Machine Drawing

Class 3 : Limits, Fits & Dimensional Tolerances

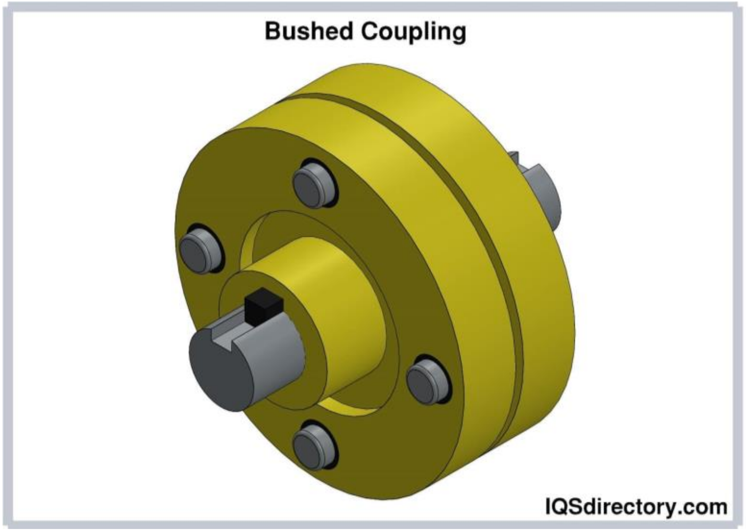
Textbooks and References

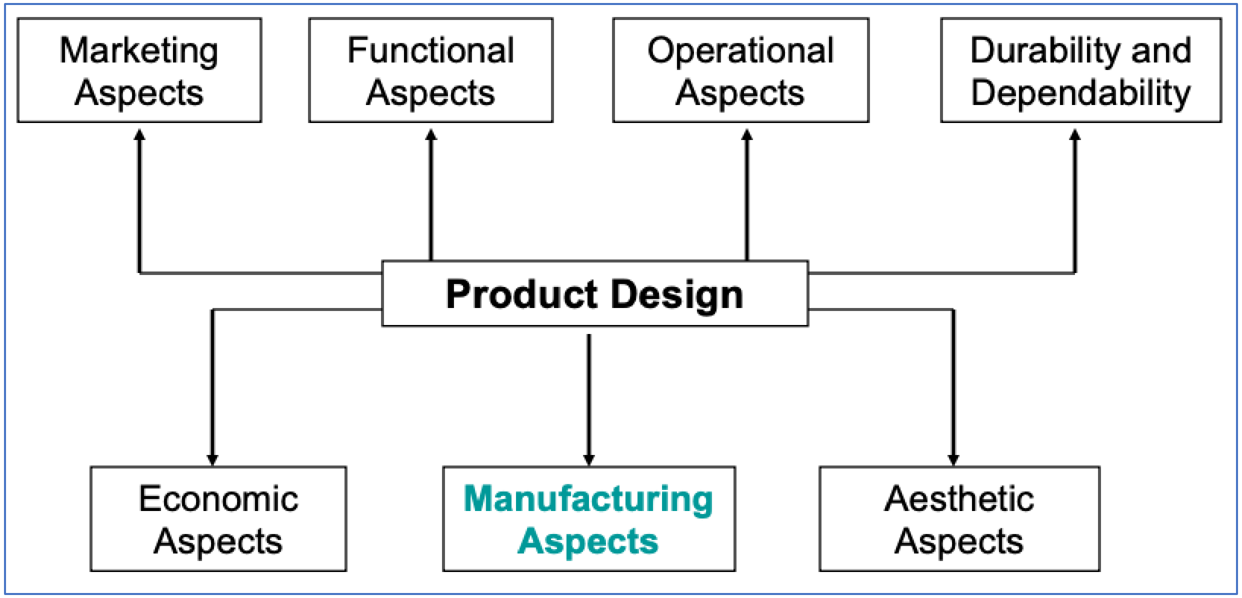
- ***N. Sidheswar, P. Kanniah and V.V.S. Sastry, Machine Drawing, Tata McGraw Hill, 2001***
- ***SP 46: 1988 Engineering Drawing Practice for School & Colleges. Bureau of Indian Standards***

Design and Manufacturing

A designer must ensure

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



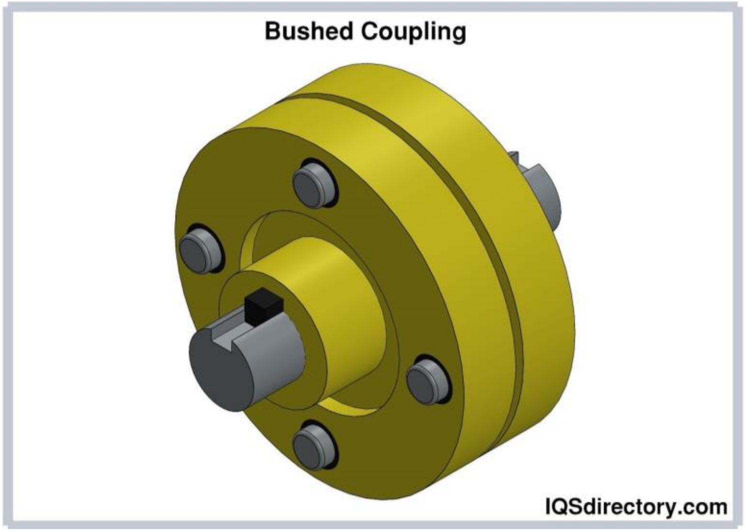


Role of Metrology in Design for Manufacturing

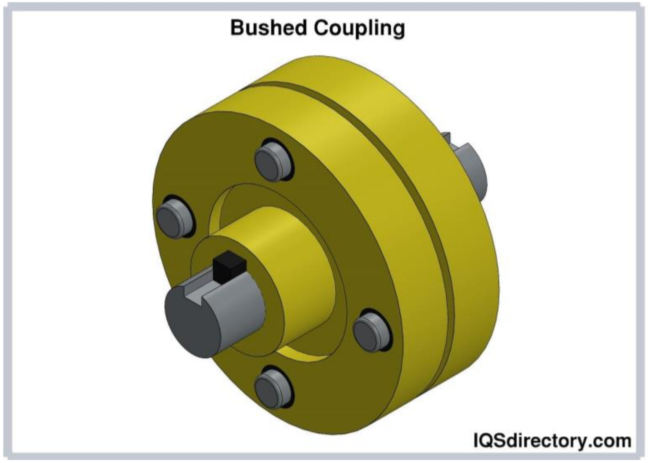
- Manufacturing Aspect
  - Key Functional Requirements
  - Fit between the mating parts
  - Tolerances, dimensions on mating parts
  - Manufacturing Processes & Sequences
  - Cost of Manufacturing

Fit:

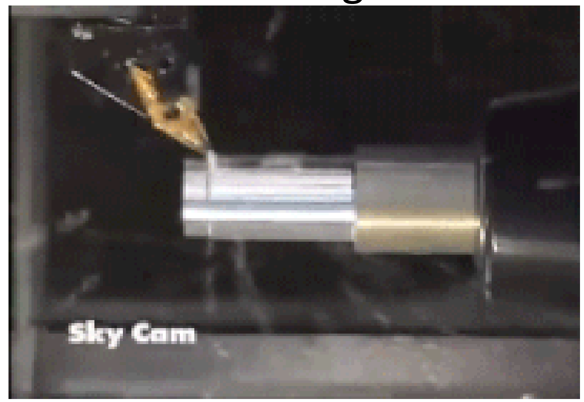
It is the interrelation between dimensions of mating parts before their assembly



Holes and shafts and their base size



Vibration induced geometric variations



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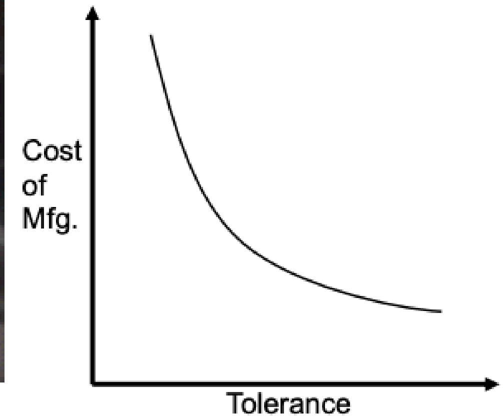
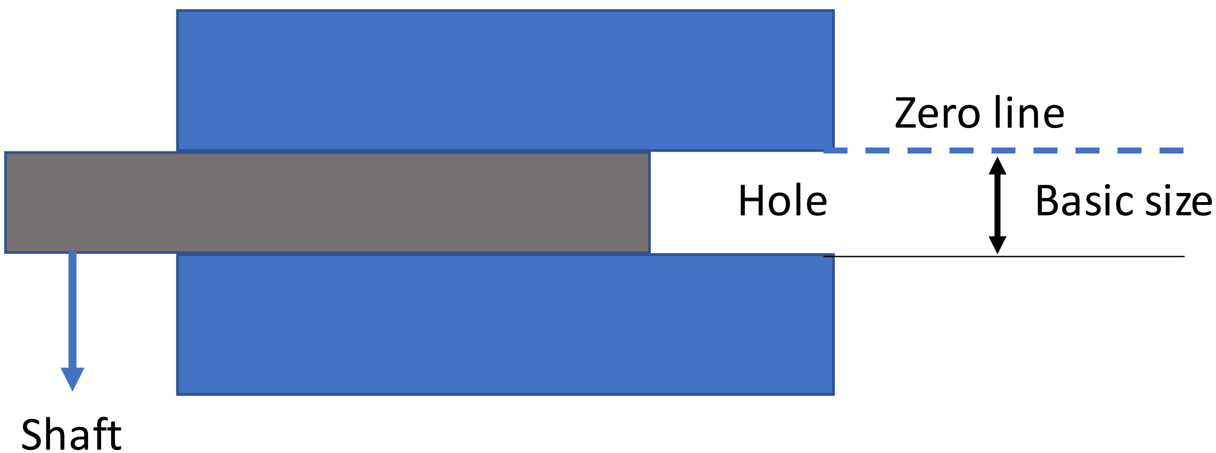
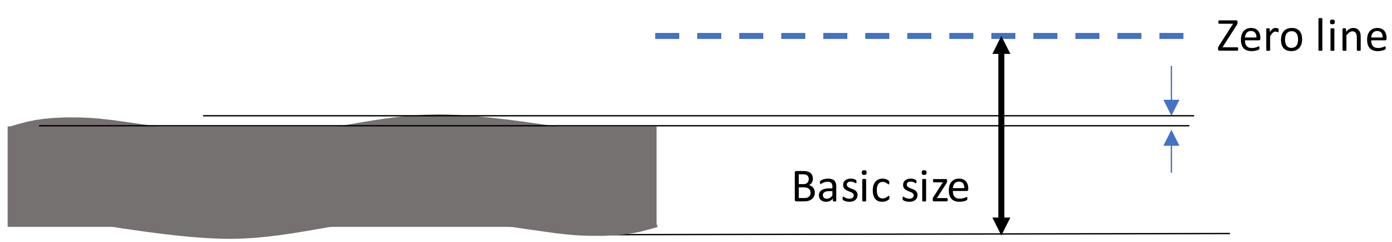


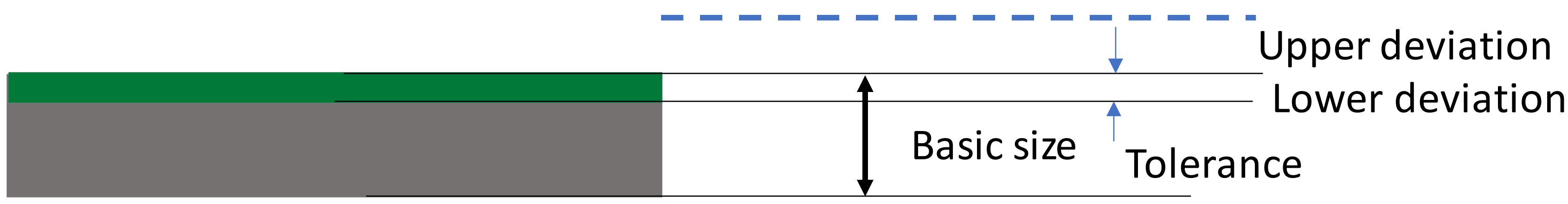


Terminologies

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	D^{+X}_{-Y}

Uni-lateral	D^{+X}_{0}

D^{-X}_{-Y}

Terminologies

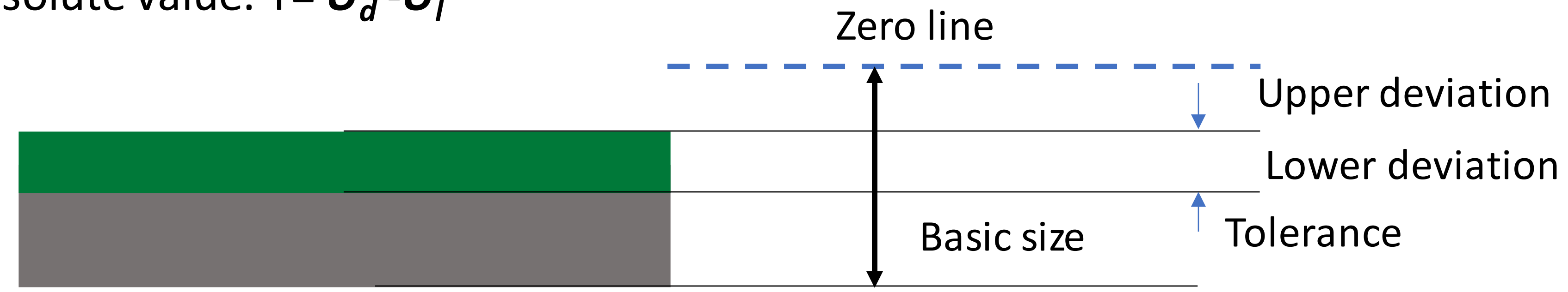
Zero Line: It is a line along which represents the basic size and zero (or initial point) for measurement of upper or lower deviations.

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

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



Basic size and zero lline

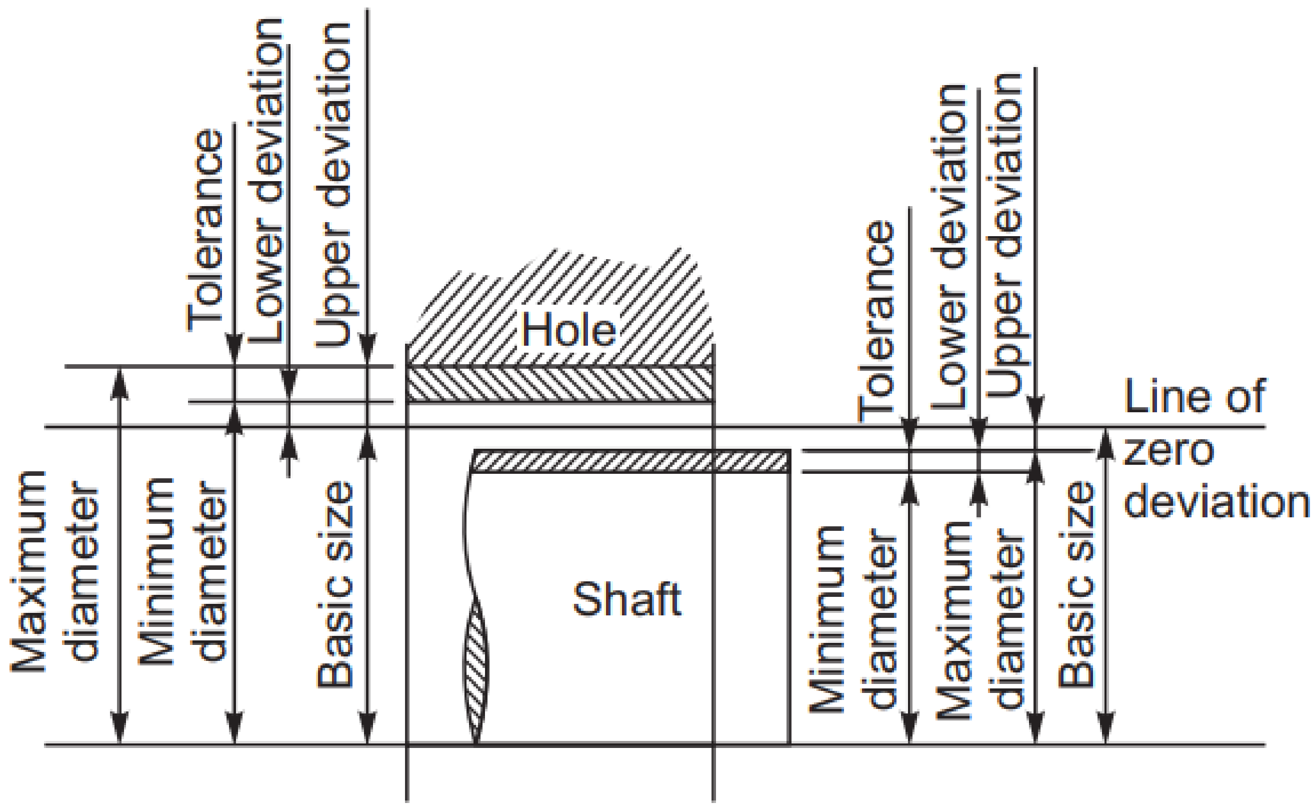


Fig. 7.3. Basic size and zero line

Dimensional Tolerances

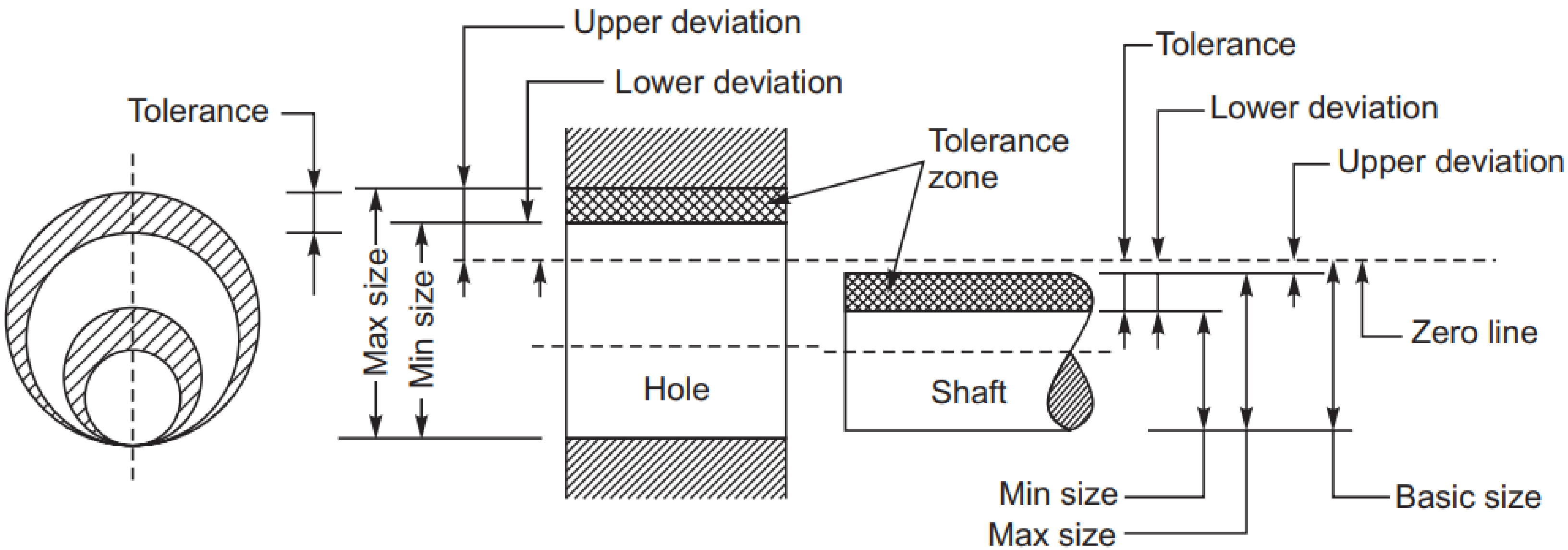


Fig. 7.6. Definition of tolerance zone

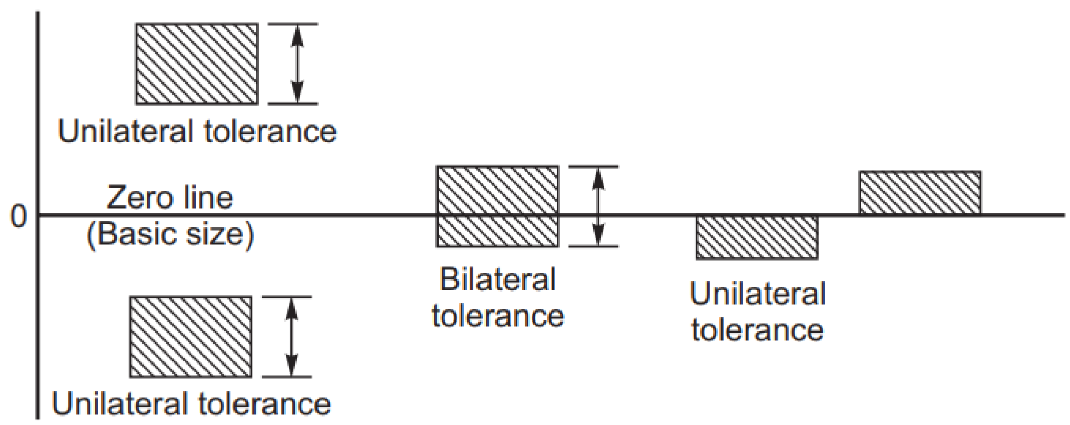


Fig. 7.5. Definition of limits of size

Deviations

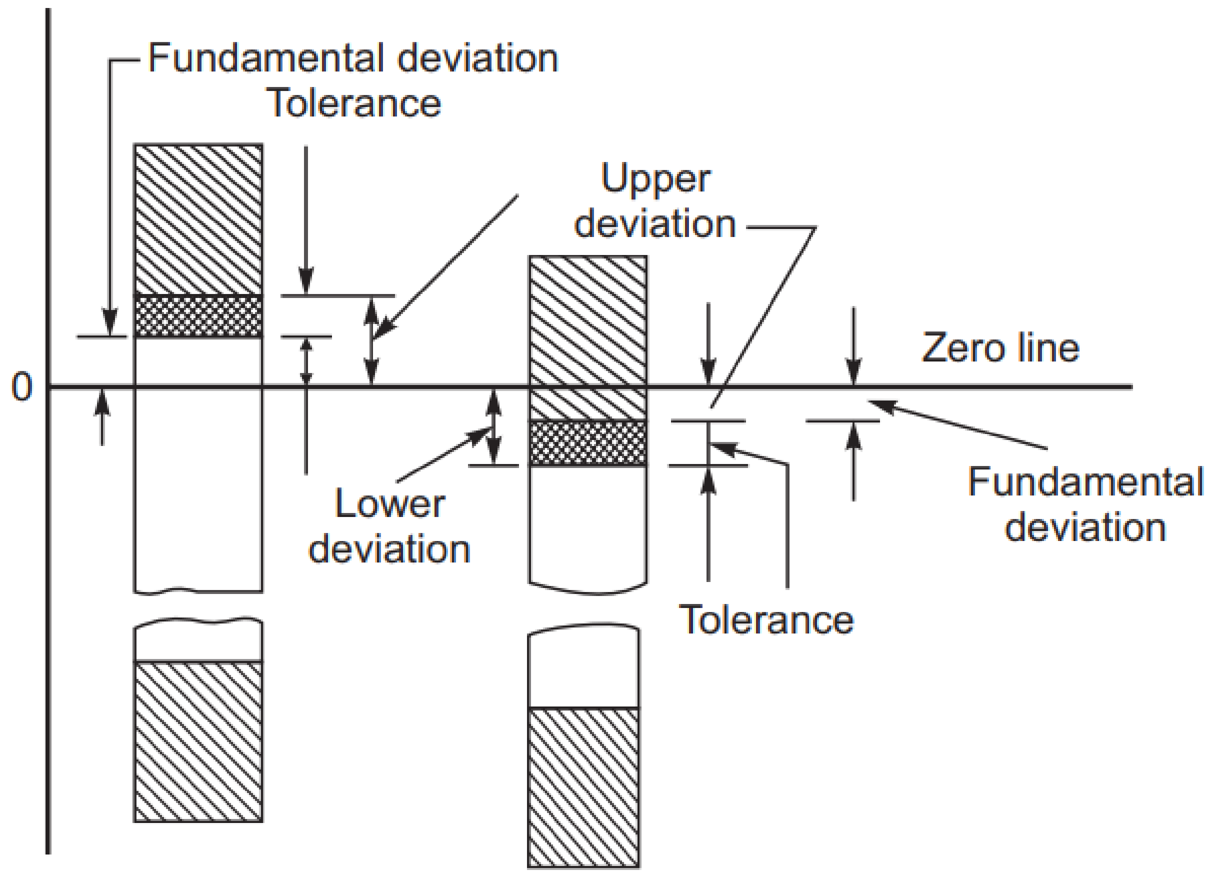


Fig. 7.7. Upper deviation, lower deviation and fundamental deviation

Degree of accuracy

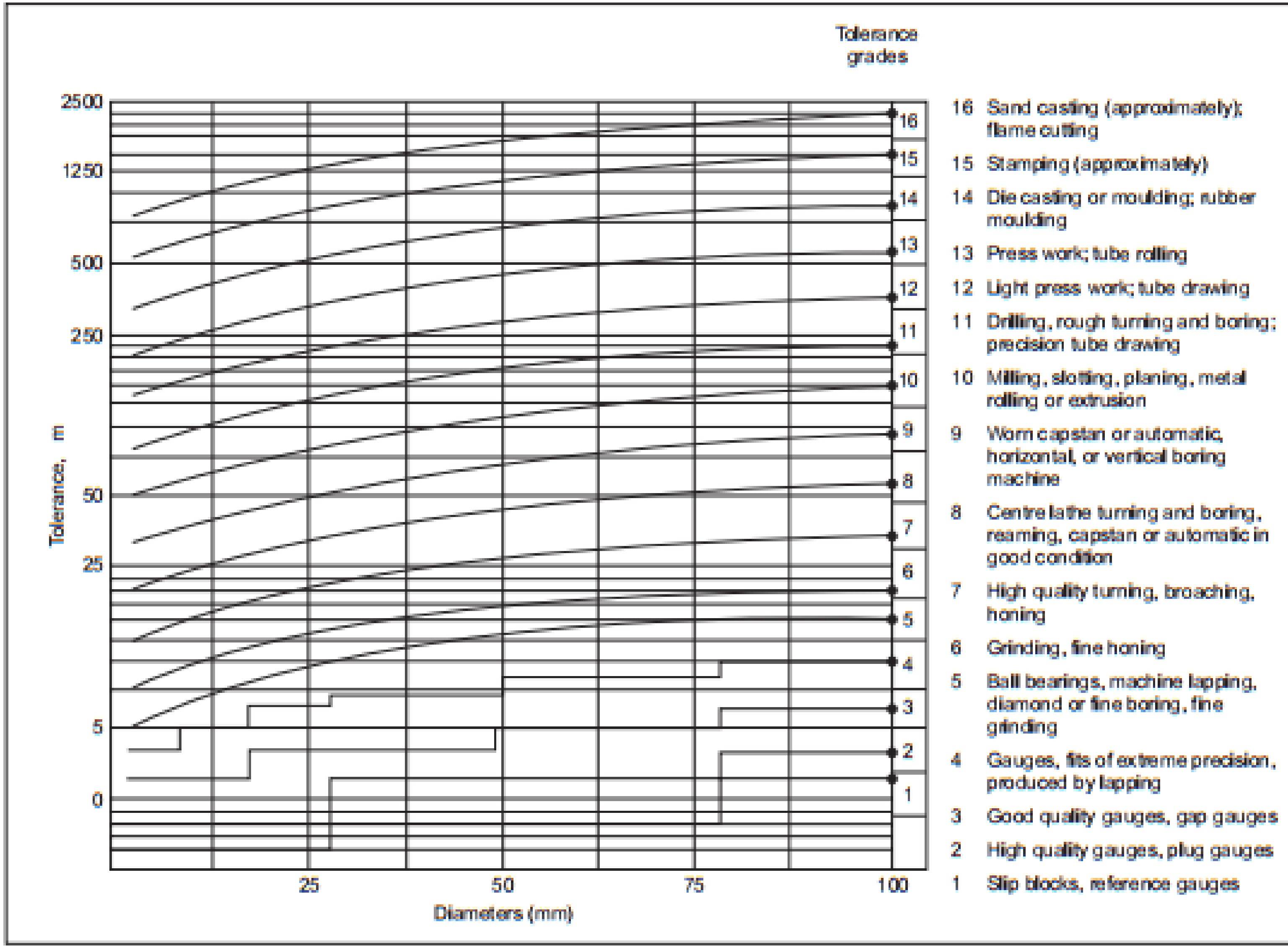
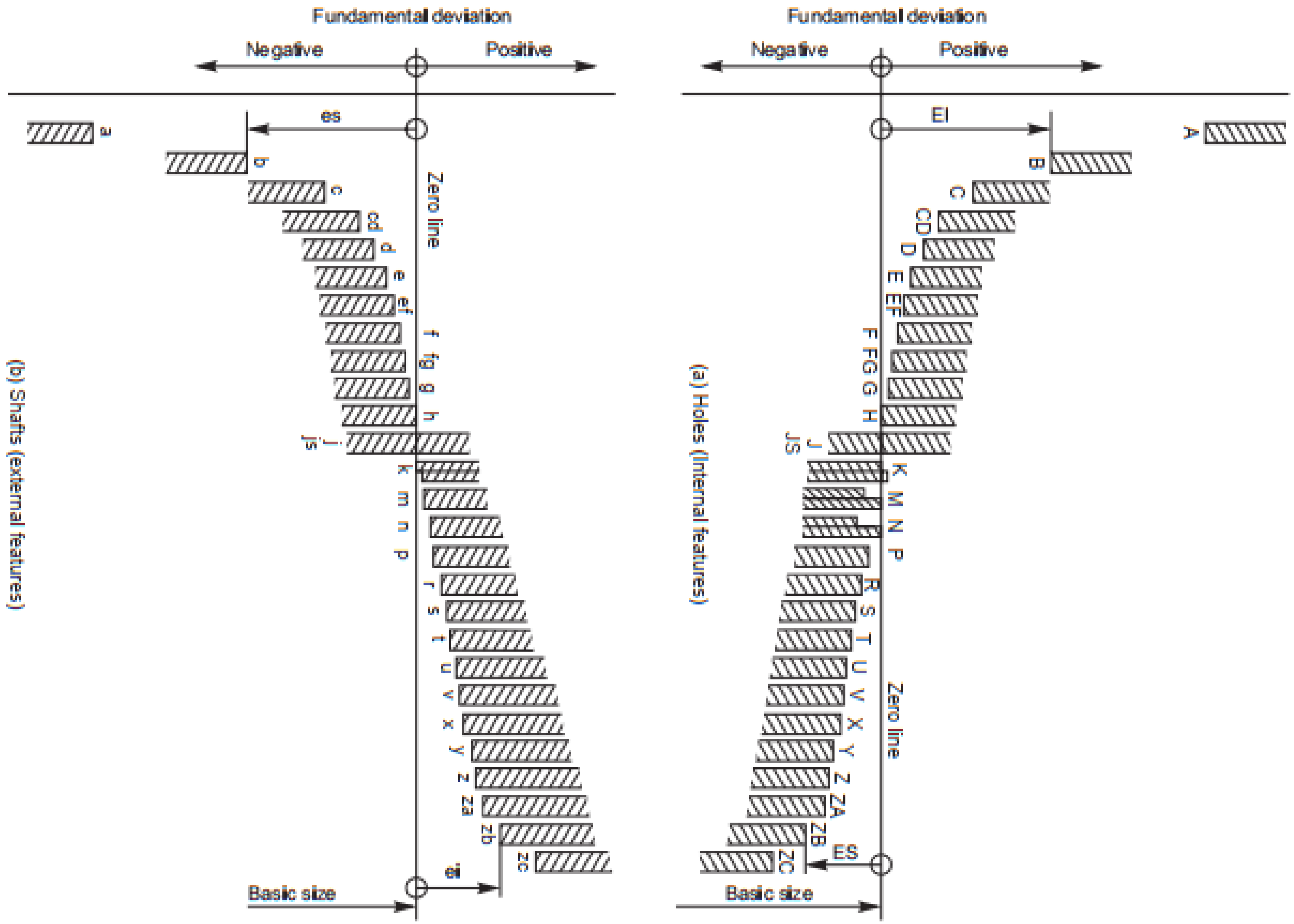


Fig. 15.2 Degree of accuracy expected of manufacturing process

Dimensional Tolerances



Method of Placing Limit Dimensions

$$\phi\, 25H7 = \phi\, 25\,^{+0.021}_{+0.000}$$

$$10H10 = 10\,^{+0.058}_{+0.000}$$

$$40C11 = 40\,^{+0.280}_{+0.120}$$

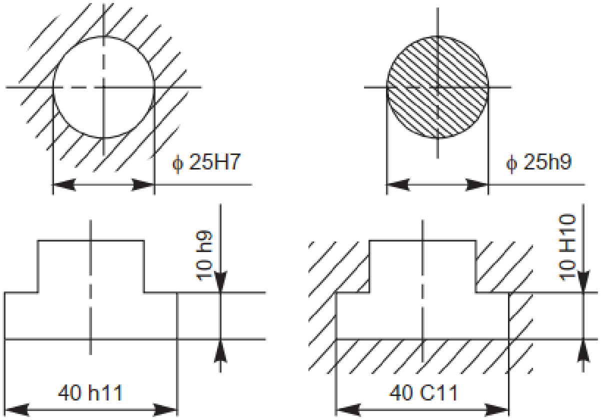


Fig. 15.4 Toleranced dimensions for internal and external features

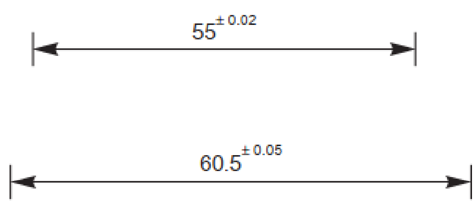


Fig. 15.5 Bilateral tolerance of equal variation

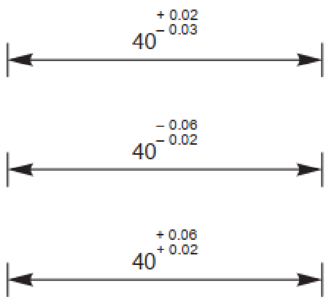


Fig. 15.6 Bilateral tolerance of unequal variation

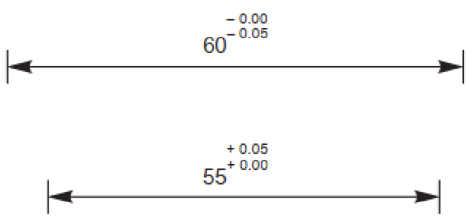


Fig. 15.7 Unilateral tolerance with zero variation in one direction

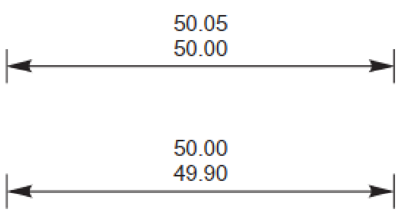


Fig. 15.8 Maximum and minimum size directly indicated

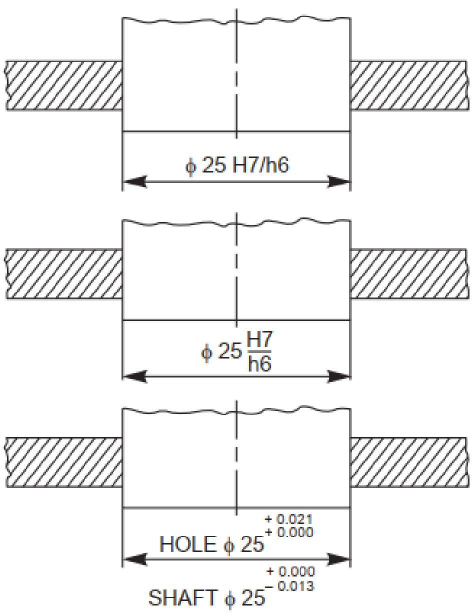
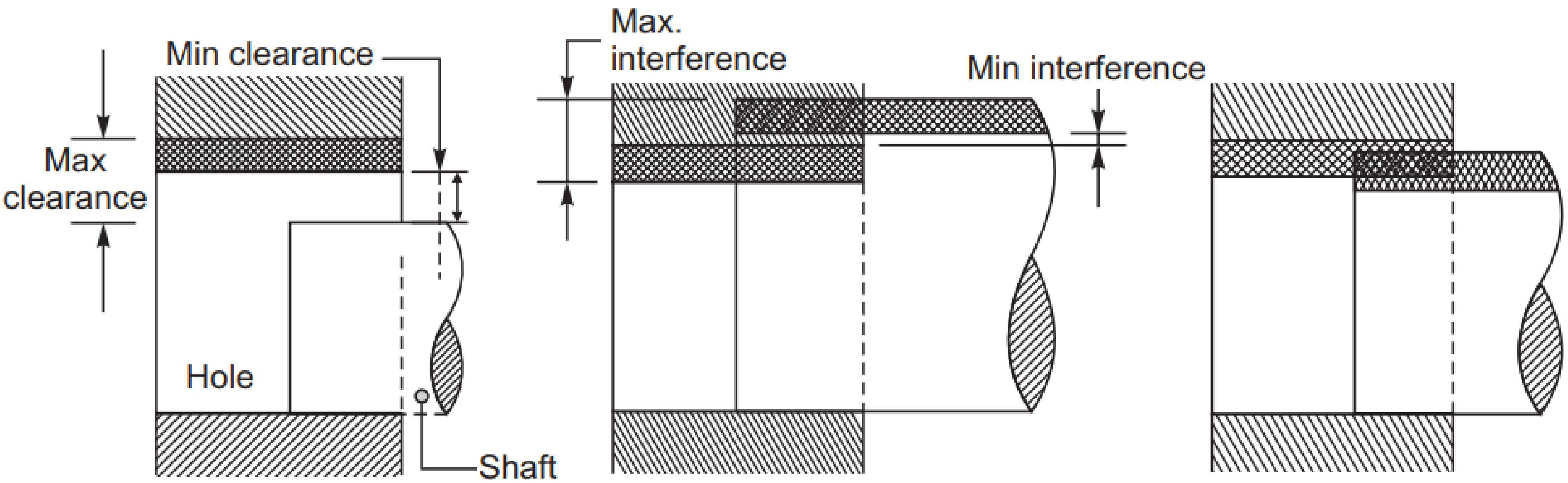


Fig. 15.9 Toleranced dimensioning of assembled parts

Fits



(a) Clearance fig.

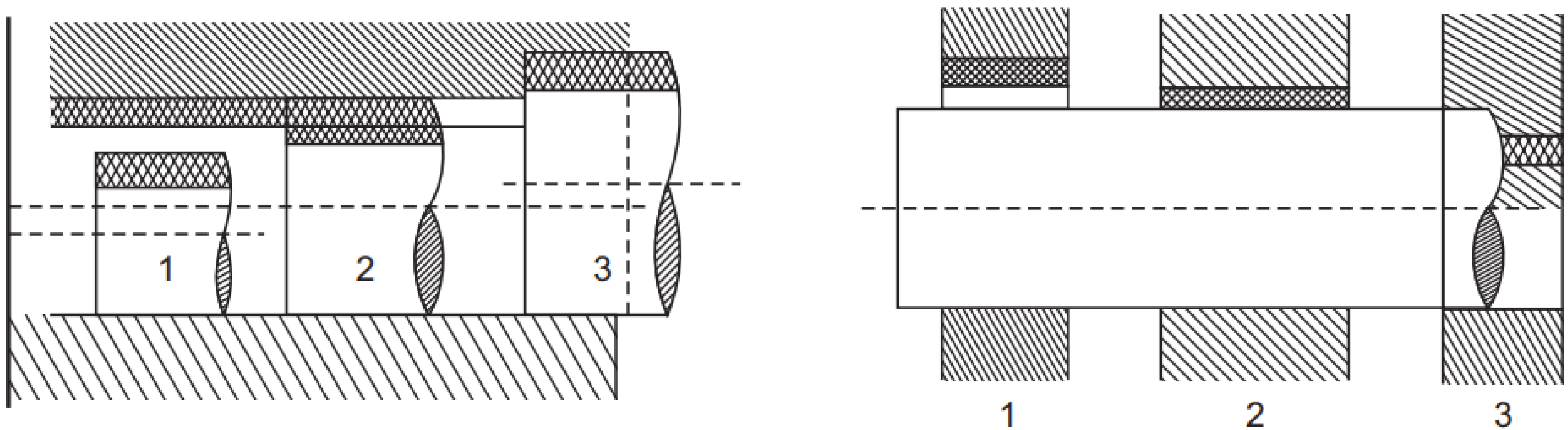
(b) Interference fits.

(c) Transition fit.

Fig. 7.8. Types of fits

Basis System

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

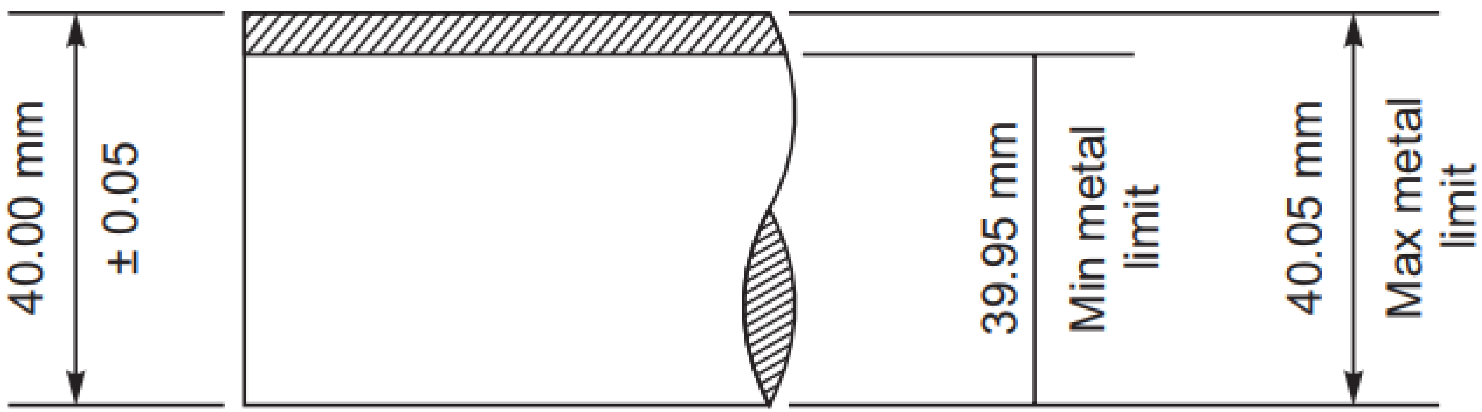


Fig. 7.11. Maximum and minimum metal limits for a shaft

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

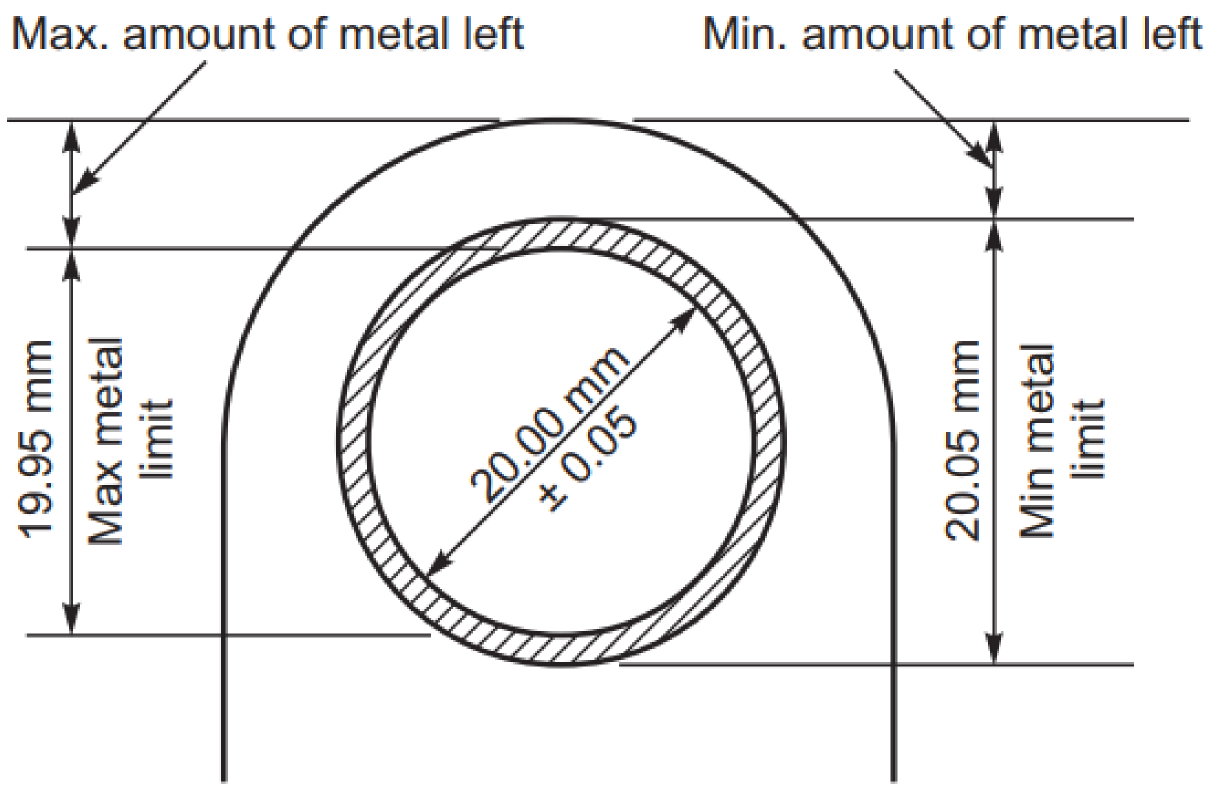


Fig. 7.12. Maximum and minimum metal limits for a hole

Selection of tolerances based on fits

Type of fit	*Symbol of fit*	*Examples of application*
Interference fit		
Shrink fit Heavy drive fit Press fit Medium press fit	H8/u8 H7/s6 H7/r6 H7/p6	Wheel sets, tyres, bronze crowns on worm wheel hubs, couplings under certain conditions, etc. Coupling on shaft ends, bearing bushes in hubs, valve seats, gear wheels.
Transition fit		
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, *e.g.*, 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, *e.g.*, pulleys, hand-wheels, bushes, bearing shells, pistons on piston rods, change gear trains.

Selection of tolerances based on fits

Clearance fit		
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.

Tolerance

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

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

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

Upper deviation (es)		*Lower deviation (ei)*	
Shaft designation	*In microns (for D in mm)*	*Shaft designation*	*In microns (For D in mm)*
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	$= +(\text{IT }7 - \text{IT }6)$
	$\approx -1.8\,D$ for $D > 160$	n	$= +5\,D^{0.34}$
		p	$= +\text{IT }7 + 0$ to 5
c	$= -52\,D^{0.2}$ for $D \leq 40$	r	= geometric mean of values *ei* for *p* and *s*
	$= -(95 + 0.8\,D)$ for $D > 40$	s	$= +\text{IT }8 + 1$ to 4 for $D \leq 50$
d	$= -16\,D^{0.44}$		$= +\text{IT }7 + 0.4\,D$ for $D > 50$
e	$= -11\,D^{0.41}$	t	$= \text{IT }7 + 0.63\,D$
f	$= -5.5\,D^{0.41}$	u	$= +\text{IT }7 + D$
g	$= -2.5\,D^{0.34}$	v	$= +\text{IT }7 + 1.25\,D$
h	$= 0$	x	$= +\text{IT }7 + 1.6\,D$
		y	$= +\text{IT }7 + 2\,D$
		z	$= +\text{IT }7 + 2.5\,D$
		za	$= +\text{IT }8 + 3.15\,D$
		zb	$= +\text{IT }9 + 4\,D$
j5 to j8	no formula	zc	$= +\text{IT }10 + 5\,D$

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

Example

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

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

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

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

Limits of tolerance for hole H7

The standard tolerance is

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

The fundamental deviation H hole is = 0

Limits of tolerance for g6 shaft

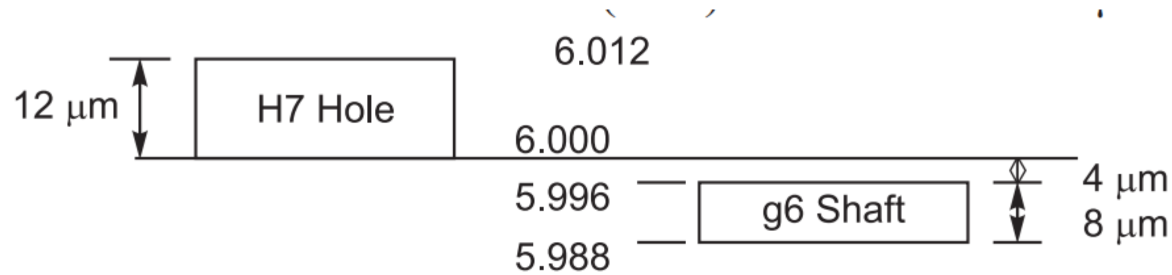
The standard tolerance is

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

Fundamental deviation for g shaft

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

Example



Disposition of tolerance zone around the zero line

Fit

Maximum clearance = Maximum size of hole – Minimum size of shaft

= 6.012 – 6.988 = 0.024 mm = 24 μm

Minimum clearance = Minimum size of hole – Maximum size of shaft

= 6.000 – 6.996 = 0.004 mm = 4 μm

Ans: The type of fit is Clearance.

Thank you !!!