IPE 381
Limit, Fits and Tolerance

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Outline

- Basics of Limit and Fit
- Interchangeable manufacturing
- Different types of fit
- Tolerance
- Tolerance Calculation

Basics

- Generally in engineering, any component manufactured is required to fit or match with some other component.
- The correct and prolonged functioning of the two components in match depends upon the correct size relationships between the two, i.e., the parts must fit with each other in a desired way

Basics

- **if a shaft is to rotate in a hole, there must be enough clearance between the shaft and hole to allow the oil film to be maintained for lubrication.**
- **If the clearance is <u>too small</u>, excessive force would be required in rotation of shaft.**
- **If clearance is <u>too wide</u>, there would be vibrations and rapid wear and ultimate failure.**

Interchangeable manufacturing

- In the early days the majority of components were actually mated together, their dimensions being adjusted until the required type of fit was obtained.
- But the interchangeable production and continuous assembly require some **standard procedure** to be followed. In order to obtain various fits, it is possible to vary the hole sizes and shaft size.
- The aim of any general system of standard limits and fits should be to provide guidance to the users in selecting basic functional clearance and interference for a given application or type of fit that minimize cost and labor.

Interchangeable manufacturing

- For a system of limits and fits to be successful, following conditions must be fulfilled :
  - It must be based on some standard so that everybody understands alike, and a given dimension has the same meaning at all places.
  - The range of sizes covered by the system should be sufficient for most purposes.
  - Number of limits and fits should be reduced and be adequate to cover all applications.

Limit

- **Basic Size or Basic dimension:** It is the theoretical size from which limits of size are derived by the application of allowances and tolerances. It is usually represented by **Zero line**
- **Actual Size:** is the measured size of the finished part.
- **Deviation:** It is the algebraic difference between a size and corresponding basic size

Basic size. Refer to Fig. 17.4. The *basic size is the standard size for the part and is the same for both the hole and its shaft.* Example : A 60 mm diameter hole and shaft.

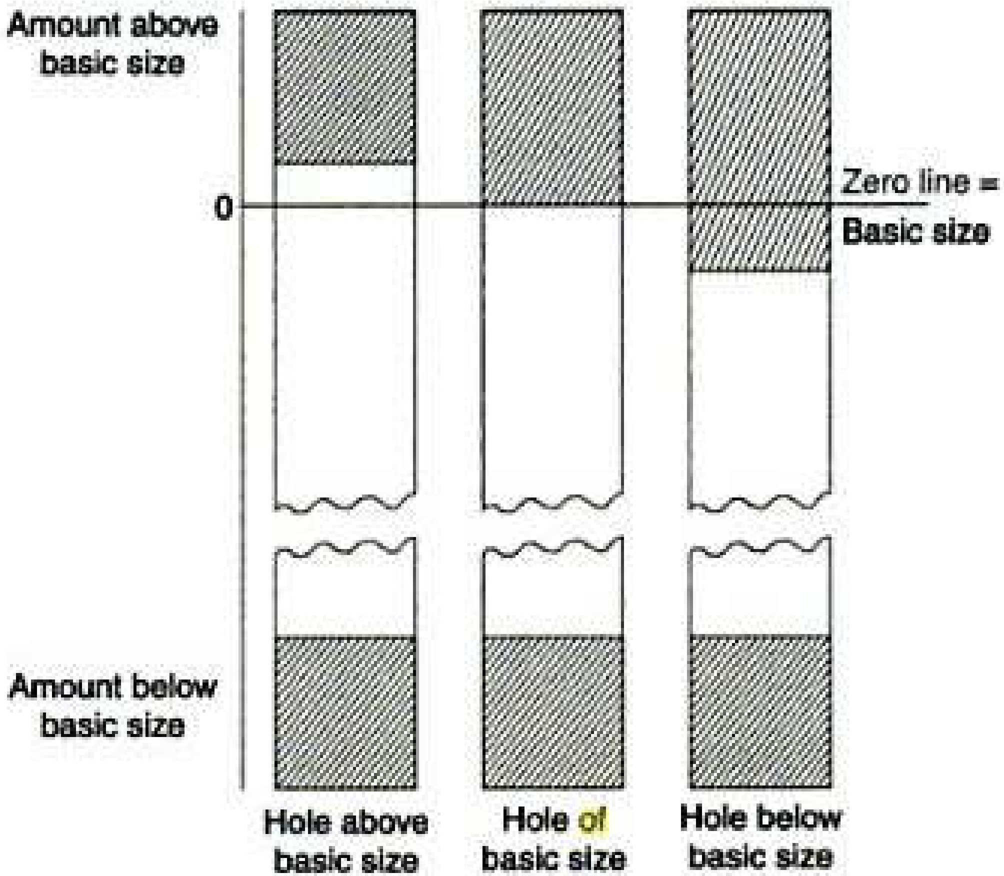
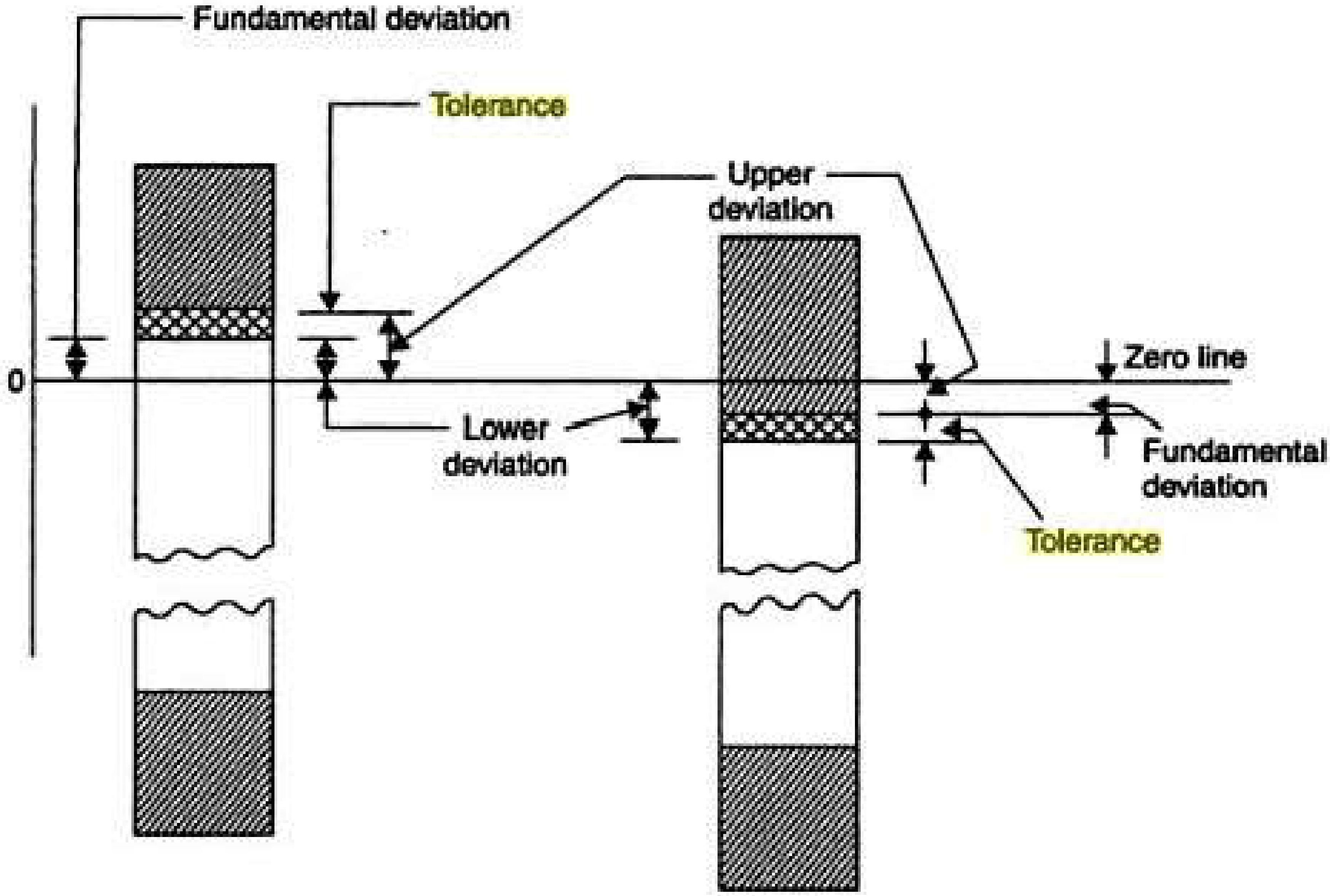


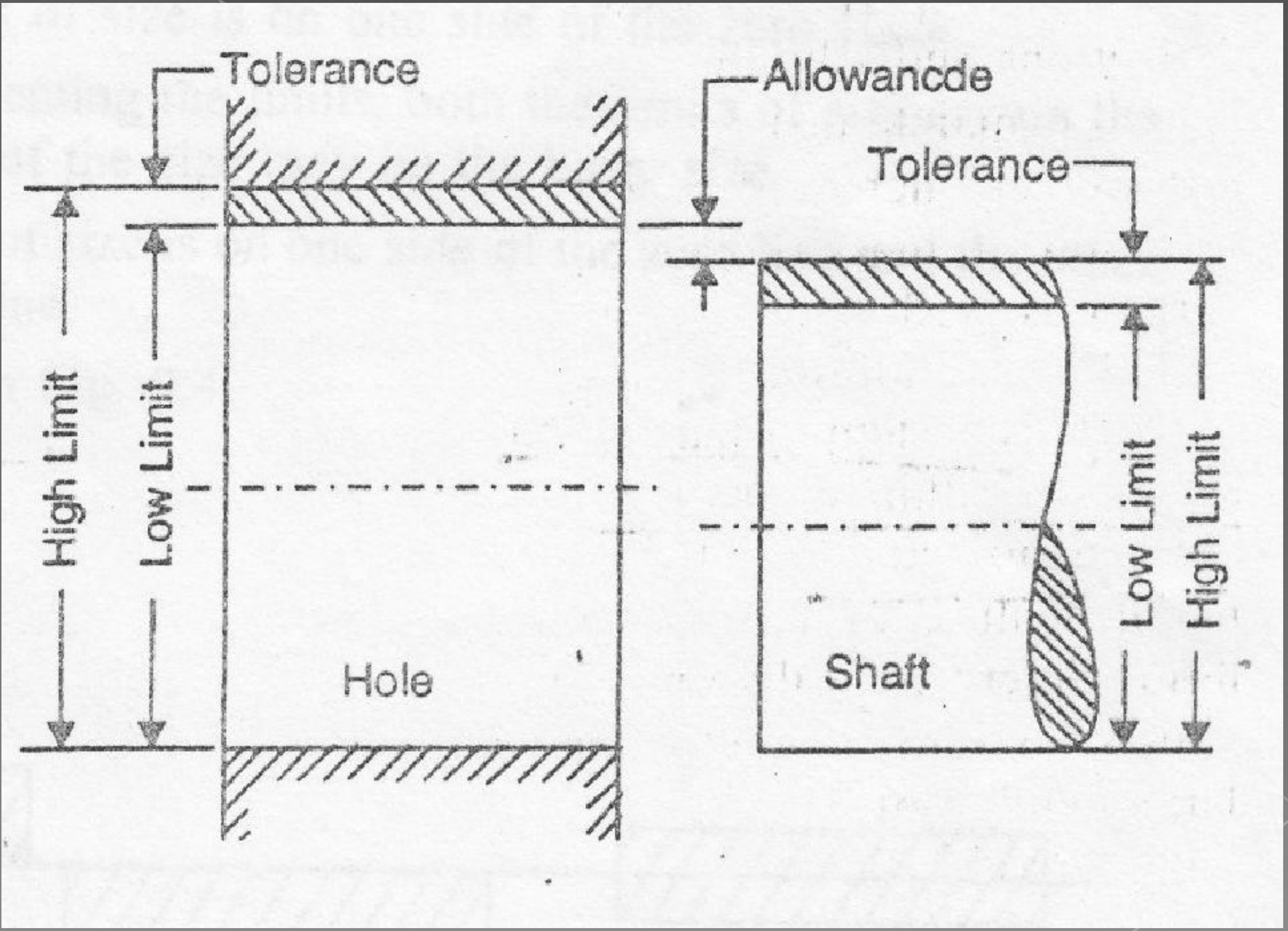
Fig. 17.4.

Limit Designations

- **Upper Deviation:** The algebraic difference between the maximum limit of size and the corresponding basic size.
- **Lower Deviation:** The algebraic difference between the minimum limit of size and the corresponding basic size.
- **Fundamental Deviation:** It is equal to either upper or lower deviation which is closer to the zero line.
- **Allowance:** It is the intentional difference between the Maximum Material Limit(MML) of mating parts. For shaft, the maximum material limit will be its high limit and the for the hole the maximum material limit will be its low limit


Fundamental deviation
Tolerance
Upper
deviation
0
Zero line
Lower
deviation
Fundamental
deviation
Tolerance

Limits



Tolerance
Allowancde
Tolerance
High Limit
Low Limit
Hole
Shaft
Low Limit
High Limit

limits

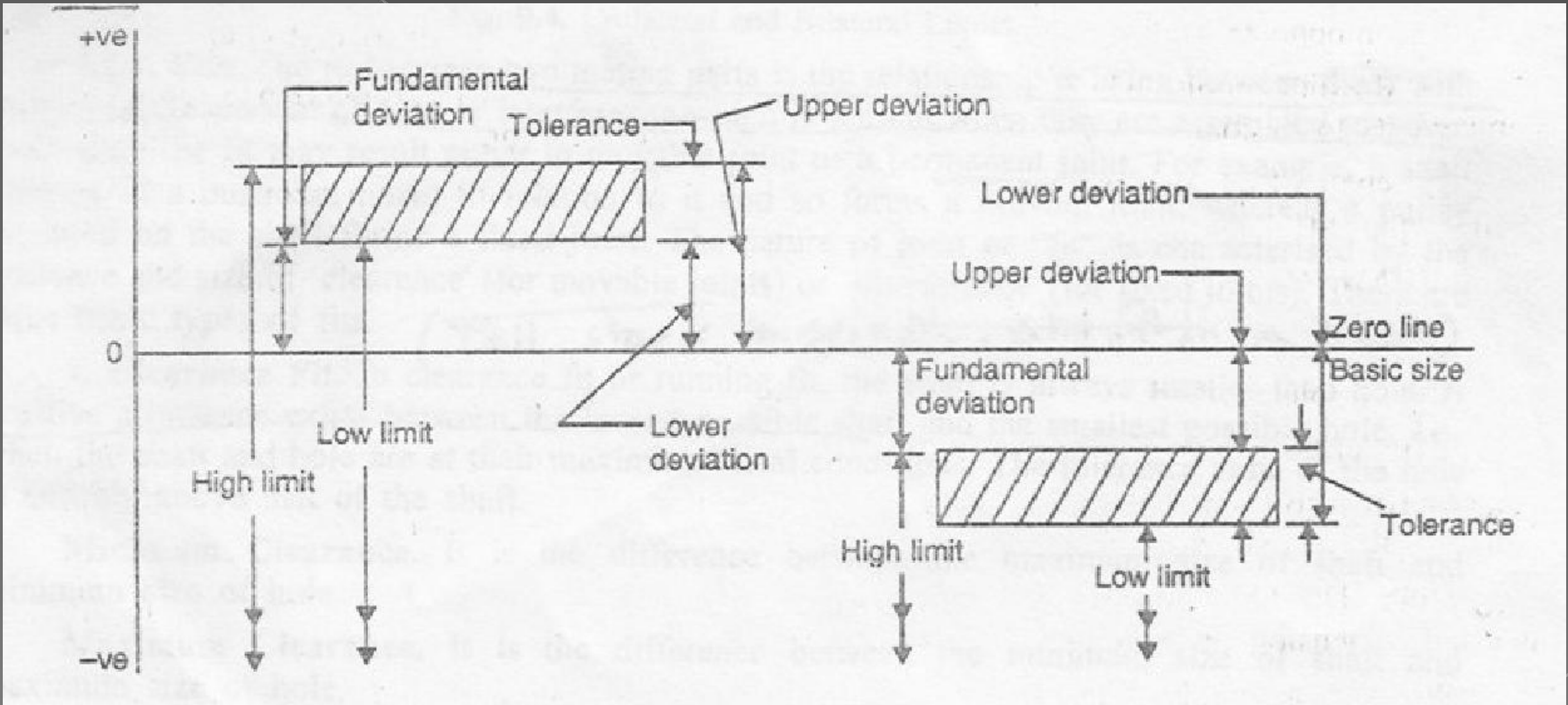


Fig. 9.3. Deviations.

Unilateral & bi-lateral system

- In unilateral system the limit dimensions are only above the basic size **or** only below the basic size.
- In Bilateral system the limit dimensions are given above and below the basic size or zero line

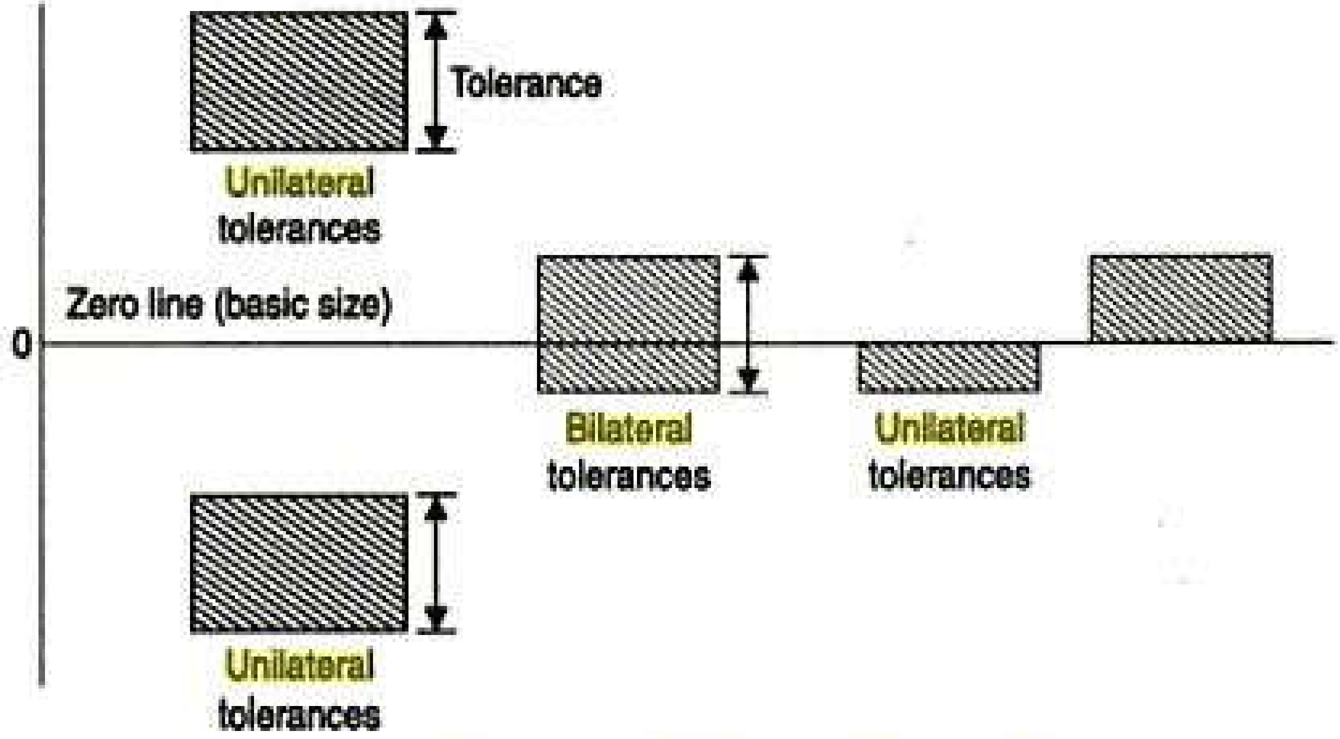


Fig. 17.9. Unilateral and bilateral tolerance.

In the ***unilateral system***, tolerance is applied only in *one direction*,

$$\textit{Example:}\quad 40.0^{+0.04}_{+0.02} \quad \text{or} \quad 40.0^{-0.02}_{-0.04}$$

In the ***bilateral system*** of writing tolerances, a dimension is permitted to vary in *two directions*.

$$\textit{Example:}\quad 40.0^{+0.02}_{-0.04}$$

Fit

- **Fit** is the general term used to signify the range of tightness or looseness that may result from the application of a specific combination of allowances and tolerances in mating parts.
- Three types of fit
  - Clearance Fit
  - Interference Fit
  - Transition Fit

Fit

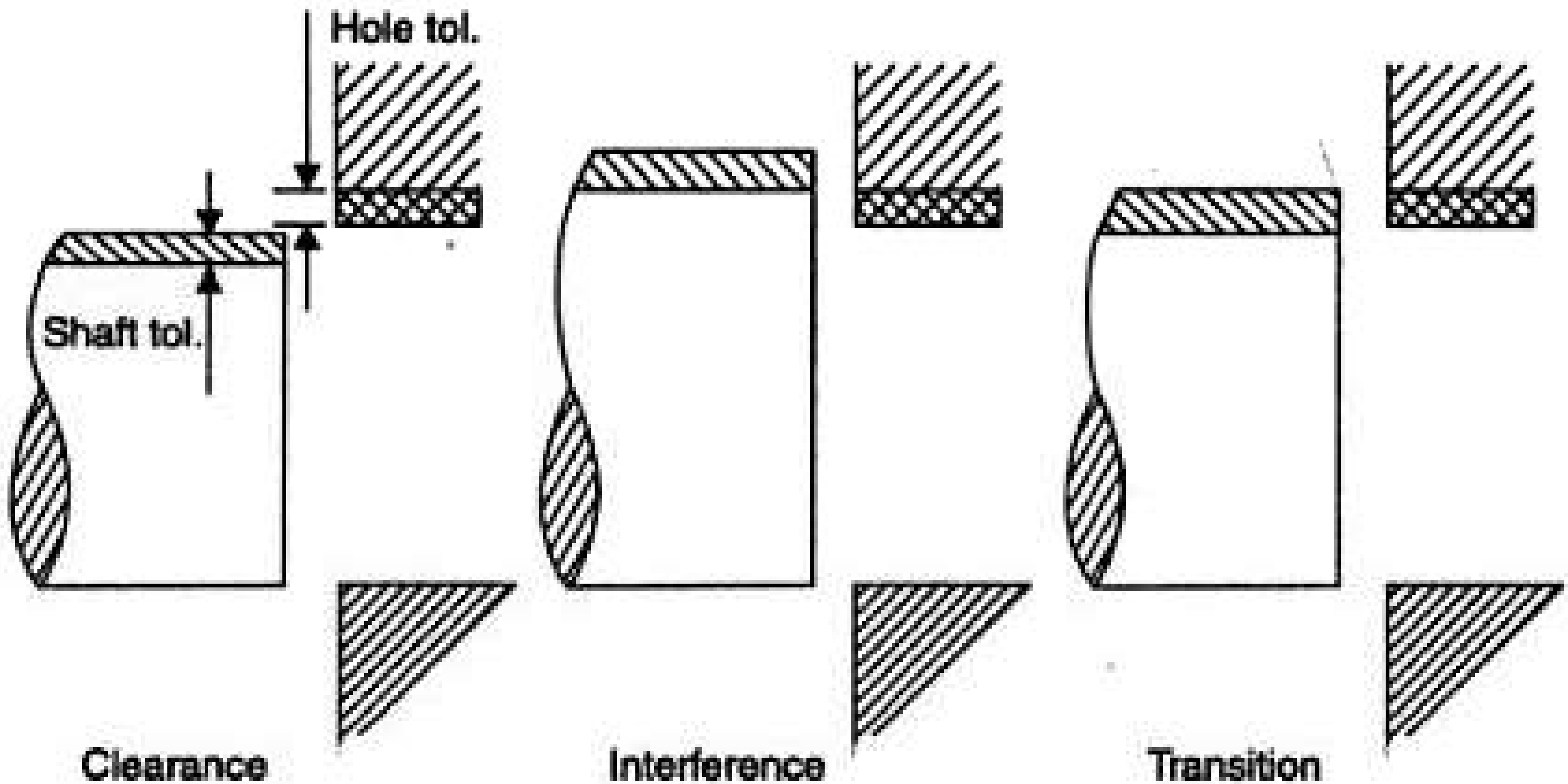
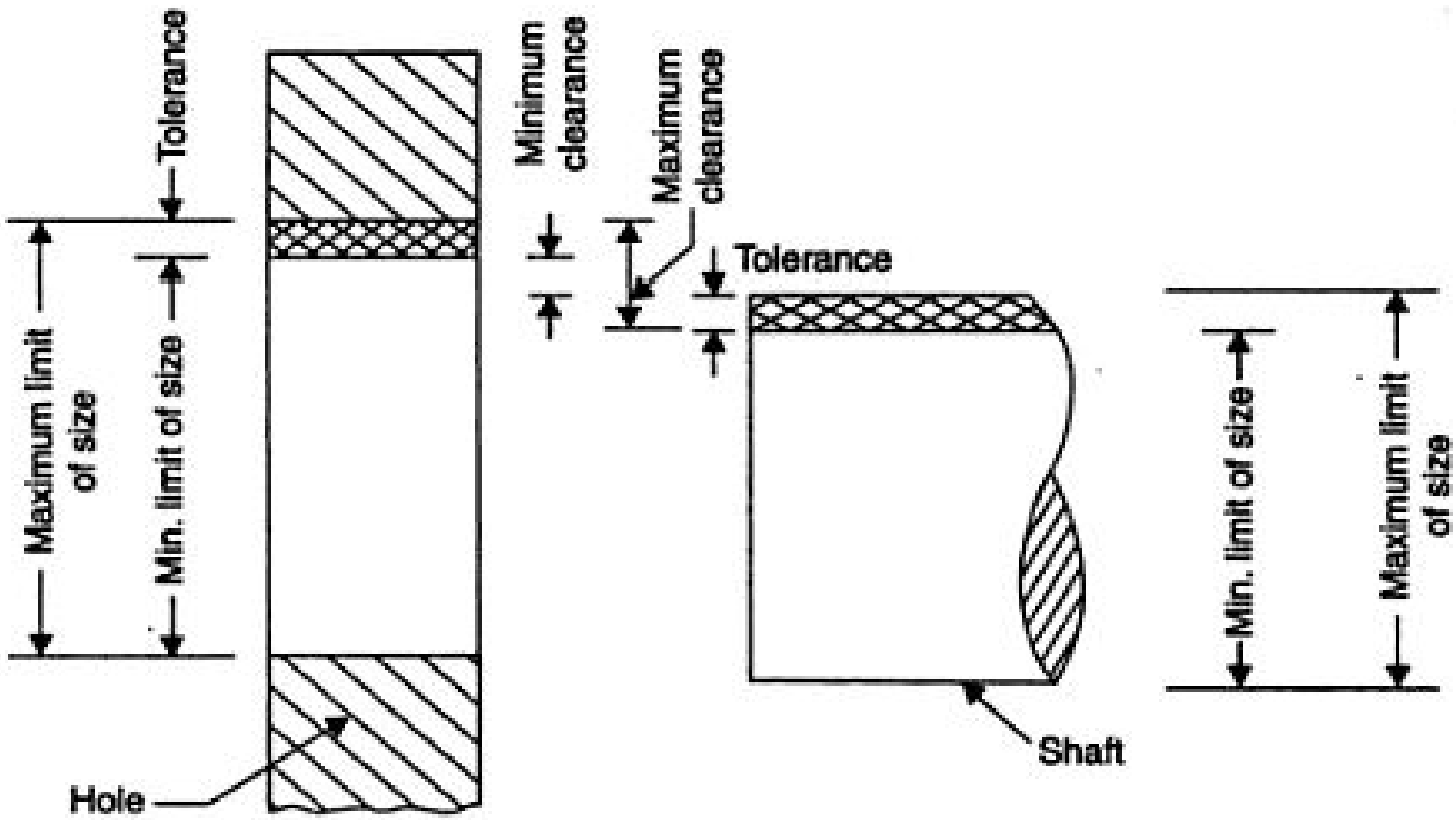


Fig. 17.7. Classes of fit.

Clearance Fit(self study)

- **5 types of clearance fit**
  - **Slide fit**
  - **Easy fit**
  - **Running fit**
  - **Slack fit**
  - **Loose fit**

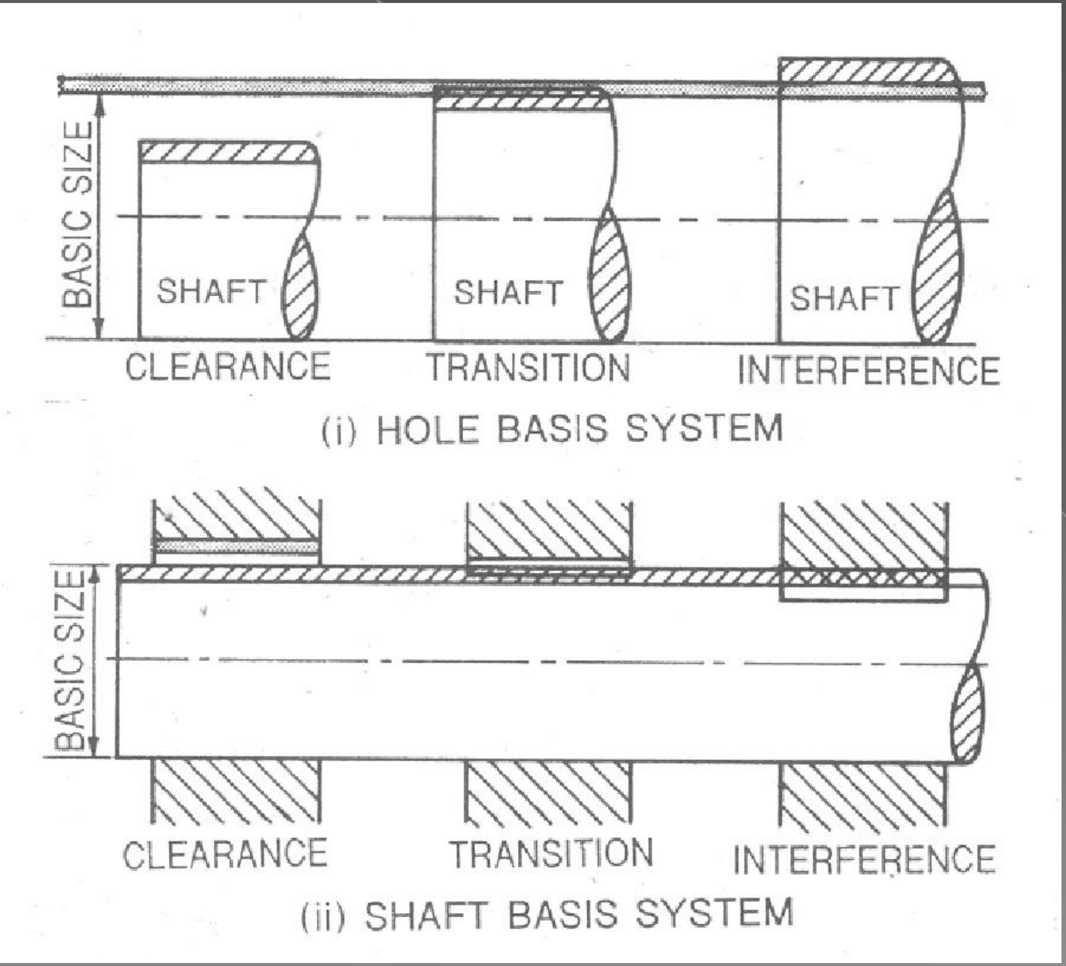
Maximum & minimum clearance



Tolerance

- **The primary purpose of tolerances is to permit variation in dimensions without degradation of the performance beyond the limits established by the specification of the design.**
- **For Example a dimension given as 1.625 ± .002 means that the manufactured part may be 1.627” or 1.623”, or anywhere between these limit dimensions.**

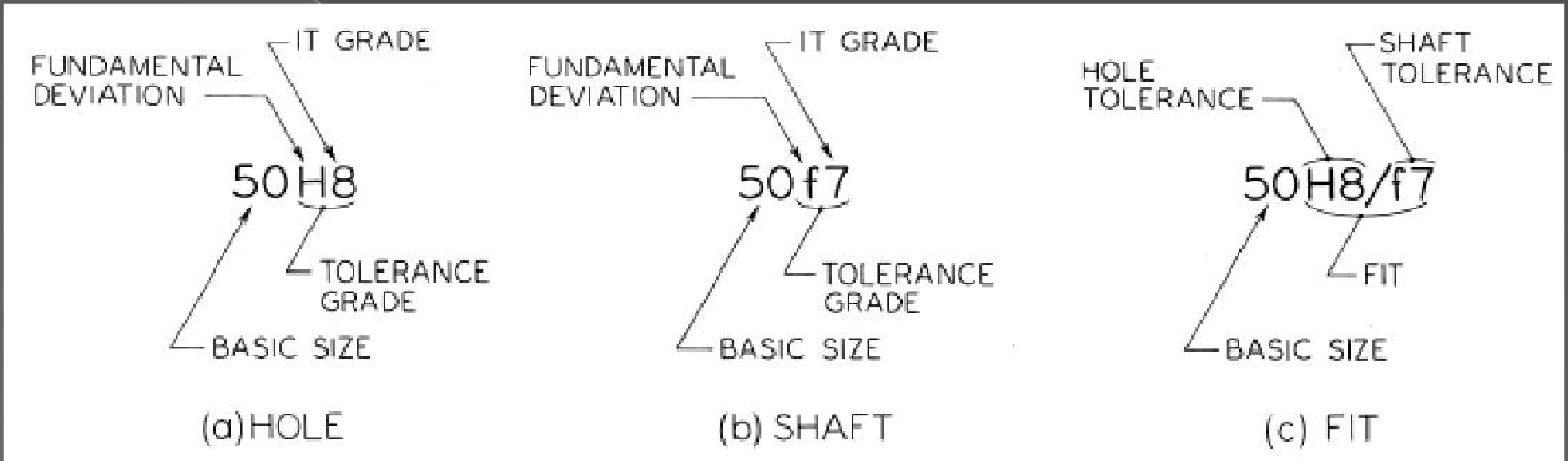
Hole and Shaft Basis System



HOLE BASED SYSTEM:
Size of hole is kept constant, shaft size is varied to get different fits.

SHAFT BASED SYSTEM:
Size of shaft is kept constant, hole size is varied to get different fits.

International Tolerance Grade (IT)



They are a set of tolerances that varies according to the basic size and provides a uniform level of accuracy within the grade. A fit is indicated by the basic size common to both components, followed by symbol corresponding to each component, the hole being quoted first.

E.g. 45mm H8/g7

- **Representation of Tolerance**
  2) Number or Grade
  IT01, IT0, IT1,….IT16

- Tolerance Grade defines range of dimensions (dimensional variation)
- There are manufacturing constraints on tolerance grade chosen

Tolerance grade	Manufacturing process and applications	Machine required
IT01, IT0 IT1 to IT5	Super finishing process, such as lapping, diamond boring etc. Use: Gauges	Super finishing machines
IT6	Grinding	Grinding machines
IT7	Precision turning, broaching, honing	Boring machine, honing machine
IT8	Turning, boring and reaming	Lathes, capstan and automats
IT9	Boring	Boring machines
IT10	Milling, slotting, planing, rolling and extrusion	Milling machine, slotting machine, planing machine and extruders
IT11	Drilling, rough turning	Drilling machine, lathes
IT12, IT13, IT14	Metal forming processes	Presses
IT15	Die casting, stamping	Die casting machine, hammer machine
IT16	Sand casting	—

Standard Tolerances

- There are eighteen grades of tolerances provided with designations ITO1, ITO, IT1, IT2, ... IT16. These are known as **standard tolerances**. For grades 5 to 16, the values of the tolerances are determined in terms of the **standard tolerance factor** *i* ,
- Where, $i = 0.45\sqrt[3]{D} + 0.001D\ (\mu m)(D \leq 500\ mm)$

  $I = 0.004D + 2.1(\mu m)(500 < D \leq 3150)$

  (D = mean diameter in mm)
- For IT6 to IT16

IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
10i	16i	25i	40i	64i	100i	160i	250i	400i	640i	1000i
10I	16I	25I	40I	64I	100I	160I	250I	400I	640I	1000I

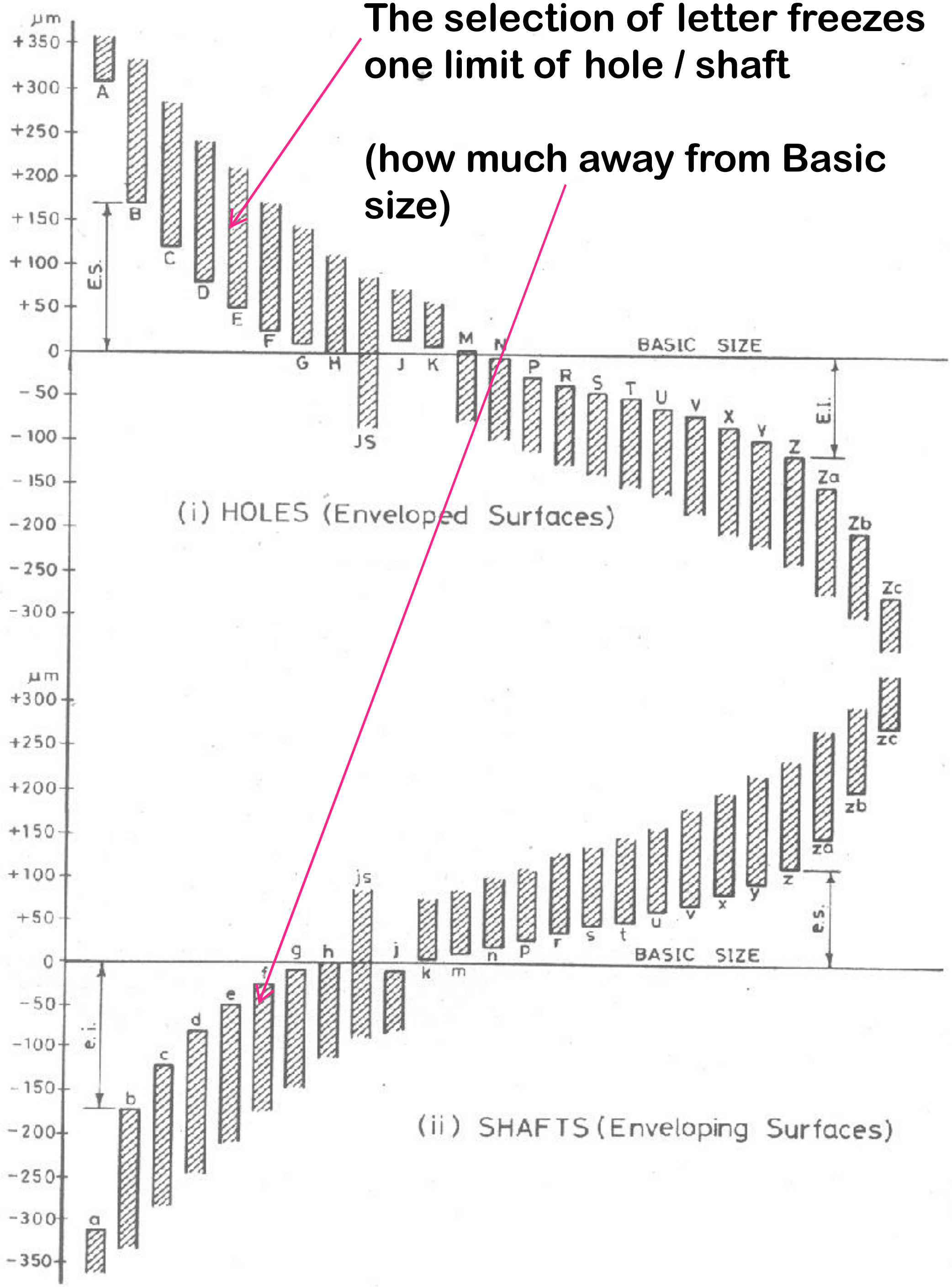
Representation of Tolerance

1) Letter Symbol

Basic Size → 45 E8/e7

The selection of letter freezes one limit of hole / shaft

(how much away from Basic size)



One can have different possible combinations; e.g. 45H6g7, 45H8r6, 45E5p7

E.S. – upper deviation
E.I. – lower deviation

H : lower deviation of hole is zero
h : upper deviation of shaft is zero

Table 4.2. Formulae for Fundamental Deviations for Shafts for sizes 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 $D \leq 120$ and $= -3.5D$ for $D > 120$	*j5* to *j8*	No formula
b	$= -(140 + 0.85D)$ for $D \leq 160$ $= -1.8D$ for $D > 160$	*k4* to *k8*	$= +0 \cdot 6\sqrt[3]{D}$
c	$= -52D^{0.2}$ for $D \leq 40$ $= -(95 + 0.8D)$ for $D > 40$	*k* for grade ≤ 3 and ≥ 4	$= 0$
d	$= -16D^{0.44}$	*m*	$= +(IT7 - IT6)$
e	$= -11D^{0.41}$	*n*	$= +5D^{0.34}$
f	$= -5.5D^{0.41}$	*p*	$= +IT7 + 0$ to 5
g	$= -2.5D^{0.34}$	*r*	= geometric mean of values *el* for *p* and *s*
h	$= 0$	*s*	$= IT8 + 1$ to 4 for $D \leq 50$ $= +IT7$ to $+0.4D$ for $D>50$
		t	$= IT7 + 0.63D$
		u	$= +IT7 + D$
		v	$= +IT7 + 1.25D$
		x	$= +IT7 + 1.6D$
		y	$= +IT7 + 2d$
		z	$= +IT7 + 2.5D$
		za	$= IT8 + 3 + 3.15D$
		zb	$= +IT9 + 4D$
		zc	$= +IT10 + 5D$

For *js* : The deviation are equal to $\pm IT/2$

Tolerance Calculation

- Determine the tolerance for 25H8/d9 Fit for diameter step 18mm and 30mm
- Here ,basic size = 25mm
- First Determine the Geometric mean of diameter $D = \sqrt{18 \times 30}\ (mm)$
- Calculate Fundamental Tolerance Unit

$$i = 0.45\sqrt[3]{D} + 0.001D\ (\mu m)$$

- Find **Tolerance Grade** and **Standard Tolerance** for Hole and Shaft using standard tolerance chart.
- Find Fundamental Deviation for Hole(H) and Shaft(d) using table 4.2

Tolerance Calculation

- **For Hole H: Fundamental Deviation is Zero**
- **For d shaft: Fundamental Deviation**

$$FD = -16D^{0.44}\ (\mu m)$$

Now calculate the limits for hole and shaft

- **For hole,**
  Low limit = basic size + FD(here 0)
  High limit= low limit + tolerance
- **For shaft,**
  high limit = basic size + FD(here -ve)
  low limit= high limit - tolerance

Tolerance and Limit

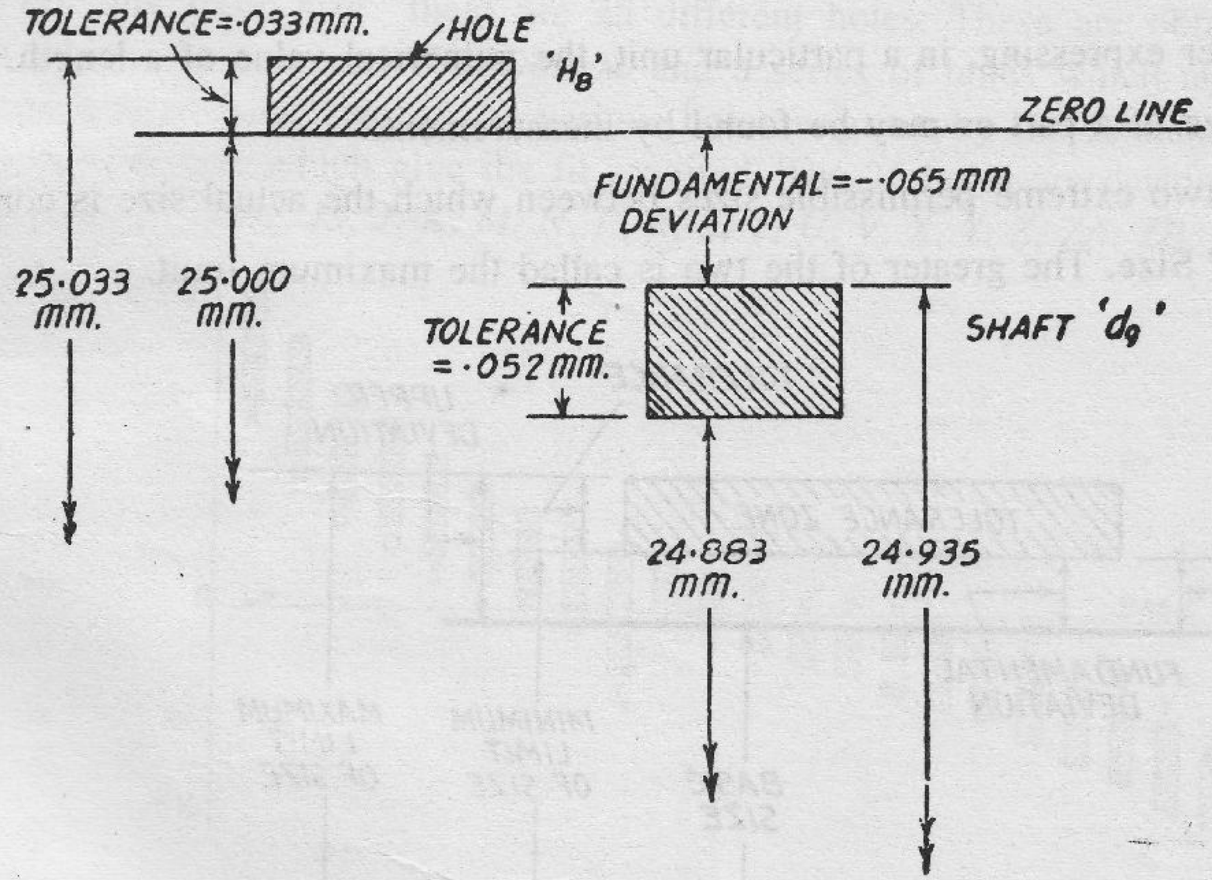


Fig. 4.20.

That's all for today