Engineering Communication

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Dimension Tolerances

Tolerances

important to interchangeability and provision for replacement parts

It is impossible to make parts to an exact size.

The tolerance, or accuracy required, will depend on the function of the part and the particular feature being dimensioned.

Therefore, the range of permissible size, or tolerance, must be specified for all dimensions on a drawing, by the designer/draftsperson.

Nominal Size: is the size used for general identification, not the exact size.

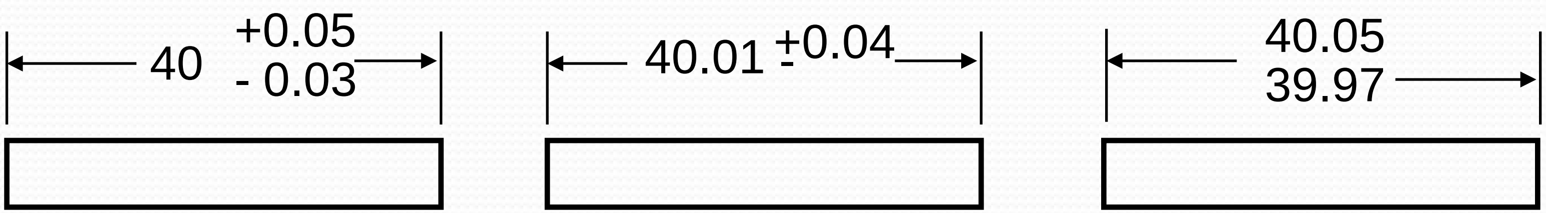
Actual Size: is the measured dimension. A shaft of nominal diameter 10 mm may be measured to be an actual size of 9.975 mm.

General Tolerances:
In ISO metric, general tolerances are specified in a note, usually in the title block, typically of the form: "General tolerances ±.25 unless otherwise stated".

Specific Tolerances

Specific Tolerances indicate a special situation that cannot be covered by the general tolerance.

Specific tolerances are placed on the drawing with the dimension and have traditionally been expressed in a number of ways:



Bilateral Tolerance *Unilateral Tolerance* *Limit Dimensions*

Limits are the maximum and minimum sizes permitted by the the tolerance.

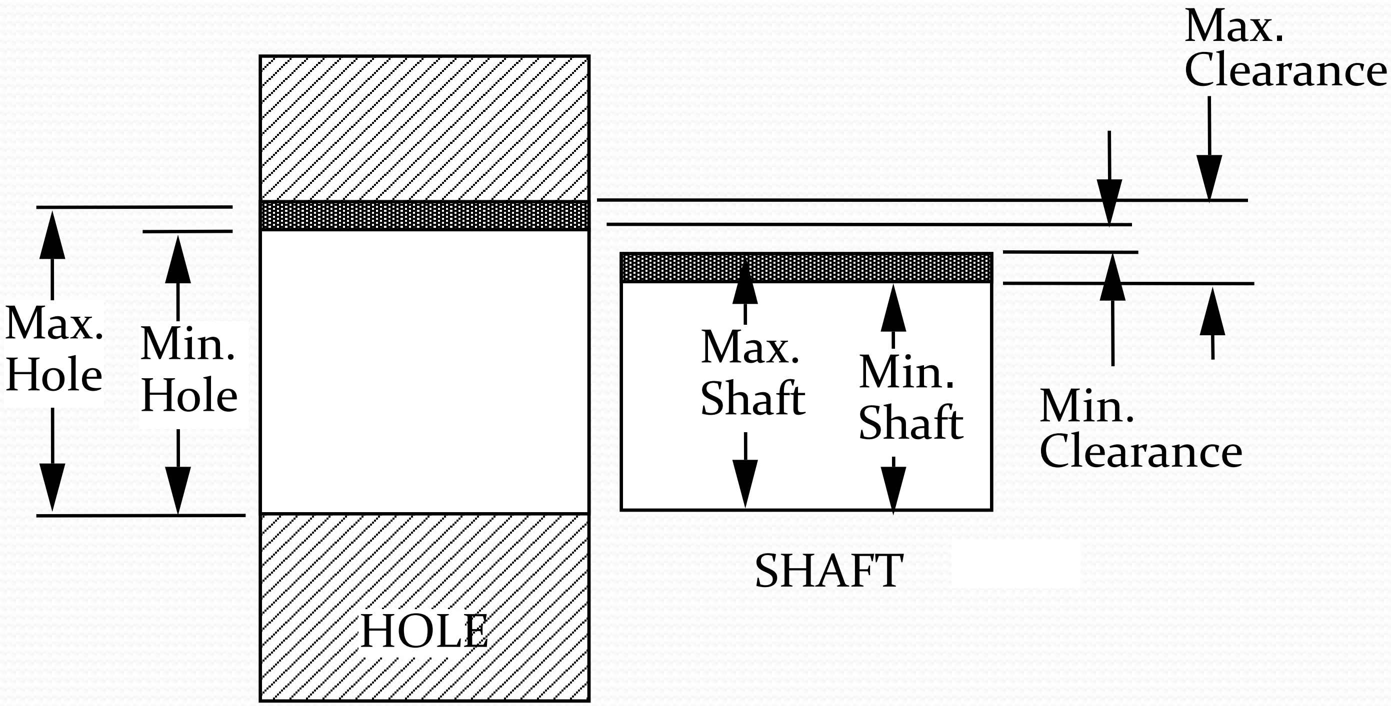
All of the above methods show that the dimension has:
a Lower Limit = 39.97 mm
an Upper Limit = 40.05 mm
a Tolerance = 0.08 mm

Manufacturing must ensure that the dimensions are kept within the limits specified. Design must not over specify as tolerances have an exponential affect on cost.

Limits and Fits

1. <u>Clearance Fits</u>

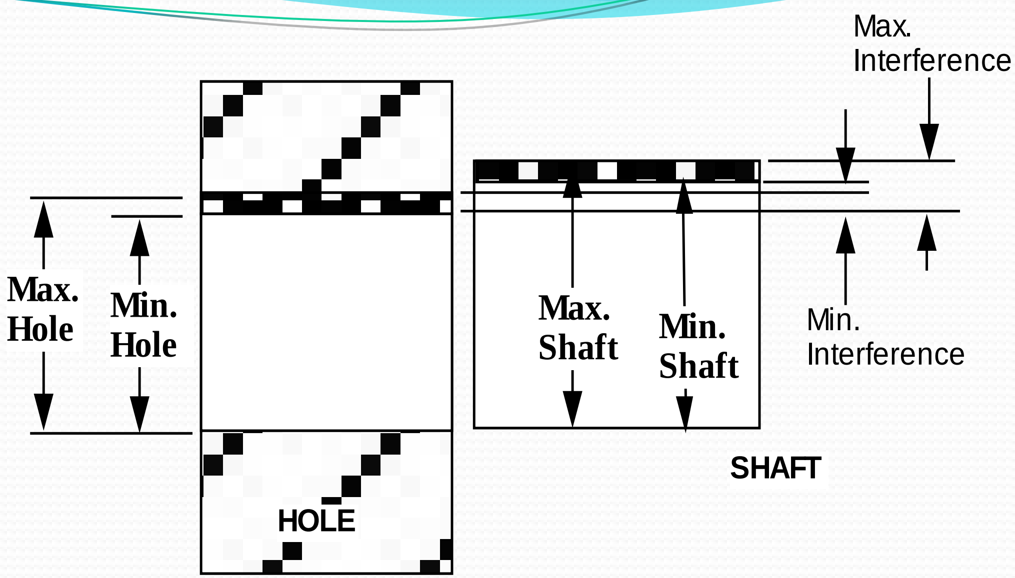
The largest permitted shaft diameter is smaller than the diameter of the smallest hole



Limits and Fits

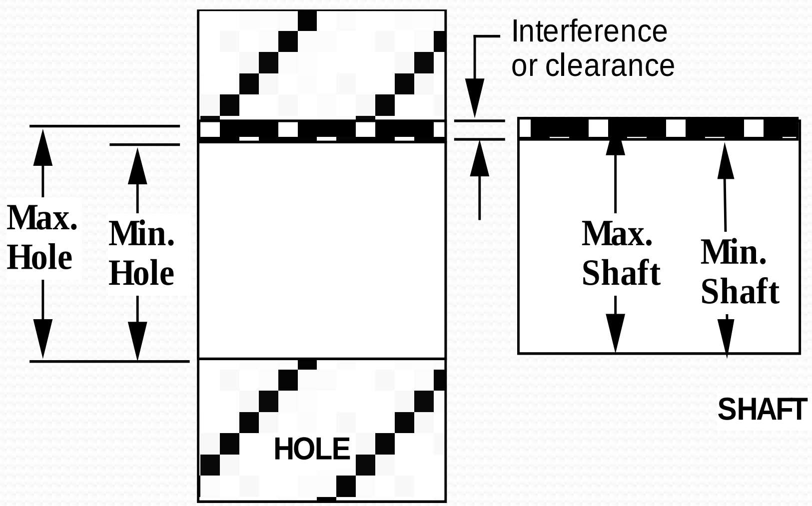
2. Interference Fits

The minimum permitted diameter of the shaft is larger than the maximum diameter of the hole



3. Transition Fits

The diameter of the largest allowable hole is greater than that of the smallest shaft, but the smallest hole is smaller than the largest shaft



ISO Tolerance Designation

The ISO system provides for:

- 21 types of holes (standard tolerances) designated by uppercase letters A, B, C, D, E....etc. and
- 21 types of shafts designated by the lower case letters a, b, c, d, e...etc.

These letters define the position of the tolerance zone relative to the nominal size. To each of these types of hole or shaft are applied 16 **grades of tolerance**, designated by numbers IT1 to IT16 - the "Fundamental Tolerances":

$$IT_n = (0.45 \times D^{0.33} + 0.001\, D)\, P_n$$

where D is the mean of the range of diameters and P_n is the progression: 1, 1.6, 2.5, 4.0, 6.0, 10, 16, 25......etc. which makes each tolerance grade approximately 60% of its predecessor.

Example

Experience has shown that the dimensional accuracy of manufactured parts is approximately proportional to the cube root of the size of the part.

<u>Example:</u>

A hole is specified as: $\Phi 30$ H7

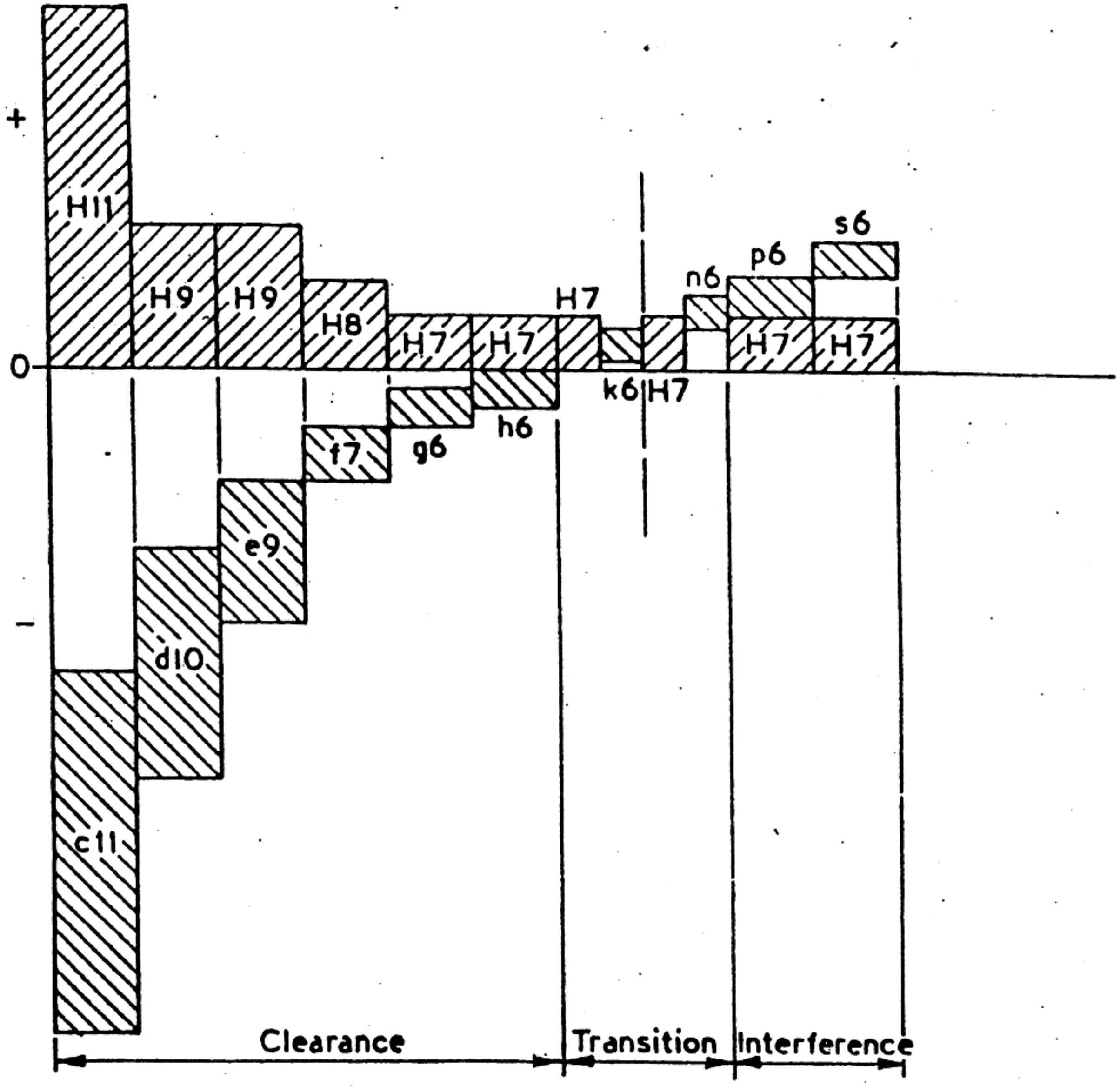
The H class of holes has limits of $\begin{matrix} +x \\ +0 \end{matrix}$. i.e. all tolerances start at the nominal size and go positive by the amount designated by the IT number.

IT7 for diameters ranging 30- 50 mm:

Tolerance for IT7 = $(0.45 \times 40^{0.3} + 0.001 \times 40) \times 16 = 0.025$ mm

Written on a drawing as $\phi 30\ H7 \begin{pmatrix} +0.025 \\ +0 \end{pmatrix}$

Graphical illustration of ISO standard fits



Hole Series – H hole Standard

Selection of Fits

From the above it will be realized that there are a very large number of combinations of hole deviation and tolerance with shaft deviation and tolerance. However, a given manufacturing organization will require a number of different types of fit ranging from tight drive fits to light running fits for bearings etc. Such a series of fits may be obtained using one of two ISO standard systems:

The Shaft Basis System

For a given nominal size a series of fits is arranged for a given nominal size using a standard shaft and varying the limits on the hole.

The Hole Basis System

For a given nominal size, the limits on the hole are kept constant, and a series of fits are obtained by only varying the limits on the shaft.

The HOLE SYSTEM is commonly used because holes are more difficult to produce to a given size and are more difficult to inspect. The H series (lower limit at nominal, 0.00) is typically used and standard tooling (e.g. H7 reamers) and gauges are common for this standard.

Clearance Fits ISO Standard "Hole Basis"

Type of Fit	Hole	Shaft
Loose Running Fits . Suitable for loose pulleys and the looser fastener fits where freedom of assembly is of prime importance	H11	c11
Free Running Fit. Where accuracy is not essential, but good for large temperature variation, high running speeds, heavy journal pressures	H9	d10
Close Running Fit. Suitable for lubricated bearing, greater accuracy, accurate location, where no substantial temperature difference is encountered.	H8	f7
Sliding Fits . Suitable for precision location fits. Shafts are expensive to manufacture since the clearances are small and they are not recommended for running fits except in precision equipment where the shaft loadings are very light.	H7	g6
Locational Clearance Fits . Provides snug fit for locating stationary parts; but can be freely assembled and disassembled.	H7	h6

Transition Fits ISO Standard "Hole Basis"

Type of Fit	Hole	Shaft
Locational Transition Fits . for accurate location, a compromise between clearance and interference	H7	k6
Push Fits . Transition fits averaging little or no clearance and are recommended for location fits where a slight interferance can be tolerated for the purpose, for example, of eliminating vibration.	H7	n6

Interference Fits ISO Standard "Hole Basis"

Type of Fit	Hole	Shaft
Press Fit. Suitable as the standard press fit into ferrous, i.e. steel, cast iron etc., assemblies.	H7	p6
Drive Fit Suitable as press fits in material of low modulus of elasticity such as light alloys.	H7	s6

Comparative Roughness Values

Roughness Ra	Typical Processes
25 µm (1000 µ")	*Flame Cutting*
12.5 µm (500µ")	*Sawing*, sand casting,
6.3 µm (250µ")	*forging,* shaping, planing
3.2 µm (125µ")	*Rough machining*, milling, rough turning, drilling, die casting
1.6 µm (63µ")	*Machining*, turning, milling, die and investment casting, injection molding, and stamping
0.8 µm (32µ")	*Grinding*, fine turning & milling, reaming, honing, injection molding, stamping, investment casting
0.4 µm (16µ")	*Diamond Turning*, Grinding, lapping, honing
0.2 µm (8µ")	*Lapping*, honing, polishing
0.1 µm (4µ")	*Superfinishing*, polishing, lapping