed by the outermost surface of the spline. It is the outside circle (tooth tip circle) of the external spline or the root circle of the internal spline.

2.19 major diameter, D_{ee}, D_{ei} : The diameter of the major circle (see figure 12).

2.20 minor circle : The circle formed by the innermost surface of the spline. It is the root circle of the external spline or the inside circle (tooth tip circle) of the internal spline.

2.21 minor diameter, D_{ie}, D_{ii} : The diameter of the minor circle (see figure 12).

2.22 form circle : The circle which establishes the deepest points of involute form control of the tooth profile. This circle along with the tooth tip circle (or start of chamfer circle) determines the limits of tooth profile requiring control. It is located near and below the major circle on the internal spline and near and above the minor circle on the external spline.

2.23 form diameter, D_{Fe}, D_{Fi} : The diameter of the form circle (see figure 12).

2.24 depth of engagement : The radial distance from the minor circle of the internal spline to the major circle of the external spline, minus corner clearance and/or chamfer depth (see reference figure 2).

2.25 basic (circular) space width or tooth thickness at the pitch diameter, E **or** S : For 30°, 37.5° and 45° pressure angle splines, half the circular pitch (see figure 12)

Informative reference : Unless otherwise indicated, the basic (circular) space width and basic tooth thickness are the arc lengths at the pitch diameter.

2.26 actual space width : The practically measured circular space width, on the pitch circle, of any single space width within the limit values $E_{max.}$ and $E_{min.}$ (see figure 12).

2.27 effective space width, E_v : For an internal spline, equal to the circular tooth thickness on the pitch circle of an imaginary perfect external spline which would fit the internal spline without looseness or interference, considering engagement of the entire axial length of the splinted assembly. The minimum effective space width ($E_{v\,min.}$, always equal to E) of the internal spline is always basic, as shown in table 1.

Fit variations may be obtained by adjusting the tooth thickness of the external spline (see figure 12).

2.28 actual tooth thickness : The practically measured circular tooth thickness, on the pitch circle, of any single tooth within the limit values $S_{max.}$ and $S_{min.}$ (see figure 12).

2.29 effective tooth thickness, S_v : For an external spline, equal to the circular space width on the pitch circle of an imaginary perfect internal spline which would fit the external spline without looseness or interference, considering engagement of the entire axial length of the splined assembly. Fit variations are obtained by adjusting this value S_v (see figure 12).

2.30 effective clearance, c_v (looseness or interference) : The effective space width of the internal spline minus the effective tooth thickness of the mating external spline (see reference figure 2).

2.31 theoretical clearance, c (looseness or interference) : The actual space width of an internal spline minus the actual tooth thickness of the mating external spline. It does not define the fit between mating members, because of the effect of variations (see reference figure 2).

2.32 form clearance, c_F : The radial depth of involute profile beyond the depth of engagement with the mating part. It allows eccentricity of the minor circle (internal), of the major circle (external and of their respective pitch circle (see figure 12).

2.33 total index variation : Amount of absolute values of the two greatest actual (or practically measured) positive and negative variations from the theoretical spacing (see figure 9).

2.34 total profile variation : Amount of absolute values of the two greatest positive and negative variations, from the theoretical tooth profiles, measured normal to flanks (see figure 18).

2.35 total lead variation : Amount of absolute values of the two greatest opposite direction variations, from the theoretical direction (parallel to the datum axis), also including parallelism and alignment variations (see figure 1).

Note : Straight (non-helical) splines have an infinite lead.

2.36 parallelism variation : The variation of parallelism of a single spline tooth to any other single spline tooth (see figure 1).

2.37 alignment variation : The variation of the effective spline axis with respect to the reference axis (see figure 1).

Informative reference : The effective spline axis is the ideal axis determined by effective tooth thickness and effective space width.

2.38 out-of-roundness : The variation of the spline from a true circular configuration.

2.39 effective variation : The accumulated effect of the spline variations on the fit with the mating part.

2.40 variation allowance, λ : The permissible effective variation.

2.41 machining tolerance, T : The permissible variation in actual space width or actual tooth thickness.

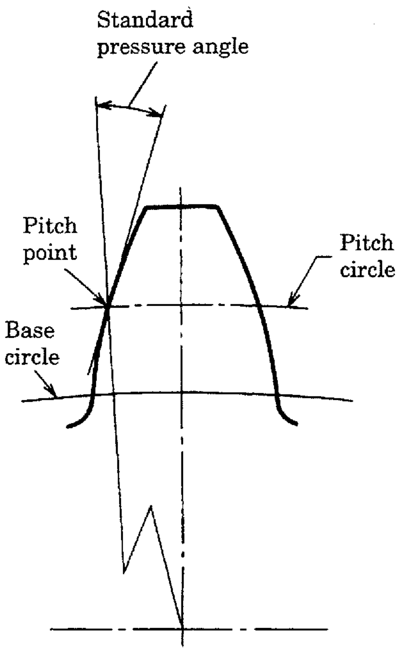
2.42 total tolerance, $(T+\lambda)$: The machining tolerance plus the variation allowance. The total tolerance on an internal spline is the difference between the minimum effective space width and the maximum actual space width; on an external spline, it is the difference between the maximum effective tooth thickness and the minimum actual tooth thickness.

2.43 length of engagement, g_γ: The axial length of contact between mating splines (see figure 17).

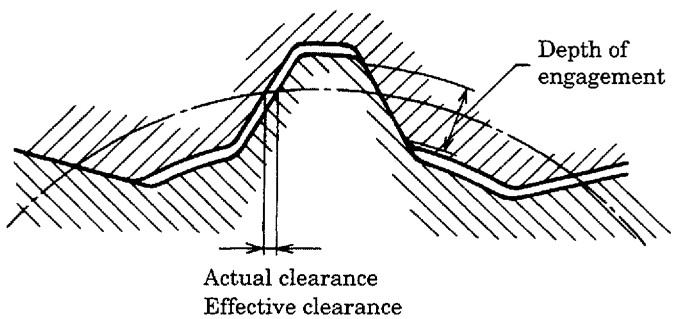
2.44 active spline length, g_w : The maximum axial spline length in contact (with working) with the mating spline. On sliding splines, the active length exceeds the length of engagement (see figure 17).

2.45 basic dimension : A numerical value to describe the theoretically exact size, shape or location of a feature. It is the basis from which permissible variations are established by tolerances.

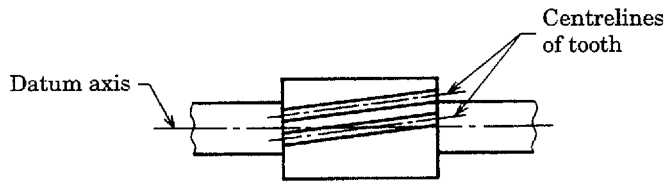
2.46 auxiliary dimension : A dimension, without tolerance, given for information purposes only, for the determination of the useful production and control dimensions.



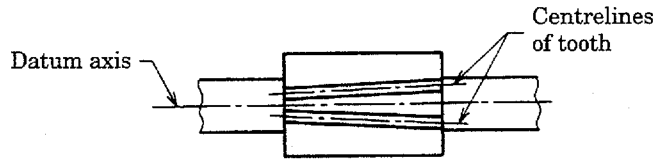
Informative reference figure 1



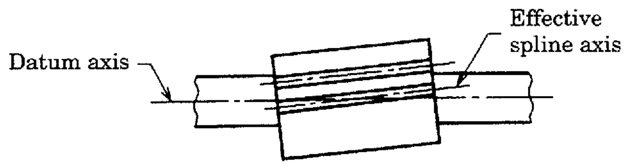
Informative reference figure 2



(1) Lead variation



(2) Parallelism variation



(3) Alignment variation

Figure 1 Total lead variation

3 Symbols

3.1 General symbols The general symbols used to designate the various spline terms and dimensions are given below (see figures 11, 12, 13, 14 and 15).

Note : In electronic data processing (EDP), it is not always possible to present symbols in their theoretically correct form because of limitations of connected printing equipment. For this reason, some alternative symbols for EDP usage are given in brackets below (for example, the symbol D_b for base diameter may be printed as DB).

c_v = effective clearance (looseness or interference)

c_F = form clearance

D = pitch diameter

D_b [DB] = base diameter

d_{ci} = pin contact diameter, internal spline

D_{Fi} [DFI] = form diameter, internal spline

D_{ii} [DII] = minor diameter, internal spline

D_{ei} [DEI] = major diameter, internal spline

D_{Ri} [DRI] = diameter of measuring pin for internal spline

d_{ce} = pin contact diameter, external spline

D_{Fe} [DFE] = form diameter, external spline

D_{ee} [DEE] = major diameter, external spline

D_{ie} [DIE] = minor diameter, external spline

D_{Re} [DRE] = diameter of measuring pin for external spline

λ = variation allowance

$inv\ \alpha$ = involute α (= $\tan\alpha - \alpha \cdot \pi/180$)

K_i [KI] = approximation factor for internal spline

Ke [KE] = approximation factor for external spline

g = spline length

g_w = active spline length

g_γ = length of engagement

T = machining tolerance

M_{Ri} [MRI] = measurement between two pins, internal spline

M_{Re} [MRE] = measurement over two pins, external spline

W = measurement over k teeth, external spline

z = number of teeth m = module

P_b = base pitch

p = circular pitch

ρ_{Fi} = fillet radius of the basic rack, internal spline

ρ_{Fe} = fillet radius of the basic rack, external spline

E = basic space maximum space width, circular

E_{max} = actual maximum space width, circular

E_{min} = actual minimum space width, circular

E_v [EV] = effective space width, circular

S = basic tooth thickness, circular

S_{max} = actual maximum tooth thickness, circular

S_{min} = actual minimum tooth thickness, circular

S_v [SV] = effective tooth thickness, circular

α = pressure angle

α_D = standard pressure angle

α_{ci} = pressure angle at pin contact diameter, internal spline

α_{ce} = pressure angle at pin contact diameter, external spline

α_i = pressure angle at pin centre, internal spline

α_e = pressure angle at pin centre, external spline

α_{Fi} = pressure angle at form diameter, internal spline

α_{Fe} = pressure angle at form diameter, external spline

k, j_s, h, f, e and d = fundamental deviation of the external spline = $c_{v\,min}$

Informative reference : It is upper or lower deviation of dimension, whichever is close to the zero line (see **JIS B 0401**).

H = lower deviation on the internal spline = 0

Tables 1 and 2 give the basic dimensions and fundamental formulae, a graphical presentation of which is given by figure 2.

3.2 Subscripts The following subscripts (see also the note in **3.1**) are used as part of the above general symbols to designate relative conditions or locations:

$_i$ [I] = minor or internal (in this last case, in the last position)

$_e$ [E] = major or external (in this last case, in the last position)

$_b$ [B] = at base

$_c$ = at contact point

$_F$ [F] = pertaining to form diameter

$_v$ [V] = effective

$_w$ = active

$_R$ [R] = pertaining to gauges

$_\gamma$ = of engagement

$_D$ = standard

4 Pressure angle (standard) Standard pressure angles included in this Standard for involute splines are 30°, 37.5° and 45°.

5 Type of fit This Standard deals with only one type of fit, the side fit, for 30°, 37.5° and 45° pressure angle splines. Formulae for the dimensions and tolerances for these splines are shown in table 2.

5.1 Side fit In this fit, the mating members contact on the sides of the teeth only. Major and minor diameters are clearance dimensions. The tooth sides act as drivers and centralize mating splines.

5.2 Spline fit classes This Standard provides the side fit in six spline fit classes as follows:

Spline fit class	Effective interference
H/k	$c_{v\,max}$ = deviation allowance k = $(T+\lambda)$
H/js	$c_{v\,max}$ = deviation allowance $j_s = (T+\lambda)/2$
	Effective looseness
H/h	$c_{v\,min}$ = deviation allowance h = 0
H/f	$c_{v\,min}$ = deviation allowance f
H/e	$c_{v\,min}$ = deviation allowance e
H/d	$c_{v\,min}$ = deviation allowance d

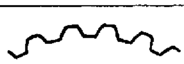
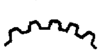
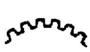
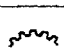
The deviation allowances (fundamental) k, j_s, h, f, e and d are the standard deviations selected from **ISO/R286** *ISO System of limits and fits—Part 1 : General, tolerances and deviations*, which are applied to the external spine. A prescribed maximum effective interference or minimum effective looseness is obtained, allowing the fitting by adjusting from the zero line the maximum effective and minimum actual limit values of tooth thickness by the amount of the deviation allowance (see **8.7.2**).

The spline dimensions in the spline tables in section two of this Standard are given for spline fit class H/h, $c_{v\,min} = 0$.

Informative reference : The zero line is the straight line which shows the standard dimension and is standard against deviation allowance when illustrating dimensional limits or fit (see **JIS B 0401**).

Table 1 Theoretical dimensions for splines

Dimensions in millimetres

Tooth $\alpha_D 30°$*	Module m	Circular pitch p	Basic space width or tooth thickness at pitch diameter E or S			Base pitch P_b		
			$\alpha_D 30°$	$\alpha_D 37.5°$	$\alpha_D 45°$	$\alpha_D 30°$	$\alpha_D 37.5°$	$\alpha_D 45°$
	10	31.416	15.708	15.708	—	27.207 0	24.923 9	—
	8	25.133	12.566	12.566	—	21.765 6	19.939 2	—
	6	18.850	9.425	9.425	—	16.324 2	14.954 4	—
	5	15.708	7.854	7.854	—	13.603 5	12.462 0	—
	4	12.566	6.283	6.283	—	10.882 8	9.969 6	—
	3	9.425	4.712	4.712	—	8.162 1	7.477 2	—
	2.5	7.854	3.927	3.927	3.927	6.801 7	6.231 0	5.553 6
	2	6.283	3.142	3.142	3.142	5.441 4	4.984 8	4.442 9
	1.75	5.498	2.749	2.749	2.749	4.761 2	4.361 7	3.887 5
	1.5	4.712	2.356	2.356	2.356	4.081 0	3.738 6	3.332 2
	1.25	3.927	1.963	1.963	1.963	3.400 9	3.115 5	2.776 8
	1	3.142	1.571	1.571	1.571	2.720 7	2.492 4	2.221 4
	0.75	2.356	1.178	1.178	1.178	2.040 5	1.869 3	1.666 1
	0.5	1.571	0.785	0.785	0.785	1.360 4	1.246 2	1.110 7
	0.25	0.785	—	—	0.393	—	—	0.555 4

* For illustration purposes: relative tooth sizes for various spline modules for pressure angle $\alpha_D = 30°$.