



Machine Drawing

Class 3 : Limits, Fits & Dimensional Tolerances

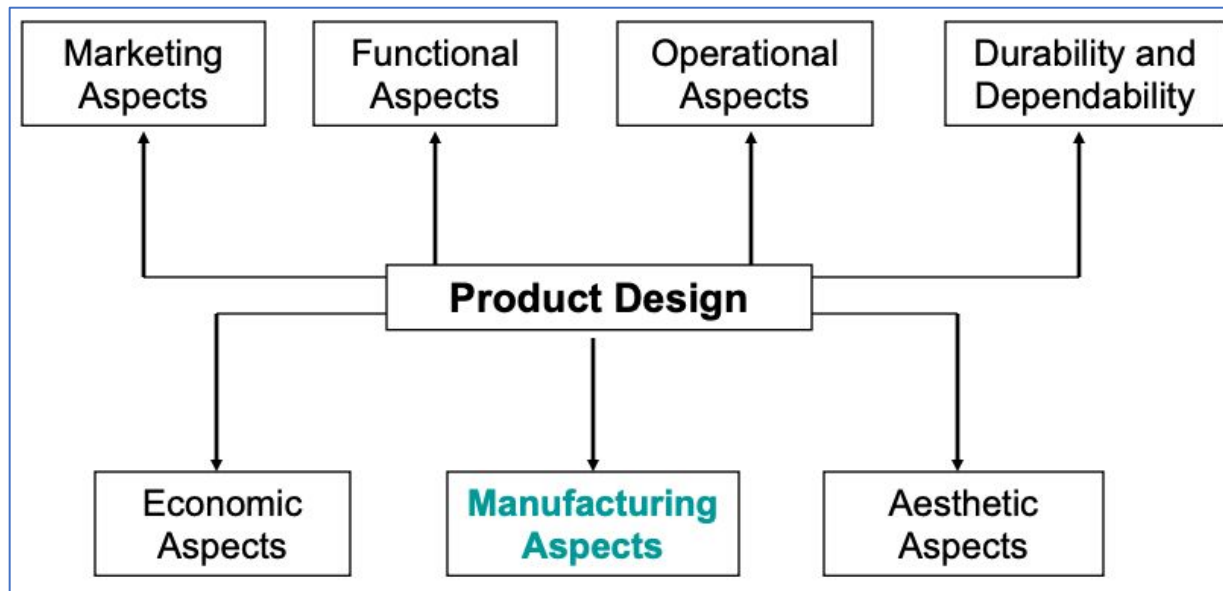
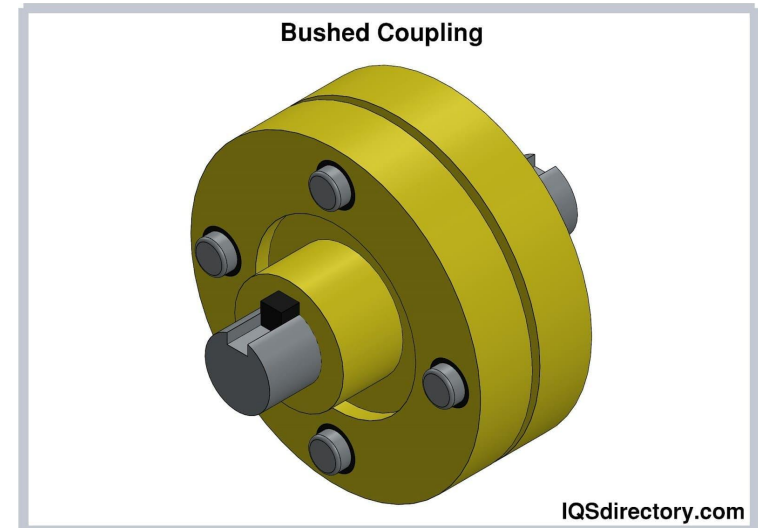


Textbooks and References

- *N. Sidheswar, P. Kanniah and V.V.S. Sastry, Machine Drawing, Tata McGraw Hill, 2001*
- *SP 46: 1988 Engineering Drawing Practice for School & Colleges. Bureau of Indian Standards*

A designer must ensure

- Selection of proper material
- Ensuring proper strength
- Dimension to guard against failure
- **Basic manufacturing aspects**



Manufacturing Aspect

Key Functional Requirements

Fit between the mating parts

Tolerances, dimensions on mating parts

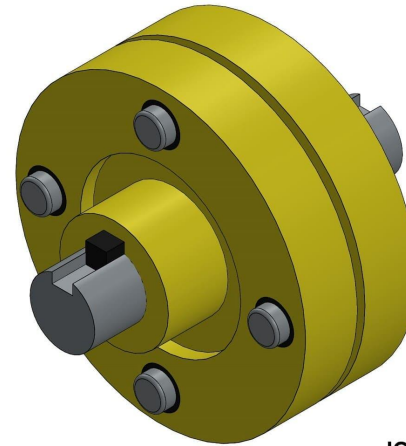
Manufacturing Processes & Sequences

Cost of Manufacturing

Fit:

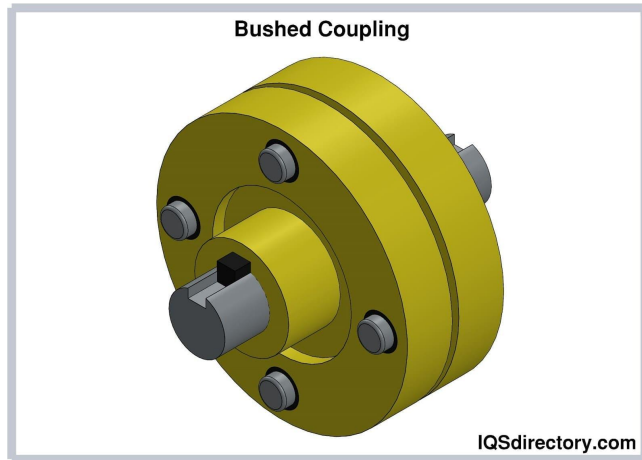
It is the interrelation between dimensions of mating parts before their assembly

Bushed Coupling

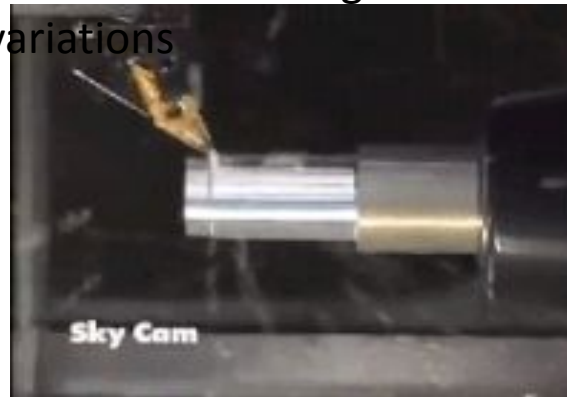


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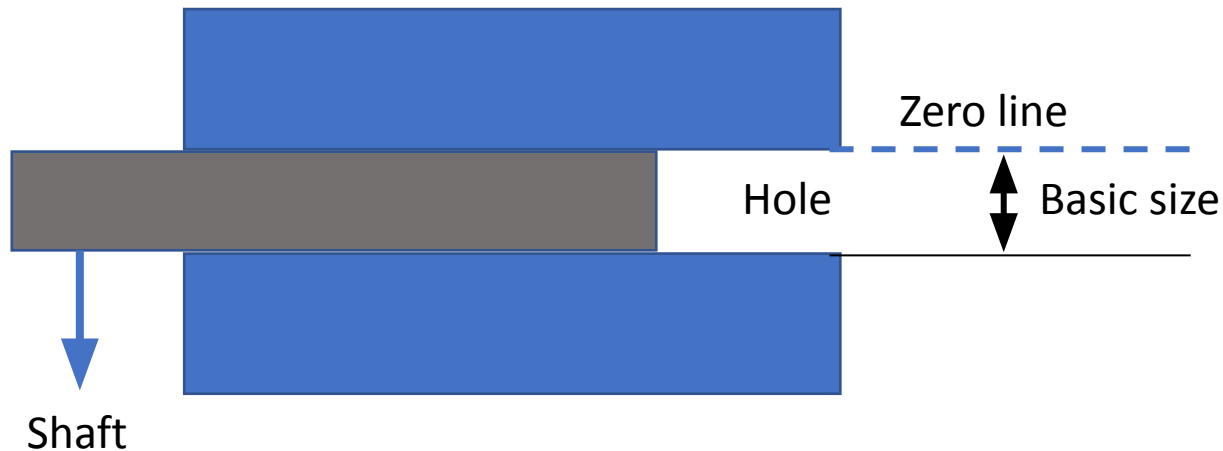
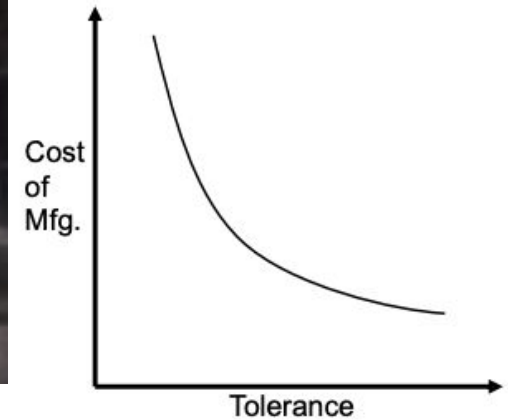
Holes and shafts and their base size



Vibration induced geometric variations



Lathe GIFs - Get the best gif on GIFER

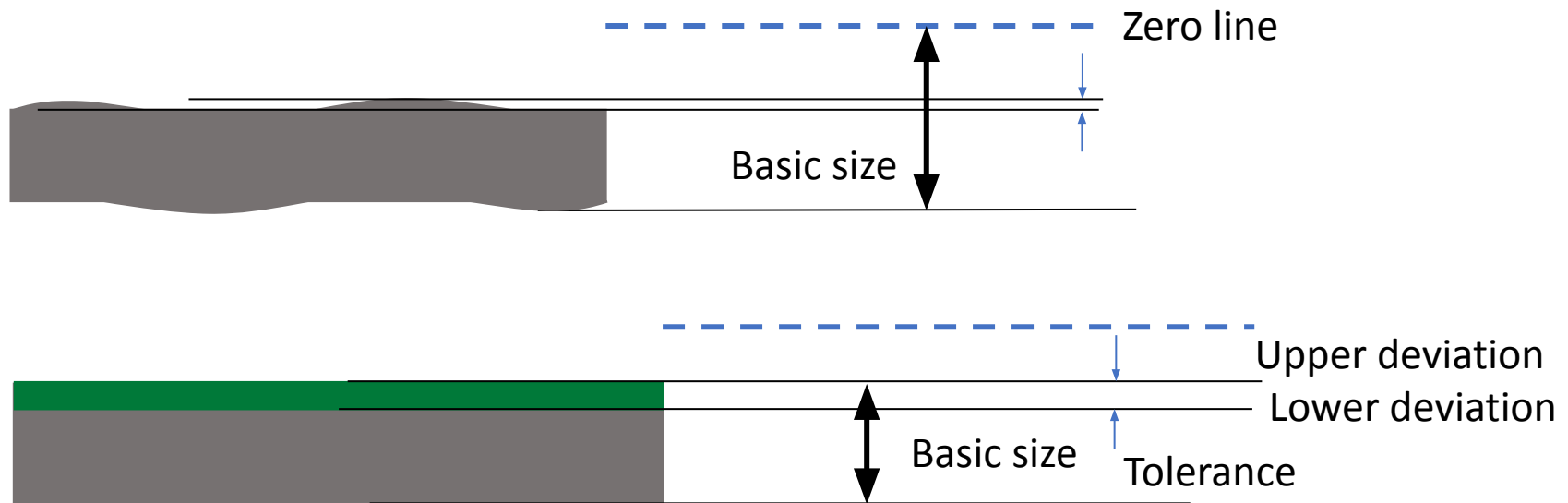


Terminologies



Zero Line: It is a line along which represents the basic size and zero (or initial point) for measurement of upper or lower deviations.

Basic Size: It is the size with reference to which upper or lower limits of size are defined.



Bilateral

Uni-lateral

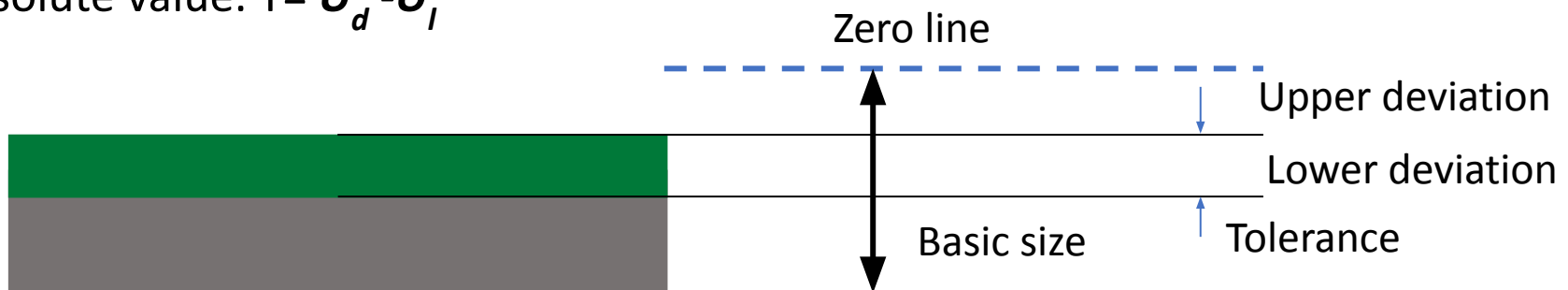
Zero Line: It is a line along which represents the basic size and zero (or initial point) for measurement of upper or lower deviations.

Basic Size: It is the size with reference to which upper or lower limits of size are defined.

Upper Deviation: The algebraic difference between the maximum limit of size (of either hole or shaft) and the corresponding basic size. U_d

Lower Deviation: The algebraic difference between the minimum limit of size (of either hole or shaft) and the corresponding basic size. U_l

Tolerance: The algebraic difference between upper and lower deviations. It is an absolute value. $T = U_d - U_l$



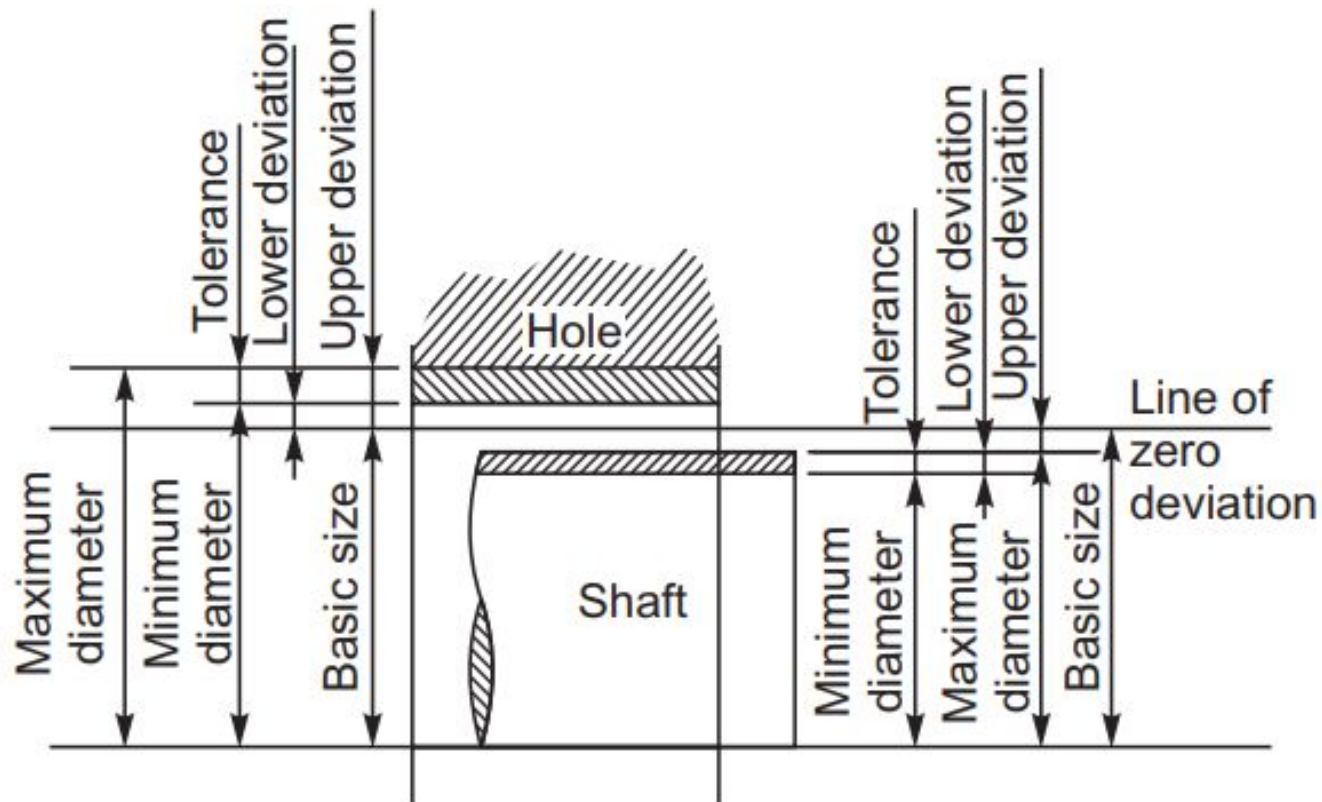


Fig. 7.3. Basic size and zero line

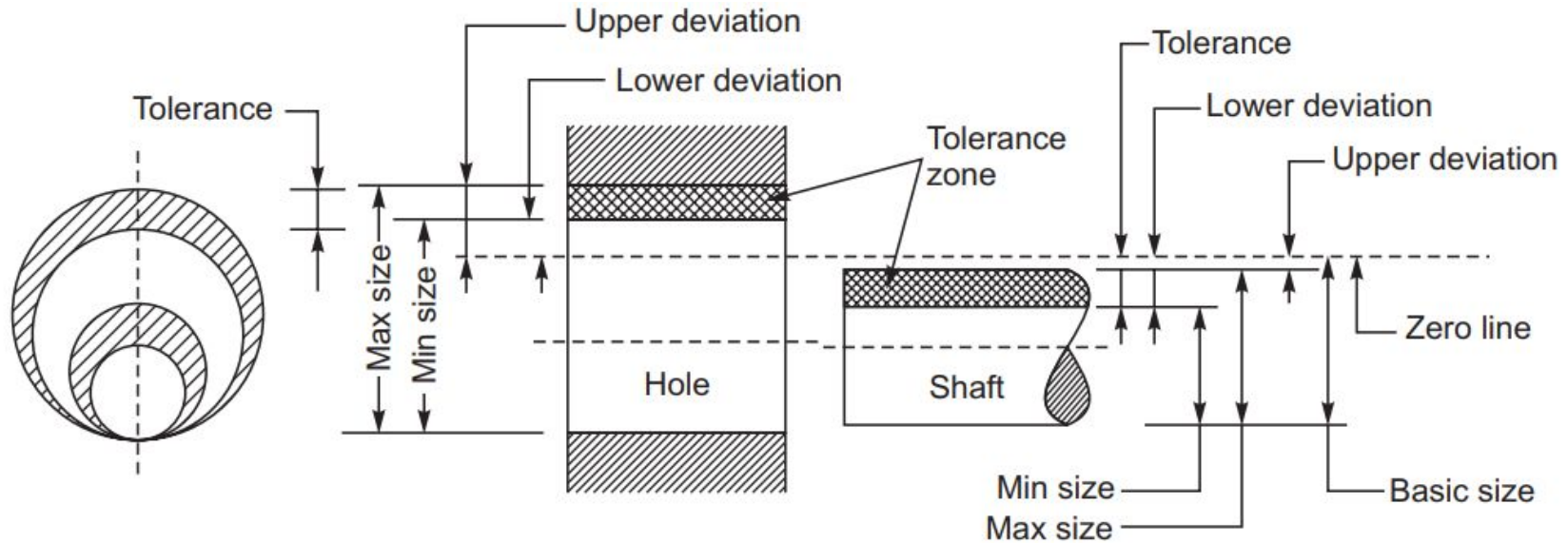


Fig. 7.6. Definition of tolerance zone

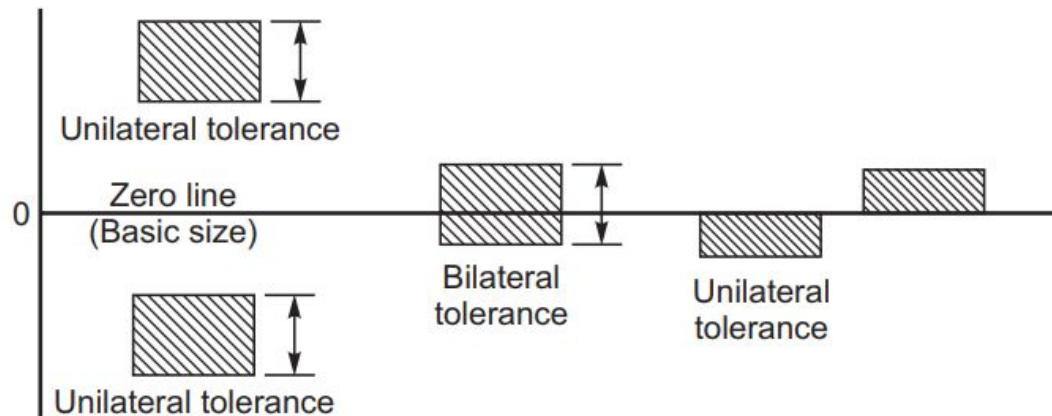


Fig. 7.5. Definition of limits of size

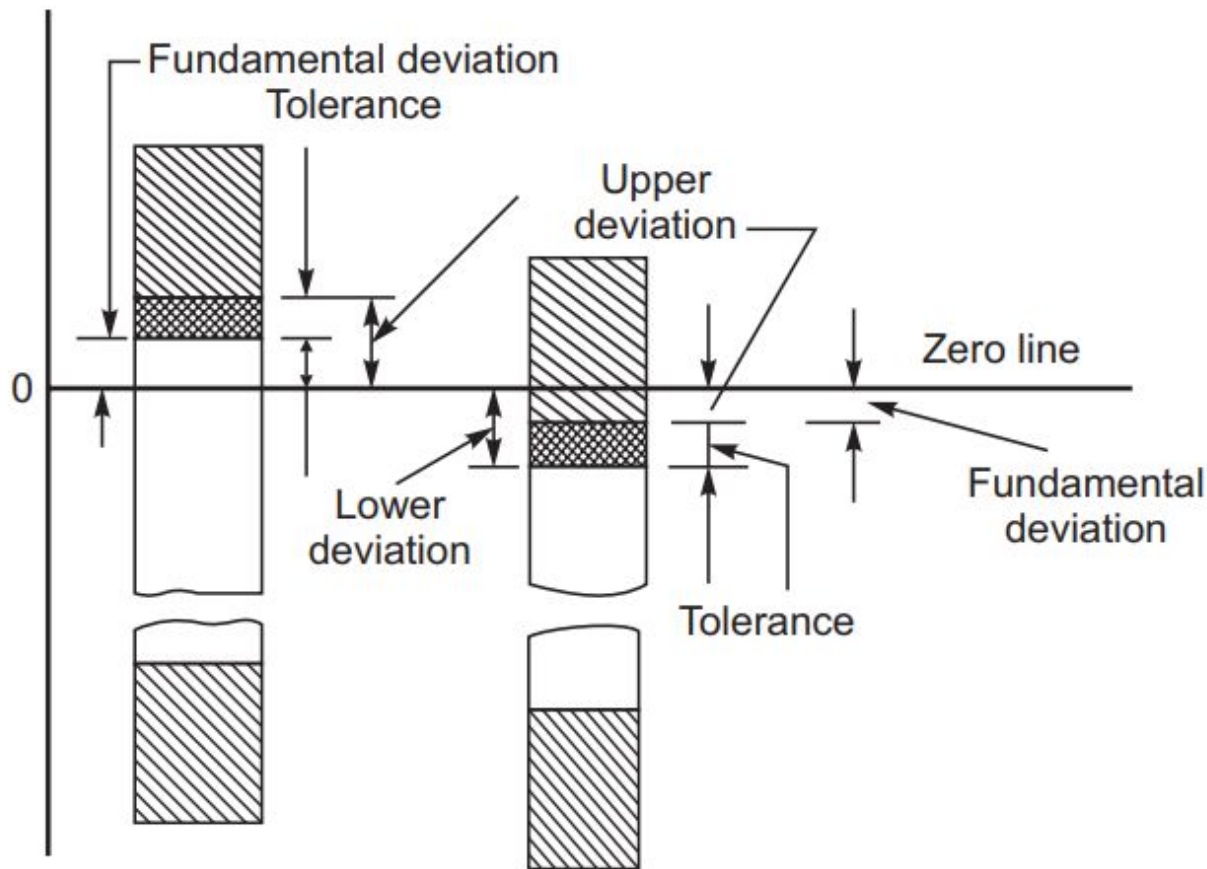


Fig. 7.7. Upper deviation, lower deviation and fundamental deviation

Degree of accuracy

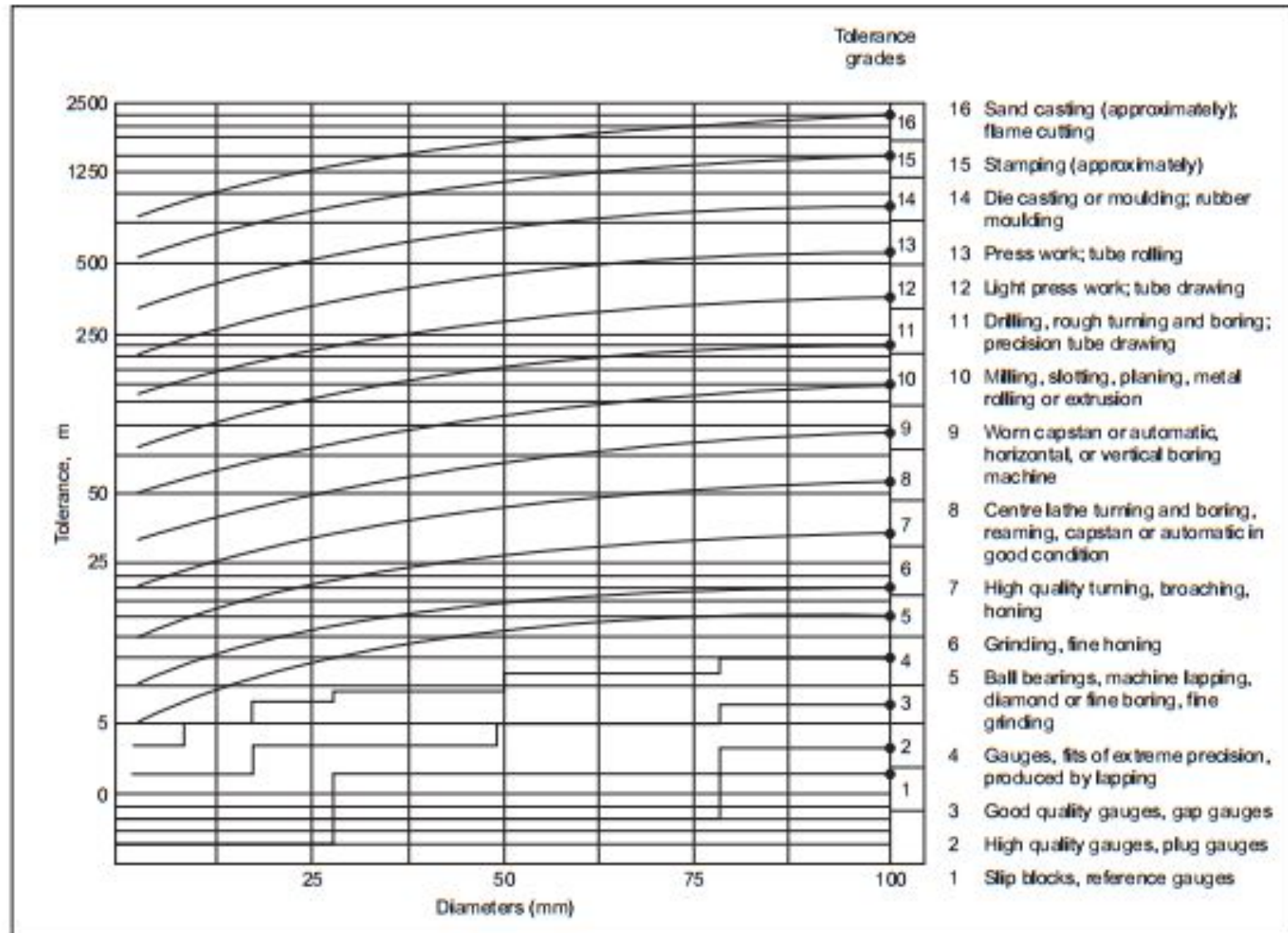


Fig. 15.2 Degree of accuracy expected of manufacturing process



Method of Placing Limit Dimensions



$$\phi 25H7 = \phi 25 \begin{matrix} +0.021 \\ +0.000 \end{matrix}$$

$$10H10 = 10 \begin{matrix} +0.058 \\ +0.000 \end{matrix}$$

$$40C11 = 40 \begin{matrix} +0.280 \\ +0.120 \end{matrix}$$

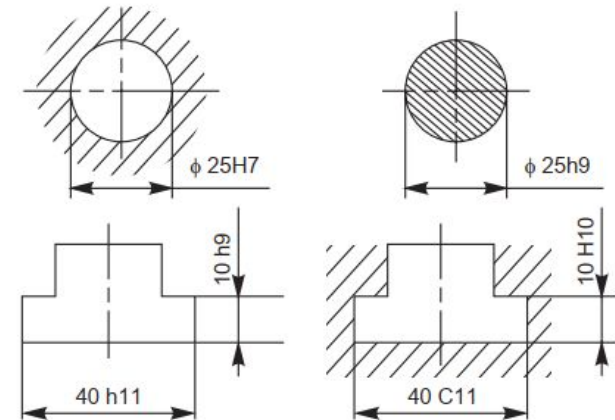


Fig. 15.4 Toleranced dimensions for internal and external features

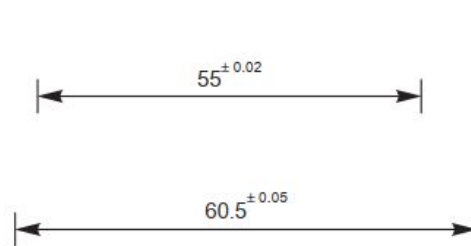


Fig. 15.5 Bilateral tolerance of equal variation

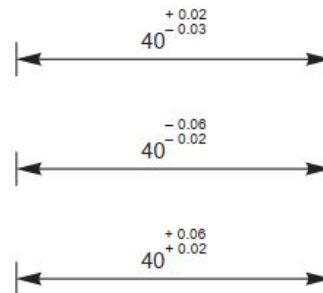


Fig. 15.6 Bilateral tolerance of unequal variation

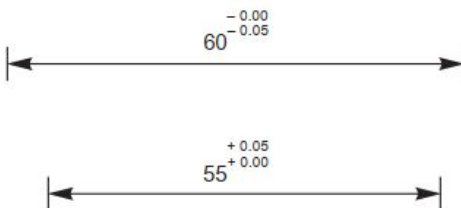


Fig. 15.7 Unilateral tolerance with zero variation in one direction

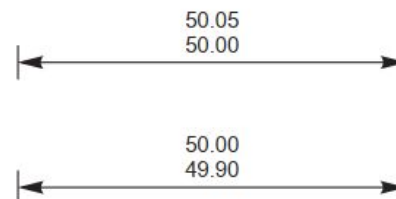


Fig. 15.8 Maximum and minimum size directly indicated

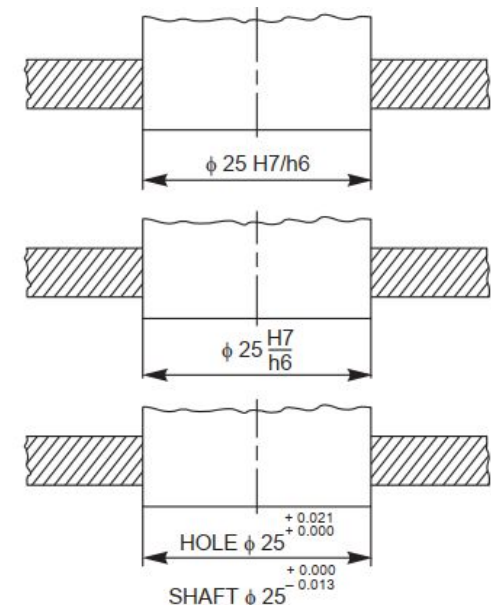


Fig. 15.9 Toleranced dimensioning of assembled parts

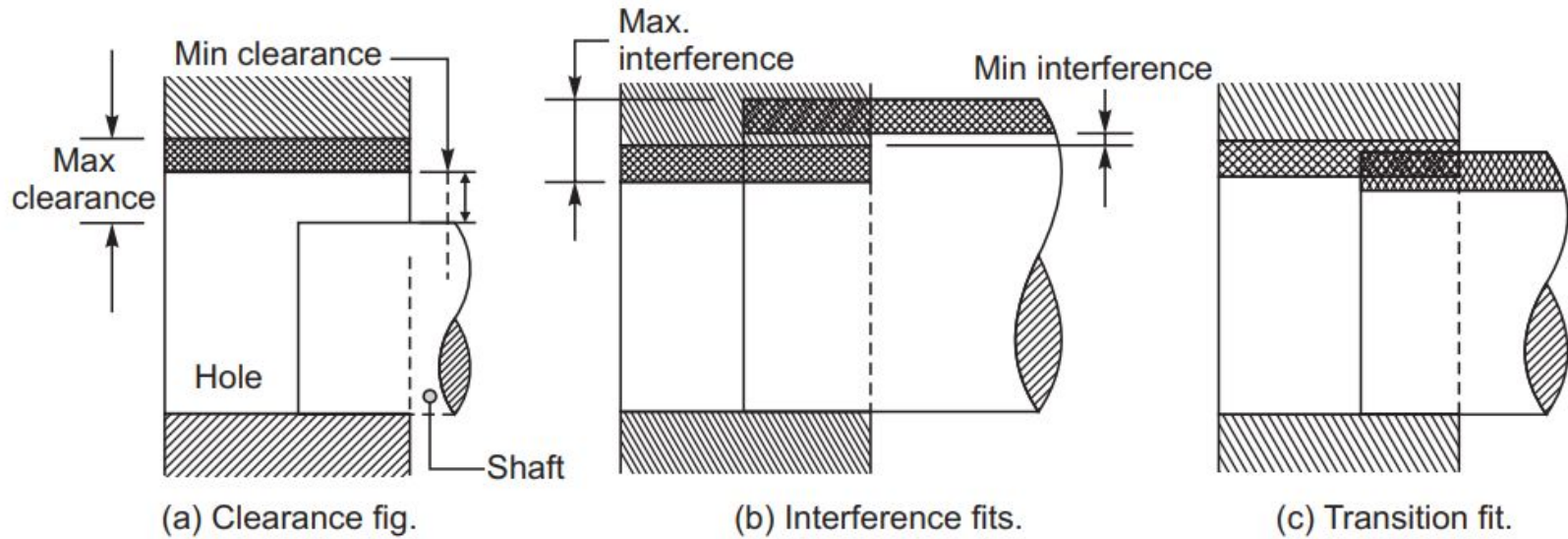
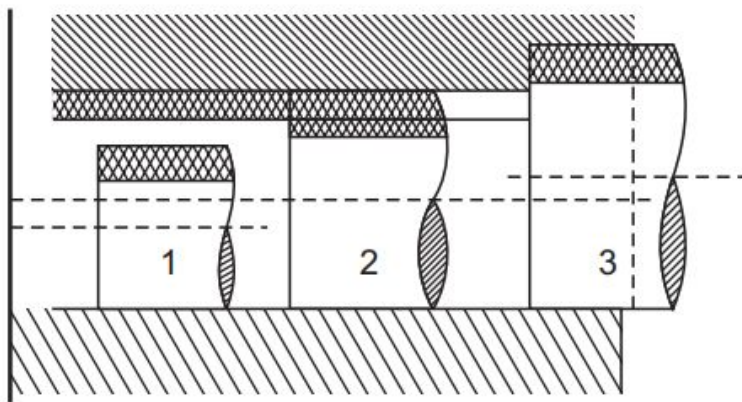


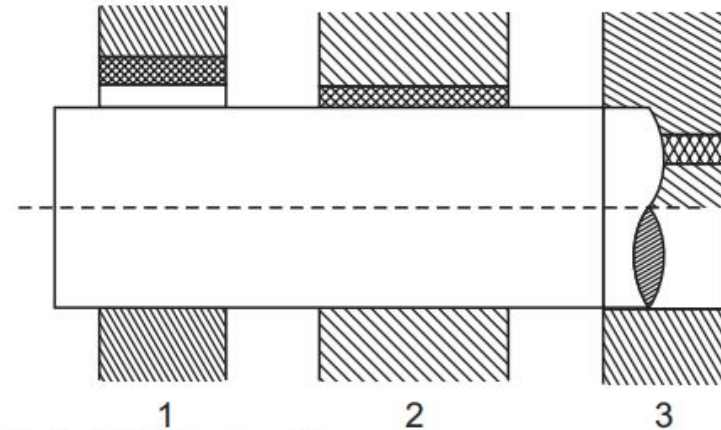
Fig. 7.8. Types of fits

In hole basis system, the size of the hole is constant and different fits are obtained by varying the size of shaft.



1. Clearance fit. 2. Transition fit. 3. Interference fit.

(a) Hole basis system.



(b) Shaft basis system.

Fig. 7.9. Basis of limit system

In shaft basic system, the size of the shaft is constant and different fits are obtained by varying the size of the hole

Maximum Metal Limit (MML) and Least or Minimum Metal Limit (LML) for a Shaft

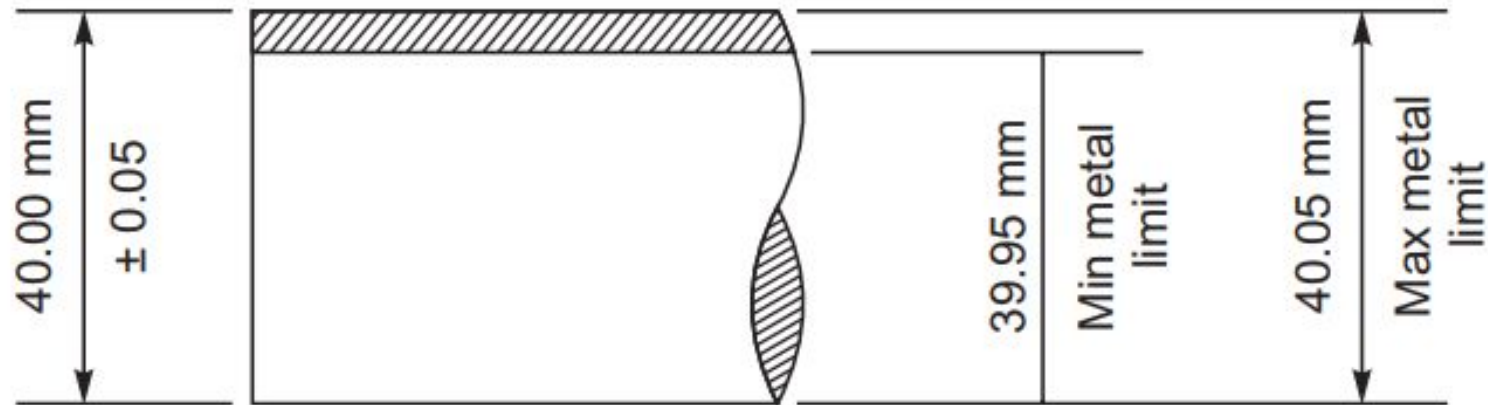


Fig. 7.11. Maximum and minimum metal limits for a shaft

Maximum Metal Limit (MML) and Least or Minimum Metal Limit (LML) for a Hole

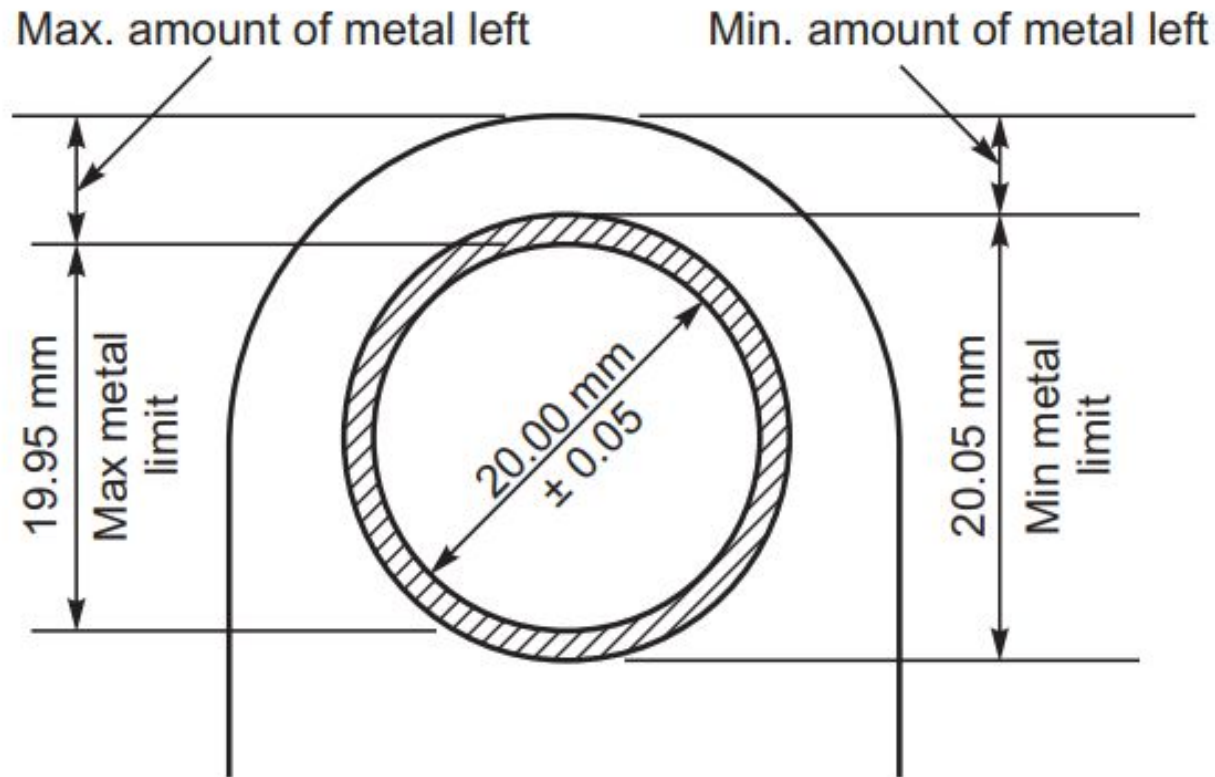


Fig. 7.12. Maximum and minimum metal limits for a hole

Selection of tolerances based on fits



<i>Type of fit</i>	<i>Symbol of fit</i>	<i>Examples of application</i>
<i>Interference fit</i>		
Shrink fit	H8/u8	Wheel sets, tyres, bronze crowns on worm wheel
Heavy drive fit	H7/s6	hubs, couplings under certain conditions, etc.
Press fit	H7/r6	Coupling on shaft ends, bearing bushes in hubs, valve
Medium press fit	H7/p6	seats, gear wheels.
<i>Transition fit</i>		
Light press fit	H7/n6	Gears and worm wheels, bearing bushes, shaft and wheel assembly with feather key.
Force fit	H7/m6	Parts on machine tools that must be changed without damage, <i>e.g.</i> , gears, belt pulleys, couplings, fit bolts, inner ring of ball bearings.
Push fit	H7/k6	Belt pulleys, brake pulleys, gears and couplings as well as inner rings of ball bearings on shafts for average loading conditions.
Easy push fit	H7/j6	Parts which are to be frequently dismantled but are secured by keys, <i>e.g.</i> , pulleys, hand-wheels, bushes, bearing shells, pistons on piston rods, change gear trains.

Selection of tolerances based on fits



<i>Clearance fit</i>		
Precision sliding fit	H7/h6	Sealing rings, bearing covers, milling cutters on milling mandrels, other easily removable parts.
Close running fit	H7/g6	Spline shafts, clutches, movable gears in change gear trains, etc.
Normal running fit	H7/f7	Sleeve bearings with high revolution, bearings on machine tool spindles.
Easy running fit	H8/e8	Sleeve bearings with medium revolution, grease lubricated bearings of wheel boxes, gears sliding on shafts, sliding blocks.
Loose running fit	H8/d9	Sleeve bearings with low revolution, plastic material bearings.
Slide running fit	H8/c11	Oil seals (Simmerrings) with metal housing (fit in housing and contact surface on shaft), multi-spline shafts.

Various grades of tolerances are defined using the 'standard tolerance unit', (i) in μm , which is a function of basic size.

$$i = 0.45 \sqrt[3]{D} + 0.001D$$

where, D (mm) is the geometric mean of the lower and upper diameters of a particular diameter step within which the chosen the diameter D lies.

Diameter steps in I.S.I are: (a - b , where a is above and b is up to)

1-3, 3-6, 6-10, 10-18, 18-30, 30-50, 50-80, 80-120, 120-180, 180-250, 250-315, 315-400 and 400-500 mm

Table 15.1A Relative magnitude of IT tolerances for grades 5 to 16 in terms of tolerance unit i for sizes upto 500 mm

Grade	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16
Tolerance values	$7i$	$10i$	$16i$	$25i$	$40i$	$64i$	$100i$	$160i$	$250i$	$400i$	$640i$	$1000i$

Thus, the fundamental tolerance values for different grades (IT) may be obtained either from Table 15.1 or calculated from the relations given in Table 15.1A.

Example 1 Calculate the fundamental tolerance for a shaft of 100 mm and grade 7.

The shaft size, 100 lies in the basic step, 80 to 120 mm and the geometrical mean is

$$D = \sqrt{80 \times 120} = 98 \text{ mm}$$

The tolerance unit, $i = 0.45 \sqrt[3]{98} + 0.001 \times 98 = 2.172$ microns

For grade 7, as per the Table 15.1A, the value of tolerance is,

$$16i = 16 \times 2.172 = 35 \text{ microns}$$

Fundamental deviations



Table 15.4 Formulae for fundamental deviation for shafts upto 500 mm

<i>Upper deviation (es)</i>		<i>Lower deviation (ei)</i>	
<i>Shaft designation</i>	<i>In microns (for D in mm)</i>	<i>Shaft designation</i>	<i>In microns (For D in mm)</i>
a	$= - (265 + 1.3D)$ for $D \leq 120$	k4 to k7	$= 0.6 \sqrt[3]{D}$
	$= - 3.5 D$ for $D > 120$	k for grades ≤ 3 and ≥ 8	$= 0$
b	$\approx - (140 + 0.85 D)$ for $D \leq 160$	m	$= + (IT\ 7 - IT\ 6)$
	$\approx - 1.8 D$ for $D > 160$	n	$= + 5 D^{0.34}$
		p	$= + IT\ 7 + 0$ to 5
c	$= - 52 D^{0.2}$ for $D \leq 40$	r	$=$ geometric mean of values <i>ei</i> for <i>p</i> and <i>s</i>
	$= - (95 + 0.8 D)$ for $D > 40$	s	$= + IT\ 8 + 1$ to 4 for $D \leq 50$
d	$= - 16 D^{0.44}$		$= + IT\ 7 + 0.4 D$ for $D > 50$
e	$= - 11 D^{0.41}$	t	$= IT\ 7 + 0.63 D$
f	$= - 5.5 D^{0.41}$	u	$= + IT\ 7 + D$
g	$= - 2.5 D^{0.34}$	v	$= + IT\ 7 + 1.25 D$
h	$= 0$	x	$= + IT\ 7 + 1.6 D$
		y	$= + IT\ 7 + 2 D$
		z	$= + IT\ 7 + 2.5 D$
		za	$= + IT\ 8 + 3.15 D$
		zb	$= + IT\ 9 + 4 D$
j5 to j8	no formula	zc	$= + IT\ 10 + 5 D$

For Js : the two deviations are equal to $\pm \frac{IT}{2}$

Example 1: *Evaluate limits and fits for a pair of – Diameter 6 H7/g6*

Solution: The size 6 mm lies in the diametral step of 3–6, therefore, D is given by

$$D = \sqrt{3 \times 6} = 4.24 \text{ mm}$$

The value of fundamental tolerance unit is given by

$$i = 0.45 \sqrt[3]{D} + 0.001D$$

$$i = 0.45 \sqrt[3]{4.24} + 0.001 \times 4.24$$

$$i = 0.7327 \text{ } \mu\text{m}$$

Limits of tolerance for hole H7

The standard tolerance is

$$16 i = 16 \times 0.7327 = 11.72 = 12 \text{ } \mu\text{m}$$

The fundamental deviation H hole is = 0

Limits of tolerance for g6 shaft

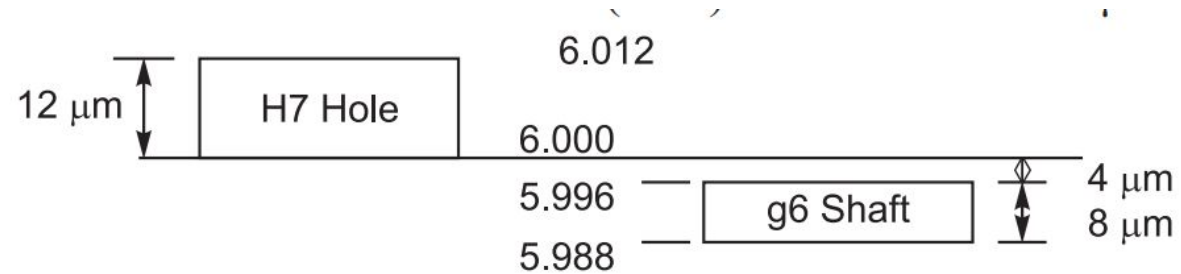
The standard tolerance is

$$-10 i = 10 \times 0.7327 = 7.327 = -8 \text{ } \mu\text{m}$$

Fundamental deviation for g shaft

$$= -2.5D^{0.34} = -2.5(4.24)^{0.34} = -4.085 = -4 \text{ } \mu\text{m}$$

Example



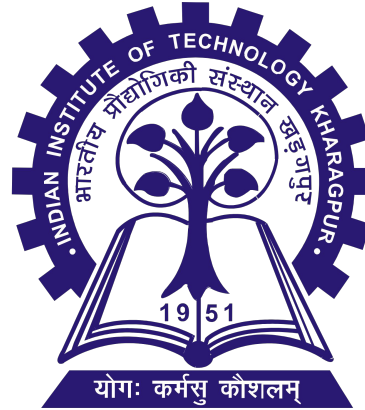
Disposition of tolerance zone around the zero line

Fit

Maximum clearance = Maximum size of hole – Minimum size of shaft
= $6.012 - 5.988 = 0.024 \text{ mm} = 24 \mu\text{m}$

Minimum clearance = Minimum size of hole – Maximum size of shaft
= $6.000 - 5.996 = 0.004 \text{ mm} = 4 \mu\text{m}$

Ans: The type of fit is Clearance.



Thank you !!!