UNIT 3 FIT AND TOLERANCES

Structure

3.1 INTRODUCTION

In the early days, majority of the components were actually matted together, their dimensions being adjusted until the required type of fit was obtained. But with the passage of time, engineers and workers realized that the variations in the sizes of the parts had always present and that such variations could be restricted but not avoided. It has also been realized that exact size components are difficult to produce. Any attempt towards very closed dimensions of a product will increase cost of the production. The functional aspects of the component may be achieved even without going for its exact dimensions using limits, fit and tolerances. This reduces the unit cost of production and increases the rate of production.

For example, a shaft of exact 10.00 mm diameter is difficult to produce by machining process. But if you provide tolerence, i.e. the amount of variation permitted in the size, then such parts can be easily produced. A dimension 10 ± 0.05 means a shaft may be produced between 10.05 and 9.95. These two figures represent limit and the difference, $(10.05 - 9.95) = 0.10$ is called tolerence.

Objectives

After studying this unit, you should be able to

- understand the basic principles of fits and tolerances,
- explain various types of fits and their applications,
- analyse the various types of tolerances and applications, and
- know the fundamental of the systems of fits.

3.2 FITS AND THEIR CLASSIFICATIONS

When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a fit. A fit may be defined as the degree of tightness and looseness between two mating parts.

The important terms related to the fit are given below :

Clearance

In a fit, this is the difference between the sizes of the hole and the shaft, before assembly, when this difference is positive. The clearance may be maximum clearance and minimum clearance. Minimum clearance in the fit is the difference between the maximum size of the hole and the minimum size of the shaft.

Interference

It is the difference between the sizes of the hole and the shaft before assembly, when the difference is negative. The interference may be maximum or minimum. Maximum interference is arithmetical difference between the minimum size of the hole and the maximum size of the shaft before assembly. Minimum interference is the difference between the maximum size of the hole and the minimum size of the shaft.

Transition

It is between clearance and interference, where the tolerence zones of the holes and shaft overlap.

So, you can see that fits depend upon the actual limits of the hole and or shaft and can be divided into three general classes :

(i) Clearance Fit.

(ii) Interference Fit.

(iii) Transition Fit.

3.2.1 Clearance Fit

In clearance fit, an air space or clearance exists between the shaft and hole as shown in Figure 3.1. Such fits give loose joint. A clearance fit has positive allowance, i.e. there is minimum positive clearance between high limit of the shaft and low limit of the hole.

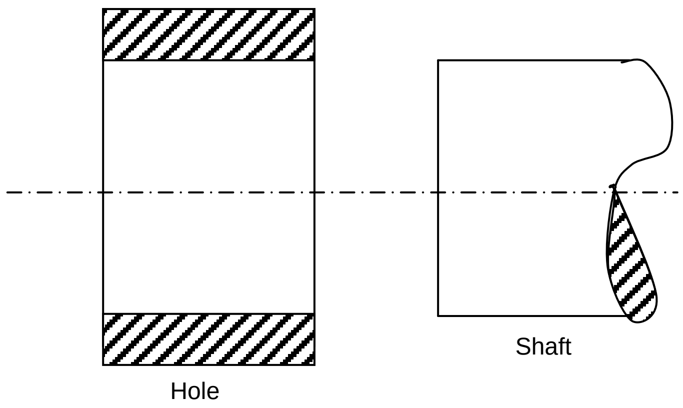

Figure 3.1 : Clearance Fit

Clearance fit can be sub-classified as follows :

Loose Fit

It is used between those mating parts where no precision is required. It provides minimum allowance and is used on loose pulleys, agricultural machineries etc.

Running Fit

For a running fit, the dimension of shaft should be smaller enough to maintain a film of oil for lubrication. It is used in bearing pair etc. An allowance 0.025 mm per 25 mm of diameter of boaring may be used.

Slide Fit or Medium Fit

It is used on those mating parts where great precision is required. It provides medium allowance and is used in tool slides, slide valve, automobile parts, etc.

Example 3.1

A spindle slides freely in a bush. The basic size of the fit is 50×10^{-3} mm. If the tolerances quoted are $\begin{matrix} +62 \\ 0 \end{matrix}$ for the holes and $\begin{matrix} -80 \\ -180 \end{matrix}$ for the shaft, find the upper limit and lower limit of the shaft and the minimum clearance.

Solution

Tolerances are given in units of one thousandth of millimeter, so the upper limit of the hole will be 50.062 mm and lower limit for the hole is the same as the basic size of 50.000 mm.

The shaft upper limit will be $(50.000 - 0.080) \times 10^{-3} = 49.92 \times 10^{-3}$ m

The shaft lower limit will be $(50.000 - 0.180) \times 10^{-3} = 49.82 \times 10^{-3}$ m

The minimum clearance or allowance is $(50.000 - 49.920) \times 10^{-3} = 8 \times 10^{-5}$ mm.

3.2.2 Interference Fit

A negative difference between diameter of the hole and the shaft is called interference. In such cases, the diameter of the shaft is always larger than the hole diameter. In Figure 3.2. Interference fit has a negative allowance, i.e. interference exists between the high limit of hole and low limit of the shaft.

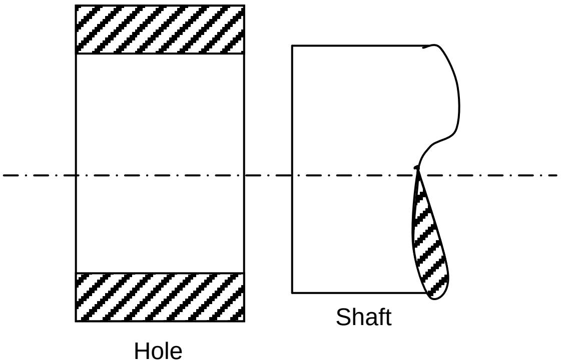

Figure 3.2 : Interference Fit

In such a fit, the tolerance zone of the hole is always below that of the shaft. The shaft is assembled by pressure or heat expansion.

The interference fit can be sub-classified as follows :

Shrink Fit or Heavy Force Fit

It refers to maximum negative allowance. In assembly of the hole and the shaft, the hole is expanded by heating and then rapidly cooled in its position. It is used in fitting of rims etc.

Medium Force Fit

These fits have medium negative allowance. Considerable pressure is required to assemble the hole and the shaft. It is used in car wheels, armature of dynamos etc.

Tight Fit or Press Fit

One part can be assembled into the other with a hand hammer or by light pressure. A slight negative allowance exists between two mating parts (more than wringing fit). It gives a semi-permanent fit and is used on a keyed pulley and shaft, rocker arm, etc.

Example 3.2

A dowel pin is required to be inserted in a base. For this application H 7 fit for hole and a p 6 fit for the shaft are chosen. The tolerance quoted are $\begin{matrix} +25 \\ 0 \end{matrix}$ for the hole and $\begin{matrix} +42 \\ 26 \end{matrix}$ for the shaft. Find the upper and lower limits of the hole and also dowel pin, and the maximum interference between dowel pin and the hole. The basic size of the fit is 50×10^{-3} m.

Solution

The upper limit for the hole will be $(50.000 + 0.025) \times 10^{-3} = 50.025 \times 10^{-3}$ m

The lower limit for the hole will be $(50.000 + 0)\ 50.000 \times 10^{-3} = 50 \times 10^{-3}$ m

The upper limit for dowel pin will be $(50.000 + 0.042) \times 10^{-3} = 50.042 \times 10^{-3}$ m

The lower limit for dowel pin will be $(50.000 + 0.026) \times 10^{-3} = 50.026 \times 10^{-3}$ mm

The maximum interference between dowel pin and the hole is
$(50.042 - 50.000) \times 10^{-3} = 0.042 \times 10^{-3}$ m $= 42 \times 10^{-6}$ m.

3.2.3 Transition Fit

It may result in either clearance fit or interference fit depending on the actual value of the individual tolerances of the mating components. Transition fits are a compromise between clearance and interference fits. They are used for applications where accurate location is important but either a small amount of clearance or interference is permissible. As shown in Figure 3.3, there is overlapping of tolerance zones of the hole and shaft.

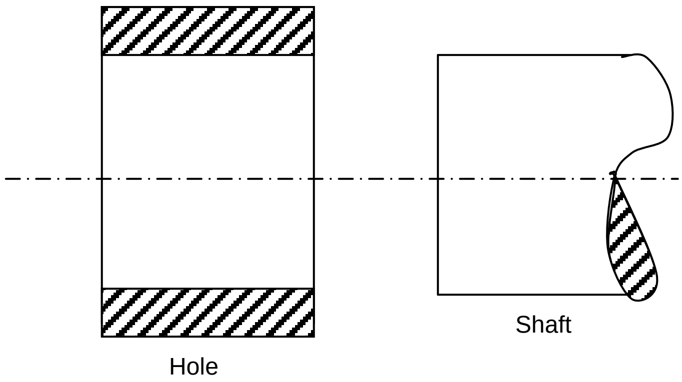

Figure 3.3 : Transition Fit

Transition fit can be sub-classified as follows :

Push Fit

It refers to zero allowance and a light pressure (10 cating dowels, pins, etc.) is required in assembling the hole and the shaft. The moving parts show least vibration with this type of fit. It is also known as **snug fit**.

Force Fit or Shrink Fit

A force fit is used when the two mating parts are to be rigidly fixed so that one cannot move without the other. It either requires high pressure to force the shaft into the hole or the hole to be expanded by heating. It is used in railway wheels, etc.

Wringing Fit

A slight negative allowance exists between two mating parts in wringing fit. It requires pressure to force the shaft into the hole and gives a light assembly. It is used in fixing keys, pins, etc.

Example 3.3

For a particular application, an H 7 fit has been selected for the hole and a K 6 fit for the shaft. The tolerance quoted are $\begin{matrix} +25 \\ 0 \end{matrix}$ for the hole and $\begin{matrix} +18 \\ 12 \end{matrix}$ for the shaft.

Find the upper limit and lower limit for the hole and also for bush. The basic size of fit is 50×10^{-3} m.

Solution

The upper limit for the hole will be $(50.000 + 0.025) \times 10^{-3} = 50.025 \times 10^{-3}$ m.

The lower limit for the hole will be $(50.000 + 0) \times 10^{-3} = 50.000 \times 10^{-3}$ m.

The upper limit for the bush will be $(50.000 + 0.018) \times 10^{-3} = 50.018 \times 10^{-3}$ m.

The lower limit for the bush will be $(50.000 + 0.002) \times 10^{-3} = 50.002 \times 10^{-3}$ m.

3.3 SYSTEMS OF FIT

A fit system is the systems of standard allowance to suit specific range of basic size. If these standard allowances are selected properly and assigned in mating parts ensures specific classes of fit.

There are two systems of fit for obtaining clearance, interference or transition fit. These are :

(i) Hole basis system (Figure 3.4)

(ii) Shaft basis system (Figure 3.5)

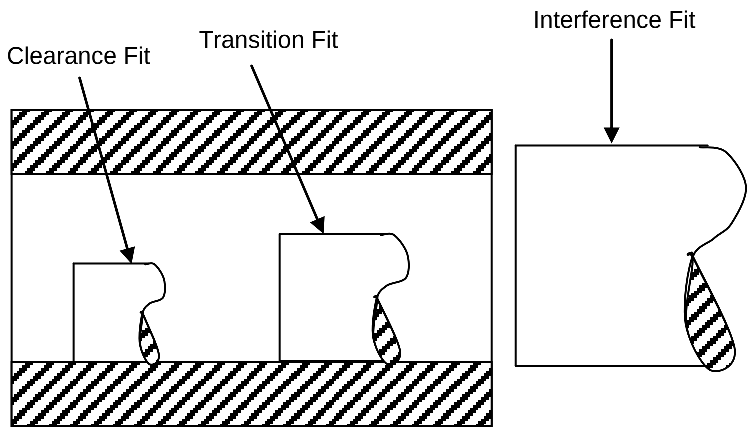

Figure 3.4 : Hole Basis System

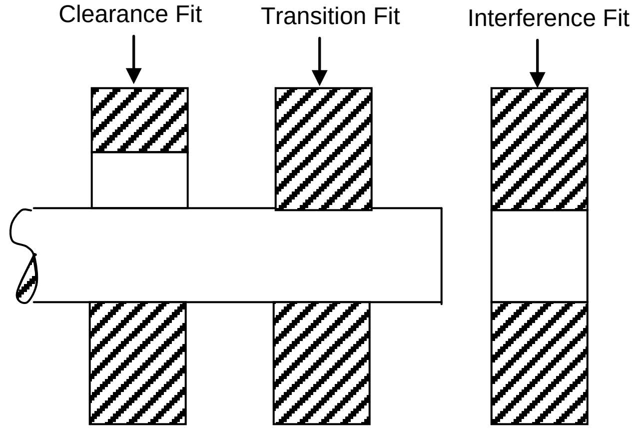

Figure 3.5 : Shaft Basis System

Hole Basis System

In the hole basis system, the size of the hole is kept constant and shaft sizes are varied to obtain various types of fits.

In this system, lower deviation of hole is zero, i.e. the low limit of hole is same as basic size. The high limit of the hole and the two limits of size for the shaft are then varied to give desired type of fit.

The hole basis system is commonly used because it is more convenient to make correct holes of fixed sizes, since the standard drills, taps, reamers and branches etc. are available for producing holes and their sizes are not adjustable. On the other hand, size of the shaft produced by turning, grinding, etc. can be very easily varied.

Shaft Basis System

In the shaft basis system, the size of the shaft is kept constant and different fits are obtained by varying the size of the hole. Shaft basis system is used when the ground bars or drawn bars are readily available. These bars do not require further machining and fits are obtained by varying the sizes of the hole.

In this system, the upper deviation (fundamental deviation) of shaft is zero, i.e. the high limit of the shaft is same as basic size and the various fits are obtained by varying the low limit of shaft and both the limits of the hole.

SAQ 1

(a) What is a fit?

(b) What is the difference between clearance and interference?

(c) Mention the applications of clearance, interference and transitions fits.

(d) Which of the following are clearance, transition and interference fits?

  (i) Push fit,

  (ii) Wringing fit,

  (iii) Force fit, and

  (iv) Slide fit.

(e) Differentiate between 'Hole basis system' and 'Shaft basis system'.

(f) A clearance fit is required between the mating parts with hole, specified as $25^{+0.04}_{-0.00}$ mm and shaft $25^{-0.02}_{-0.04}$ mm.

Find maximum and minimum permissible size of the hole and also for the shaft.

3.4 TOLERANCE AND ITS CLASSIFICATION

The permissible variation in size or dimension is tolerance. Thus, the word tolerance indicates that a worker is not expected to produce the part of the exact size, but definite a small size error is permitted. The difference between the upper limit (high limit) and the lower limit of a dimension represents the margin for variation to workmanship, and is called a tolerance zone (Figure 3.6).

Tolerance can also be defined as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functional trouble, when assembled with its mating part and put into actual service.

Example 3.4

A shaft of 25 mm basic size is given as 25 ± 0.02 mm. Find the tolerance.

Solution

The maximum permissible size (upper limit) = 25.02 mm and the minimum permissible size (lower limit) = 24.98 mm

Then, Tolerance = Upper Limit – Lower Limit

$$= 25.02 - 24.98$$

$$= 0.04 \text{ mm} = 4 \times 10^{-5} \text{ m}$$

There are two ways of writing tolerances

(a) Unilateral tolerance

(b) Bilateral tolerance.

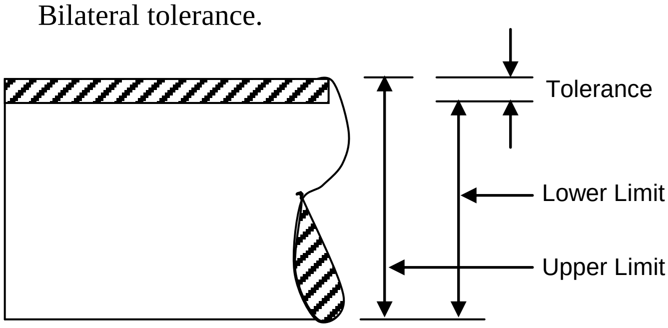

Figure 3.6 : Tolerance

3.4.1 Unilateral Tolerance

In this system, the dimension of a part is allowed to vary only on one side of the basic size, i.e. tolerance lies wholly on one side of the basic size either above or below it (Figure 3.7).

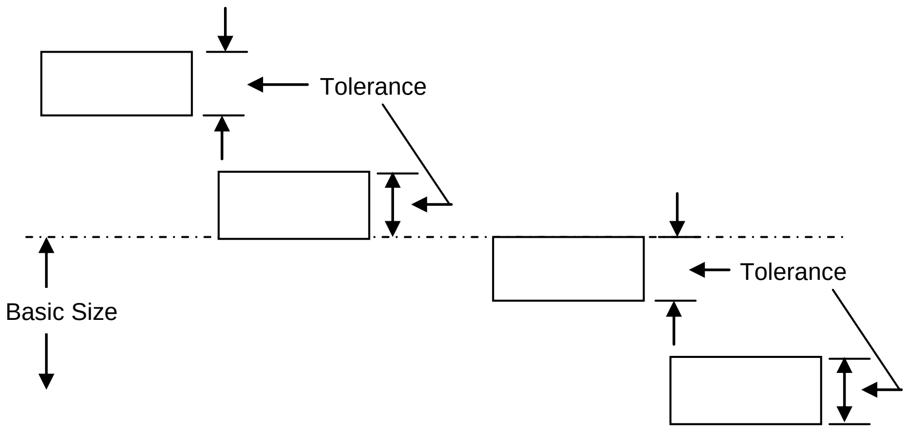

Figure 3.7 : Unilateral Tolerance

Examples of unilateral tolerance are :

$$25^{+0.02}_{+0.01},\ 25^{-0.02}_{-0.01},\ 25^{-0.01}_{-0.02},\ 25^{+0.0}_{-0.02} \text{ etc.}$$

Unilateral system is preferred in interchangeable manufacture, especially when precision fits are required, because

(a) it is easy and simple to determine deviations,

(b) another advantage of this system is that 'Go' Gauge ends can be standardized as the holes of different tolerance grades have the same lower limit and all the shafts have same upper limit, and

(c) this form of tolerance greatly assists the operator, when machining of mating parts. The operator machines to the upper limit of shaft (lower limit for hole) knowing fully well that he still has some margin left for machining before the parts are rejected.

3.4.2 Bilateral Tolerance

In this system, the dimension of the part is allowed to vary on both the sides of the basic size, i.e. the limits of tolerance lie on either side of the basic size, but may not be necessarily equally dispose about it (Figure 3.8).

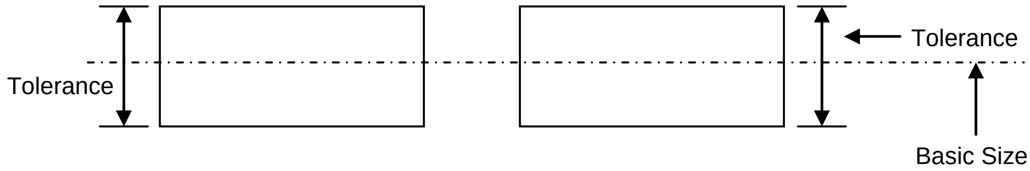

Figure 3.8 : Bilateral Tolerance

Examples of bilateral tolerance are :

$$25^{\pm 0.02},\ 25^{+0.02}_{-0.01} \text{ etc.}$$

In this system, it is not possible to retain the same fit when tolerance is varied and the basic size of one or both of the mating parts are to be varied. This system is used in mass production when machine setting is done for the basic size.

Example 3.5

A 50 mm diameter shaft is made to rotate in the bush. The tolerances for both shaft and bush are 0.050 mm. Determine the dimension of the shaft and bush to give a maximum clearance of 0.075 mm with the hole basis system.

Solution

In the hole basis system, lower deviation of hole is zero, therefore low limit of hole = 50 mm.

High limit of hole = Low limit + Tolerance

$= 50.00 + 0.050$

$= 50.050 \text{ mm} = 50.050 \times 10^{-3} \text{ m}$

High limit of shaft = Low limit of hole – Allowance

$= 50.00 - 0.075$

$= 49.925 \text{ mm} = 49.925 \times 10^{-3} \text{ m}$

Low limit of the shaft = High limit – Tolerance

$= 49.925 - 0.050$

$= 49.875 \text{ mm} = 49.875 \times 10^{-3} \text{ m}$

The dimension of the system is shown in Figure 3.8.

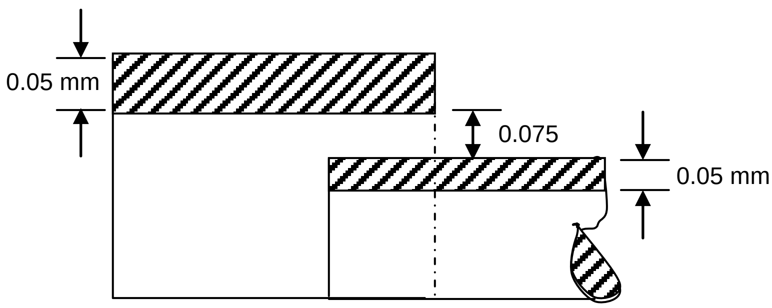

Figure 3.8 : Shaft with Bush

Example 3.5

For each of the following hole and shaft assembly, find shaft-tolerance, hole tolerance and state whether the type of fit is

(a) clearance,

(b) transition, and

(c) interference:

(i) Hole : $50^{+0.25}_{+0.00}$ mm, Shaft : $50^{+0.05}_{+0.005}$ mm

(ii) Hole : $30^{+0.05}_{+0.00}$ mm, Shaft : $30^{-0.02}_{+0.05}$ mm

(iii) Hole : $25^{+0.04}_{+0.00}$ mm, Shaft : $25^{+0.06}_{+0.04}$ mm

Solution

(a) Hole : High limit of hole = 50.025 mm

Low limit of hole = 50.00 mm

Hole tolerance = 50.025 – 50.00

= 0.025 mm = 25×10^{-6} m

Shaft : High limit of shaft = 50.05 mm

Low limit of shaft = 50.005 mm

Shaft tolerance = 50.05 – 50.005

= 0.045 mm 45×10^{-6} m

If we choose high limit of hole with high limit of shaft then

Allowance = 50.025 – 50.05

= – 0.025 (Interference)

Similarly, if we choose low limit of hole and either high limit or low limit of shaft, it is clear that there will be interference.

Thus, we conclude that the type of fit is **Transition fit**.

(b) Hole : High limit = 30.05 mm

Low limit = 30.00 mm

Tolerance = 0.05 mm = 5×10^{-5} m

Shaft : High limit = 30 – 0.02 = 29.98 mm

Low limit = 30 – 0.05 = 29.95 mm

Tolerance = 29.98 – 29.95 = 0.0 3 mm = 3×10^{-5} m

If we select high limit of hole and high limit of shaft then

Allowance = 30.05 – 29.98 = 0.07 mm

If we choose low limit of hole and high limit of shaft then

Allowance = 30.00 – 29.98 = 0.02 mm

Thus, we conclude that the type of fit is **Clearance fit.**

(c) Hole : High limit = 25.04 mm

Low limit = 25.00 mm

Tolerance = 25.04 – 25.00

= 0.04 mm = 4×10^{-5} m

Shaft : High limit = 5.06 mm

Low limit = 25.04 mm

Tolerance = 25.06 – 25.04

$= 0.02 \text{ mm} = 2 \times 10^{-5} \text{ m}$

If we select high limit of shaft and low limit of hole, then

Allowance = 25.00 – 25.06

$= -0.06 \text{ mm} = -6 \times 10^{-5} \text{ m}$

It is clear that for any combination of hole and shaft the allowance will be negative.

Thus, we conclude that the type of fit is **Interference fit**.

3.5 TOLERANCE OF FORM AND POSITION

It defines the zone within which a geometrical element should be specified in geometrical features, in addition to linear tolerance. Table 3.1 specifies tolerance of form and Table 3.2 specifies tolerance of position.

Table 3.1 : Symbol Specifying the Shape (Tolerance of Form)

Types of Error		**Symbol**
Briefly	**Interpretation**	
Flatness	Deviation from a flat Surface	–
Straighness	Deviation from a straight line	–
Cylindricality	Deviation from true cylinder	/○/
Circularity or roundness	Deviation from true circle	O
Accuracy of any surface	–	⊂

Table 3.2 : Symbol Specifying the Relative Location (Tolerance of Position)

Types of Error		**Symbol**
Briefly	**Interpretation**	
Parallelism	Lack of parallelism	//
Squareness and Perpendicularity	Lack of squareness	⊥
Concentricity	Lack of concentricity	⊚
Symmetry	Lack of symmetry	≡

3.5.1 Geometrical Tolerances

Geometric means geometric forms such as a plane, cylinder, square, etc. Geometrical features are : flatness, straightness, squareness etc. Geometrical tolerances refer to the shape of the surfaces (tolerance of form) as well as the relative location of one feature to another (tolerance of position). These tolerances are specified by special symbols (refer Tables 3.1 and 3.2).

Geometrical tolerances are specified for geometrical features, in addition to linear tolerances. Data about the tolerances on the shape and location of surfaces are indicated on drawings in a rectangular box divided into two or three parts. For example "Lack parallelism between two surfaces is within 0.1 mm" can be written as

/	0.1

Examples of geometrical tolerances are given below :

Parallelism (Figure 3.9(a))

It indicates the requirement, “Surface A is parallel to opposite face within 0.1 mm”.

Straightness (Figure 3.9(b))

It indicates the requirement, “Straight within 0.02 mm”.

Squareness (Figure 3.9(c))

It indicates the requirement, “Square within 0.03 mm total”.

Flatness (Figure 3.9(d))

It indicates the requirement, “Flat within 0.002 mm total”.

Roundness (Figure 3.9(e))

It indicates the requirement, “Taper round within 0.01 mm”.

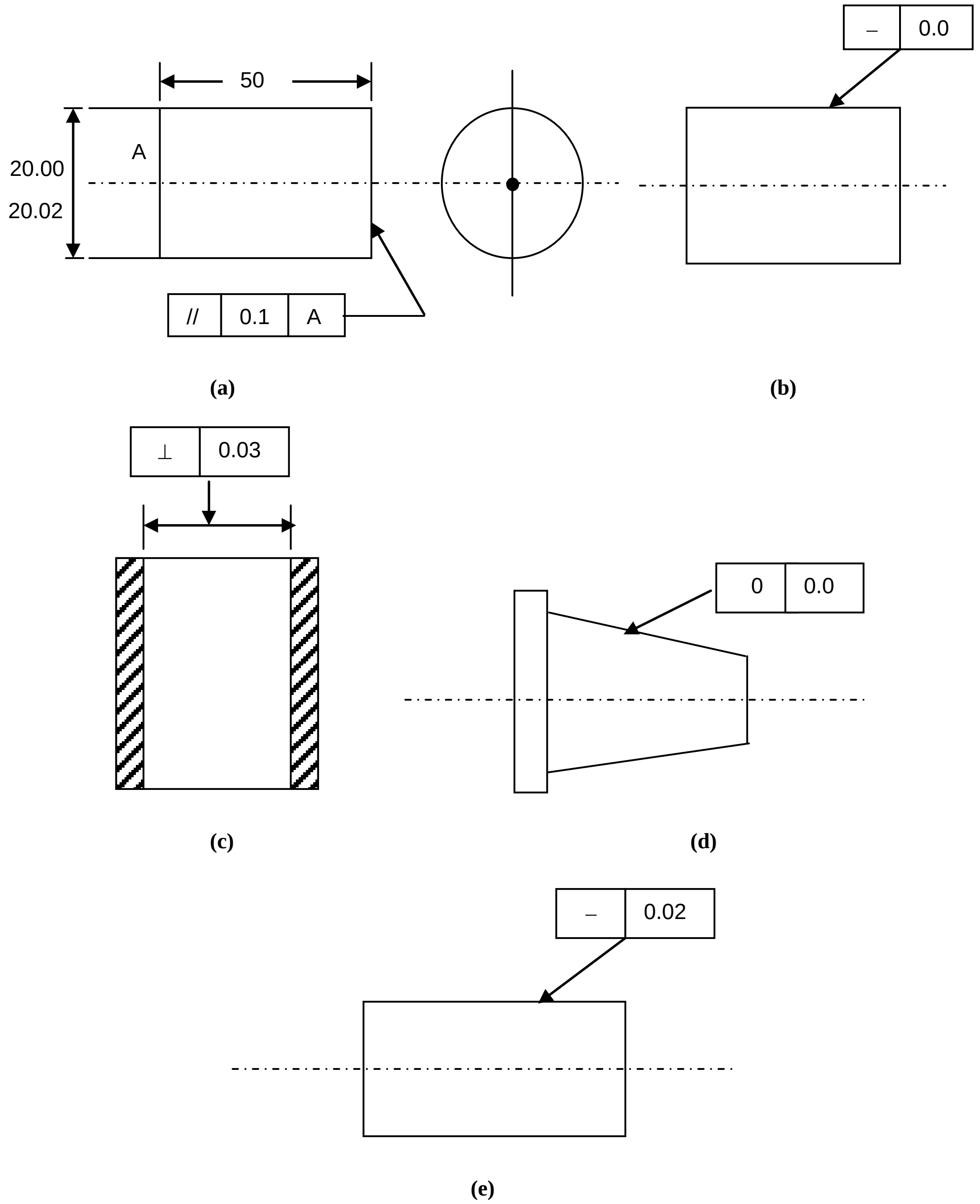

Figure 3.9 : Geometrical Tolerances

3.5.2 Tolerances of Angles

Angular tolerances are generally indicated in terms of degrees, minutes and seconds. Angular tolerances are used to give an angular dimension with high accuracy as shown in Figure 3.10. These are usually bilateral.

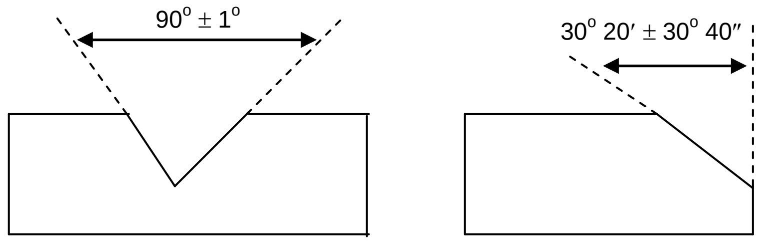

Figure 3.10 : Tolerance of Angles

SAQ 2

(a) Why it is necessary to give tolerance on engineering dimension?

(b) Explain the unilateral and bilateral system of writing tolerances with suitable examples.

(c) What is the difference between tolerance of form and position?

(d) What are geometrical tolerances? How are they specified? Give examples.

(e) In a hole and shaft assembly of 30 mm nominal size, the tolerances for hole and shaft are as specified below :

$$\text{Hole} : 30^{+0.02}_{-0.00}\ \text{mm}, \ \text{Shaft} : 30^{+0.40}_{-0.70}\ \text{mm}$$

Determine :

(i) Maximum and minimum clearance obtainable.

(ii) Hole and shaft tolerance, and

(iii) The type of fit.

3.6 SUMMARY

The aspects of various types of limits, fits and tolerances are very useful in reducing the unit cost of production and increasing the rate of production.

A fit may be defined as the degree of tightness or looseness between two mating parts. The fits depend upon the actual limits of the hole and/or shaft and can be divided into three general categories :

(a) Clearance fit,

(b) Interference fit, and

(c) Transition fit.

A fit system is the systems of standard allowance to suit specific range of basic size. If these standard allowances are selected properly and assigned in mating parts ensures specific classes of fit. There are two systems of fit for obtaining clearance, interference or transition fit. These are

(a) Hole basis system, and

(b) Shaft basis system.

Tolerance can be fixed as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functional trouble, when assembled with its mating part and put into actual service. There are two ways of writing tolerances : Unilateral tolerance and Bilateral tolerance. Geometrical tolerance refers to the shape of the surfaces as well as the relative location of one feature to another.

Angular tolerances are used to give an angular dimension with high accuracy. Angular tolerances are generally indicated in terms of degrees, minutes and seconds.

3.7 KEY WORDS

Limit : Permissible size.

Fit : The degree of tightness or looseness between two mating parts.

Clearance : The positive difference between the sizes of the hole and shaft before assembly.

Interference : The negative difference between the sizes of the hole and shaft before the assembly.

Transition : It is tolerance zone where the hole and shaft overlap.

Tolerance : The permissible variation in size or dimension.

3.8 ANSWERS TO SAQs

SAQ 1

(a) A fit indicates the degree of tightness or looseness between two mating parts.

(b) A clearance is the positive difference between the hole and shaft before assembly whereas a negative difference between the hole and shaft for the same is called interference.

(c)

Sl. No.	Type of Fit	Application
1.	Clearance	Pulleys, slide valve
2.	Interference	Rims, car wheels,
3.	Transition	Railway wheels, fixing keys, pins etc.

(d)

Sl. No.	Type of Fit	Application
1.	Push fit	Transition fit
2.	Wringing fit	Transition fit
3.	Force fit	Interference fit
4.	Slide fit	Clearance fit

(e) In the hole basis system, the size of the hole is kept constant and shaft sizes are varied to obtain various types of fit, whereas in the shaft basis system, the size of the shaft is kept constant and the different fits are obtained by varying the size of the hole.

(f) The upper limit of hole = 25 + 0.04

= 25.04 mm.

The lower limit of the hole = 25 – 0.04

= 24.96 mm.

The maximum permissible size of the shaft = 25 – 0.02

= 24.98 mm = 24 – 9.8 × 10^{-3} m.

The minimum permissible size of the shaft = 25 – 0.04

= 24.96 mm = 24.96 × 10^{-3} m.

SAQ 2

(a) It is necessary to give tolerance on engineering dimension, so that the mating parts can be easily produced without causing any functional trouble.

(b) In unilateral system, the dimension of a part is allowed to vary only on one size of the basic size, i.e. tolerance lies wholly on one side of the basic size either above or below it.

Example

$$25^{+0.04}_{+0.02}\ \text{mm},\ 25^{+0.04}_{-0.02}\ \text{mm}$$

In bilateral system, the dimension of the part is allowed to vary on both the sides of the basic size, i.e. the limits of tolerance lie on either side of the basic size.

Example

$$25^{+0.02}_{-0.01}\ \text{mm},\ 25^{\pm 0.02}\ \text{mm}$$

(c) Tolerance of form specifies the geometrical shape but tolerance of position specifies the relative location.

(d) Geometrical tolerances refer to the shape of the surfaces as well as the relative location of one feature to another.

Geometrical tolerances are specified for geometrical features in addition to linear references.

For example "Lack parallelism between the surfaces is within 0.1 mm" can be written as

/	0.1

(e) (i) Maximum clearance = 30.02 – 29.93

= 0.09 mm

Minimum clearance = 30.00 – 29.96

= 0.04 mm

(ii) High limit of hole = 30.02 mm

Low limit of hole = 30.00 mm

Hole tolerance = 30.02 – 30.00

= 0.02 mm = 2 × 10^{-3} m

High limit of shaft = 30 – 0.04

= 29.96 mm

Low limit of shaft = 30 – 0.070

= 29.93 mm

Shaft Tolerance = 29.96 – 29.93

= 0.03 mm = 3×10^{-5} m

(iii) If we consider high limit of hole with high limit of shaft, then allowance = 30.02 – 29.96

= 0.06 mm

If we choose low limit of hole and either high limit or low limit of shaft then the allowance is positive in each case, i.e.

$30 - 29.96 = +0.04 \text{ mm} = +4 \times 10^{-5} \text{ m}$

or $30 - 29.93 = +0.07 \text{ mm} = +7 \times 10^{-3} \text{ m}$

Hence, the type of fit is clearance fit.