4 TOLERANCES

CLASSES OF FIT AND TOLERANCED DIMENSIONS

1. **DEFINITIONS** (Fig. 6.8)

   - Nominal size or Basic size
   - Limits of size
   - Tolerance
   - Minimum Clearance
   - Maximum Clearance

2. **CLASSES OF FIT** (Fig. 6.7)

   - Definitions of the 3 classes

3. **METHODS OF TOLERANCING** (Fig. 6.9)

4. **ASSIGNMENT**

   - Based on table 6.1, select a nominal size and derive the respective hole and shaft dimensions for 3 different classes of fit.

   - Redraw Fig. 6.8 for each case and assign accordingly these dimensions.

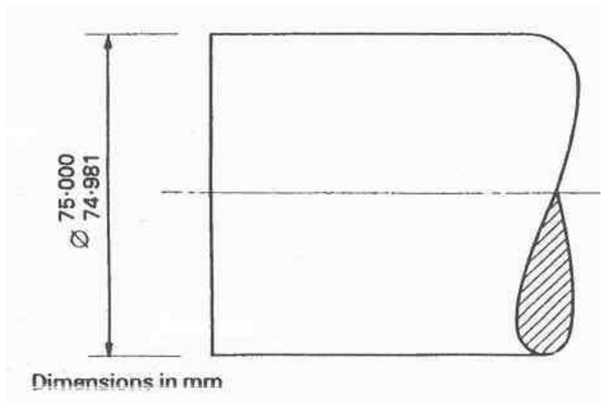
   - Determine for each case:

     a. the hole tolerance
     b. the shaft tolerance
     c. the maximum clearance
     d. the minimum clearance

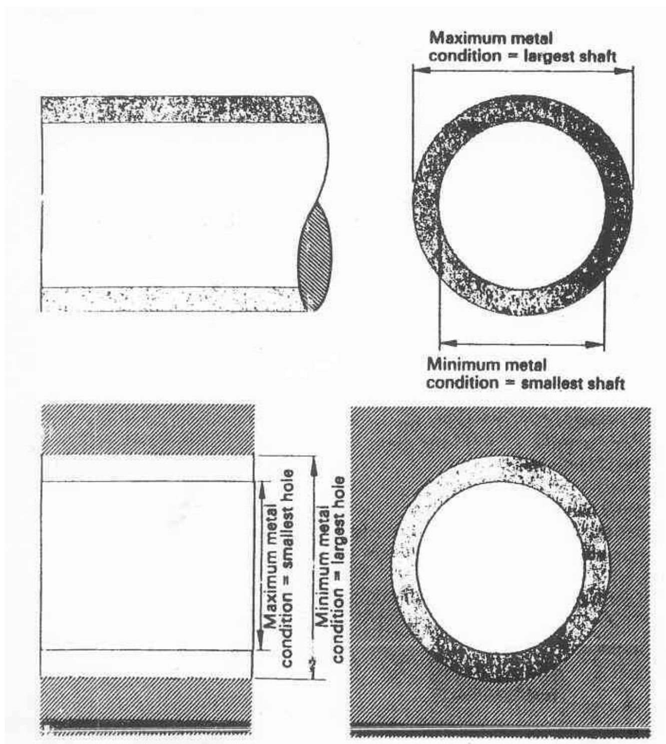
Classes of fit and Toleranced dimensioning

Accuracy of fit

Figure on the side shows a shaft which has been dimensioned so that its diameter lies between 74.981 mm and 75.000 mm. The designer has decided that any shaft lying between these sizes will function satisfactory in a given assembly. These dimensions are called limits of size and the difference between them is termed as tolerance. Toleranced dimensions are provided because is not possible to work an exact dimension.



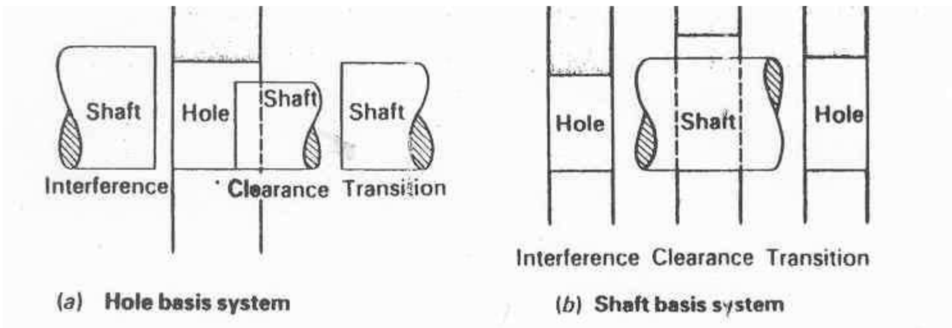
The terms maximum metal condition and minimum metal condition are often met in connection with limit systems and the gauging of work pieces. Figure below explains these terms.



The class of fit between two mating components may be obtained in two ways:

1. By having a constant size of hole and varying the diameter of the shaft to suit. This is called the hole basis system.
2. By having a constant size of shaft and varying the diameter of the hole to suit. This is called the shaft basis system.

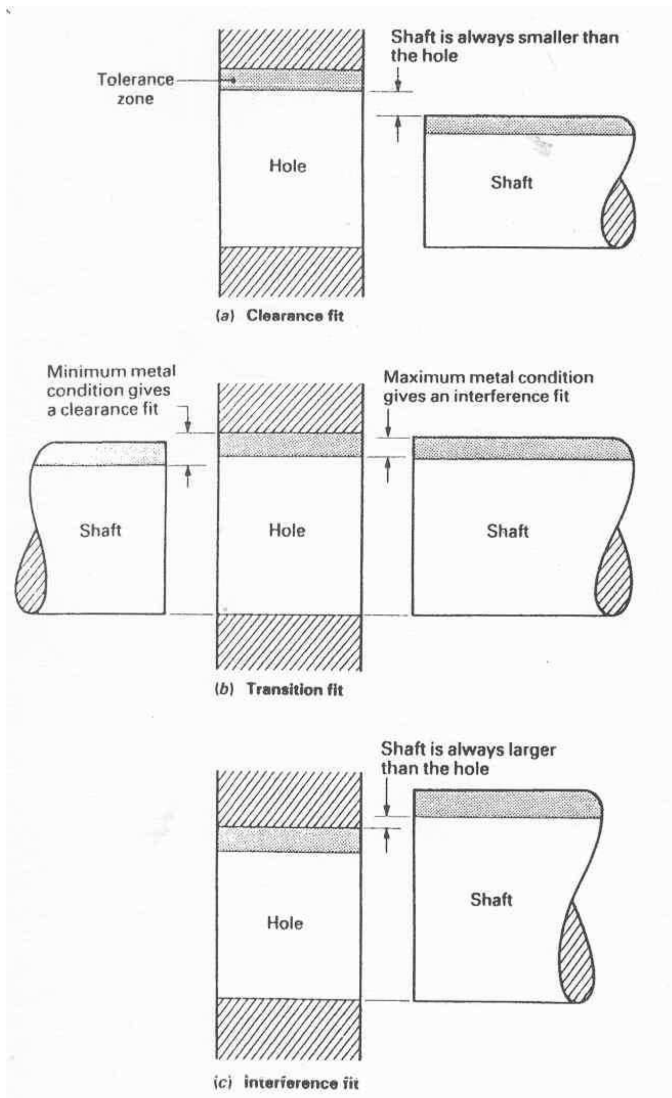
The hole basis system is the more usually employed since it is easier to maintain a standard hole size using standard drill. The shaft diameter is more easily machined to the size required by the fit during a turning or grinding operation. Figure below shows both these systems.



Clearance fit is achieved when the shaft is always smaller than the hole it is mating with, even under maximum metal conditions.

Interference fit is achieved when the shaft is always slightly larger than the hole it is mating with, even under minimum metal conditions.

Transition fits are achieved when mating shafts and holes which are within limits will give a range of fits from clearance under minimum metal conditions to interference under maximum metal conditions. The above fits are shown diagrammatically in figure at the side.



Limits of size: These are the maximum and minimum sizes between which it is permissible to manufacture a given work piece if it is to function correctly.

Tolerance: This is the algebraic difference between the upper and lower limits of size. Its magnitude and disposition is determined by the functional needs of the component and the economics of production. Generally, it can be assumed that the smaller the tolerance, the more costly will be the production process to achieve that tolerance.

Minimum clearance: This used to be known as the 'allowance' and is the arithmetical difference between the maximum metal condition of the shaft and the maximum metal condition of the hole, that is, the largest shaft and the smallest hole giving the 'tightest' fit which will function correctly. Figure 6.8 below shows how these terms are applied to a shaft and hole assembly.

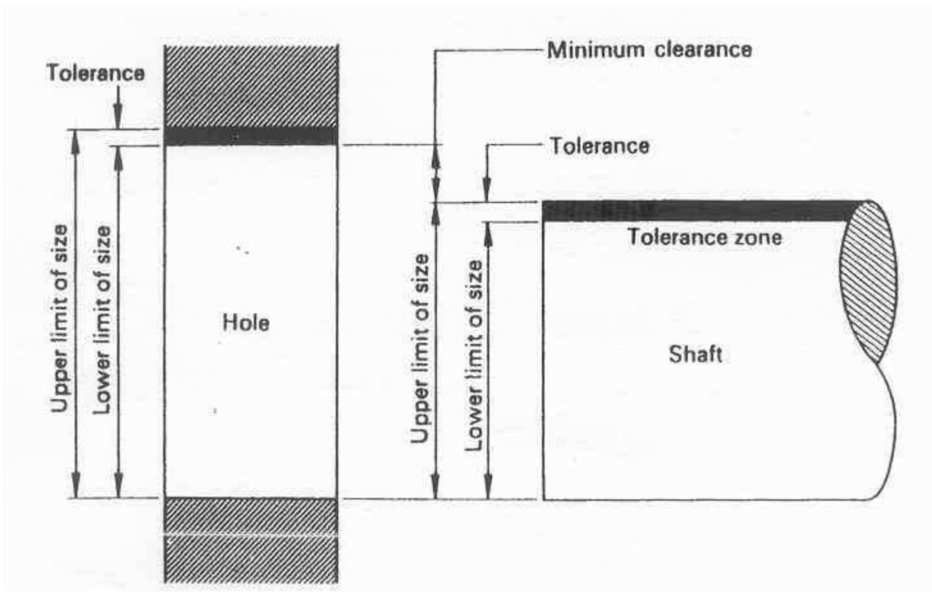


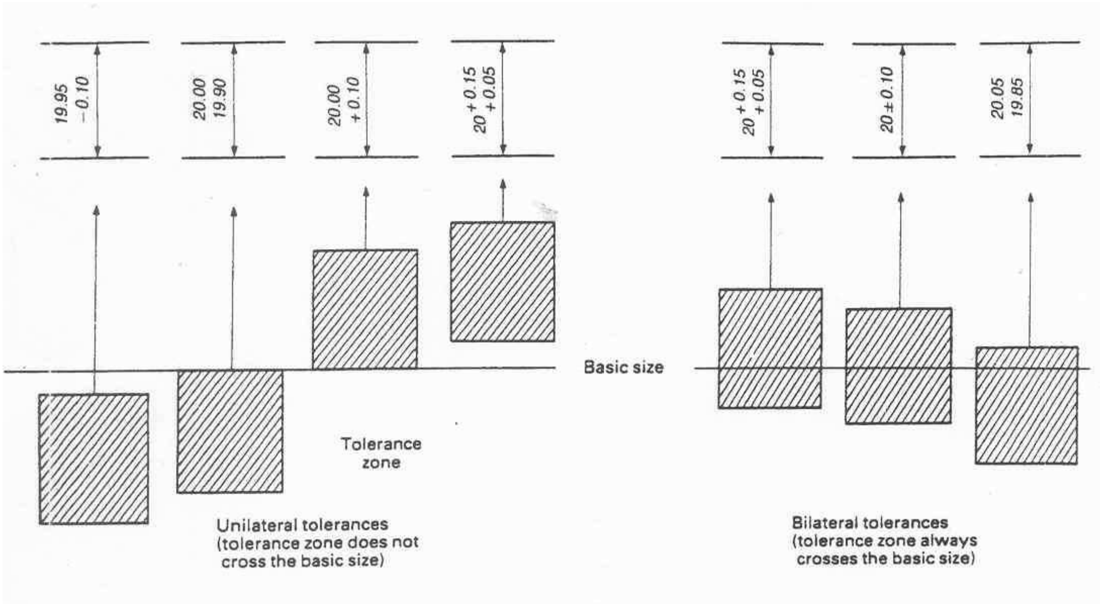
Fig. 6.8 Limit systems - definitions

The actual size of a component feature is the measured size correctly to 20°C. Figure shown in next page shows how tolerances are applied lo the basic size, together with alternative methods of dimensioning.

Unilateral tolerances are those where the tolerance zones lie to one side only of the basic size.

Bilateral tolerances are those where the tolerance zones cross the basic size. In all the examples shown the basic size is 20.00 mm'.

As dimensional tolerances get smaller and the precision of components becomes greater to satisfy present day quality requirements and facilitate assembly, geometrical tolerancing also becomes of importance.

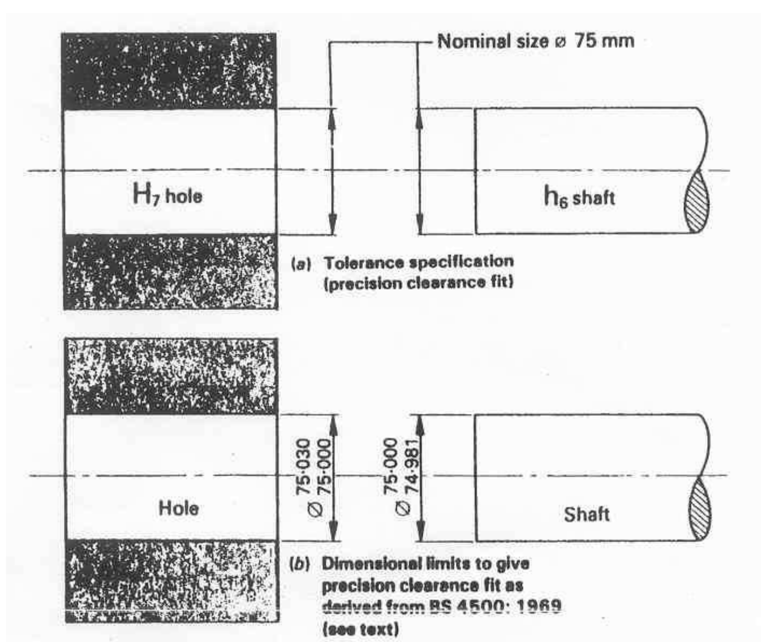


Standard Systems of limits and fits

This section is based upon BS4500 - Limits and Fits (Metric Units), which is suitable for all classes of work from the finest instruments to heavy engineering. It allows for the size of the work, the type of work, and provides for both hole basis and shaft basis systems as required.

The tables provide for twenty-eight types of shaft designated by lower- case letters, a, b, c, etc., and twenty-eight types of hole designated by upper-case (capital) letters A, B, C, etc. To each type of shaft or hole the grade of tolerance is designated by a number 01,0,1,2 ... 16, thus giving eighteen grades of tolerance in all.

The letter indicates the position of the tolerance relative to the basic size and is called the fundamental deviation size and is called the fundamental deviation. The number indicates the magnitude of the tolerance and is called the fundamental tolerance. A shaft is completely defined by its basic size, letter and number, for example: 75 mm h6. Similarly a hole is completely defined by its basic size, letter and number: for example: 75 mm H7. Figure (a) right shows how a precision clearance fit is



specified by using a 75 mm H7/h6 hole and shaft combination. Table on next page shows the primary selection of limits and fits for a wide range of hole and shaft combinations for a variety of applications and is used as follows.

(a) Hole. Enter the table along diameter band 50 mm to 80 mm, and where this band crosses the column H7 the limits are given as + 30 and +0. These dimensions are in units of 0.001 mm Therefore, when applied to a basic size of 75 mm, they give working limits of 75.030 mm and 75.000 mm as shown in Fig. 6.10(b) in previous page.

(b) Shaft. Enter the table along diameter band 50 mm to 80 mm, and where this band crosses the column h6 the limits are given as - 0 and - 19. Again these dimensions are in units of 0.001 mm. Therefore, when applied to a basic size of 75 mm, they give working limits of 75.000 mm and 74.981 mm as shown in Fig. 6.10(b) in previous page.

Table 6.1 Primary selection of fits – Abstract from BS4500

Normal sizes		Loose clearance		Average clearance		Close clearance		Precision clearance		Transition		Inter-ference	
Over mm	Up to mm	H9	e9	H8	f7	H7	g6	H7	h6	H7	k6	H7	p6
—	3	+25	−14	+14	−6	+10	−2	+10	−0	+10	+6	+10	+12
		+0	−39	+0	−16	+0	−8	+0	−6	+0	+0	+0	+6
3	6	+30	−20	+18	−10	+12	−4	+12	−0	+12	+9	+12	+20
		+0	−50	+0	−22	+0	−12	+0	−8	+0	+1	+0	+12
6	10	+36	−25	+22	−13	+15	−5	+15	−0	+15	+10	+15	+24
		+0	−61	+0	−28	+0	−14	+0	−9	+0	+1	+0	+15
10	18	+43	−32	+27	−16	+18	−6	+18	−0	+18	+12	+18	+29
		+0	−75	+0	−34	+0	−17	+0	−11	+0	+1	+0	+18
18	30	+52	−40	+33	−20	+21	−7	+21	−0	+21	+15	+21	+35
		+0	−92	+0	−41	+0	−20	+0	−13	+0	+2	+	+22
30	50	+62	−50	+39	−25	+25	−9	+25	−0	+25	+18	+25	+42
		+0	−112	+0	−50	+0	−25	+0	−16	+0	+2	+0	+26
50	80	+74	−60	+46	−30	+30	−10	+30	−0	+30	+21	+30	+51
		+0	−134	+0	−60	+0	−29	+0	−19	+0	+2	+0	+32
80	120	+87	−72	+54	−36	+35	−12	+35	−0	+35	+25	+35	+59
		+0	−159	+0	−71	+0	−34	+0	−22	+0	+3	+0	+37
120	180	+100	−85	+63	−43	+40	−14	+40	−0	+40	+28	+40	+68
		+	−185	+0	−83	+0	−39	+0	−25	+0	+3	+0	+43
180	250	+115	−100	+72	−50	+46	−15	+46	−0	+46	+33	+46	+79
		+0	−215	+0	−96	+0	−44	+0	−29	+0	+4	+0	+50
250	315	+130	−110	+81	−56	+52	−17	+52	−0	+52	+36	+52	+88
		+0	−240	+0	−108	+0	−49	+0	−32	+0	+4	+0	+56
315	400	+140	−125	+89	−62	+57	−18	+57	−0	+57	+40	+57	+98
		+0	−265	+0	−119	+0	−54	+0	−36	+0	+4	+0	+62
400	500	+155	−135	+97	−68	+63	−20	+63	−0	+63	+45	+63	+108
		+0	−290	+0	−131	+0	−60	+0	−40	+0	+5	+0	+68

Example 6.1 *Derive the dimensions for a hole and shaft of nominal diameter 40 mm so that an average clearance fit is obtained.*

Since the nominal size of the shaft/hole is 40 mm, Table 6.1 is entered at the 30–50 mm band. The following conditions then apply:

Nominal size	H8	f7
30–50 mm	+39 +0	−25 −50

tolerance unit 0·001 mm.

Hole diameter: (upper limit) $40 + 0{\cdot}039 = 40{\cdot}039$ mm
(lower limit) $40 + 0{\cdot}000 = 40{\cdot}000$ mm

Shaft diameter: (upper limit) $40 - 0{\cdot}025 = 39{\cdot}975$ mm
(lower limit) $40 - 0{\cdot}050 = 39{\cdot}950$ mm

Since only an *average clearance fit* is required, there is no benefit in working to an accuracy of three decimal places. The designer would use his experience and reduce the cost of manufacture by rounding off the limits to:

Hole diameter: (upper limit) = 40·04 mm
(lower limit) = 40·00 mm

Shaft diameter: (upper limit) = 39·98 mm
(lower limit) = 39·95 mm

Other information that can be obtained from the above dimensions:

Hole tolerance = 40·04 − 40·00 = <u>0·04 mm</u>

Shaft tolerance = 39·98 − 39·95 = <u>0·03 mm</u>

Maximum clearance = 40·04 − 39·95 = <u>0·09 mm</u>

(largest hole − smallest shaft)

Minimum clearance = 40·00 − 39·98 = <u>0·02 mm</u>

(smallest hole − largest shaft)

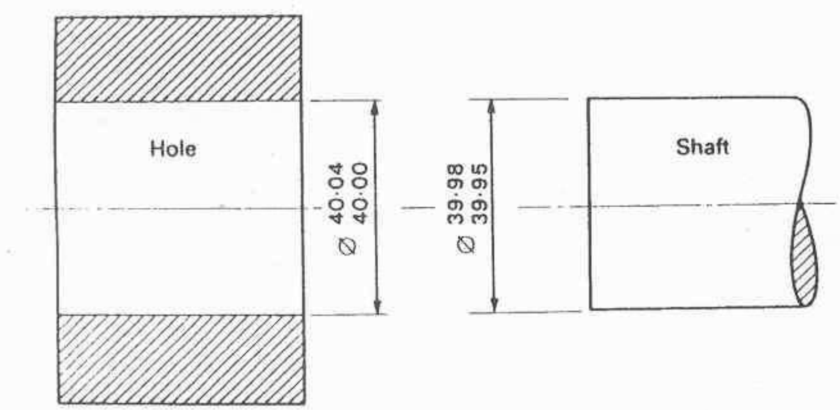


Fig. 6.11 Average clearance fit – toleranced dimensions