Engineering Metrology

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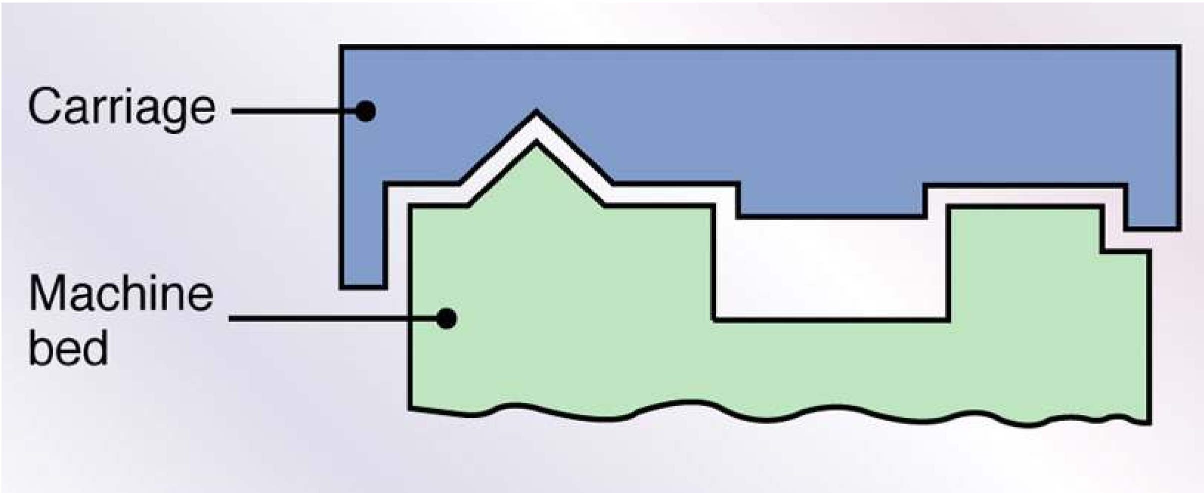
Introduction



Cross-section of a machine-tool slideway.

The width, depth, angles and other dimensions all must be produced and measured accurately for the machine tool to function as expected.

Metrology

- **Metrology is the science of measurement**

- Dimensional metrology is that branch of Metrology which deals with measurement of “dimensions“ of a part or workpiece (lengths, angles, etc.)

- Dimensional measurements at the required level of accuracy are the essential link between the designers’ intent and a delivered product.

Dimensional Metrology Needs

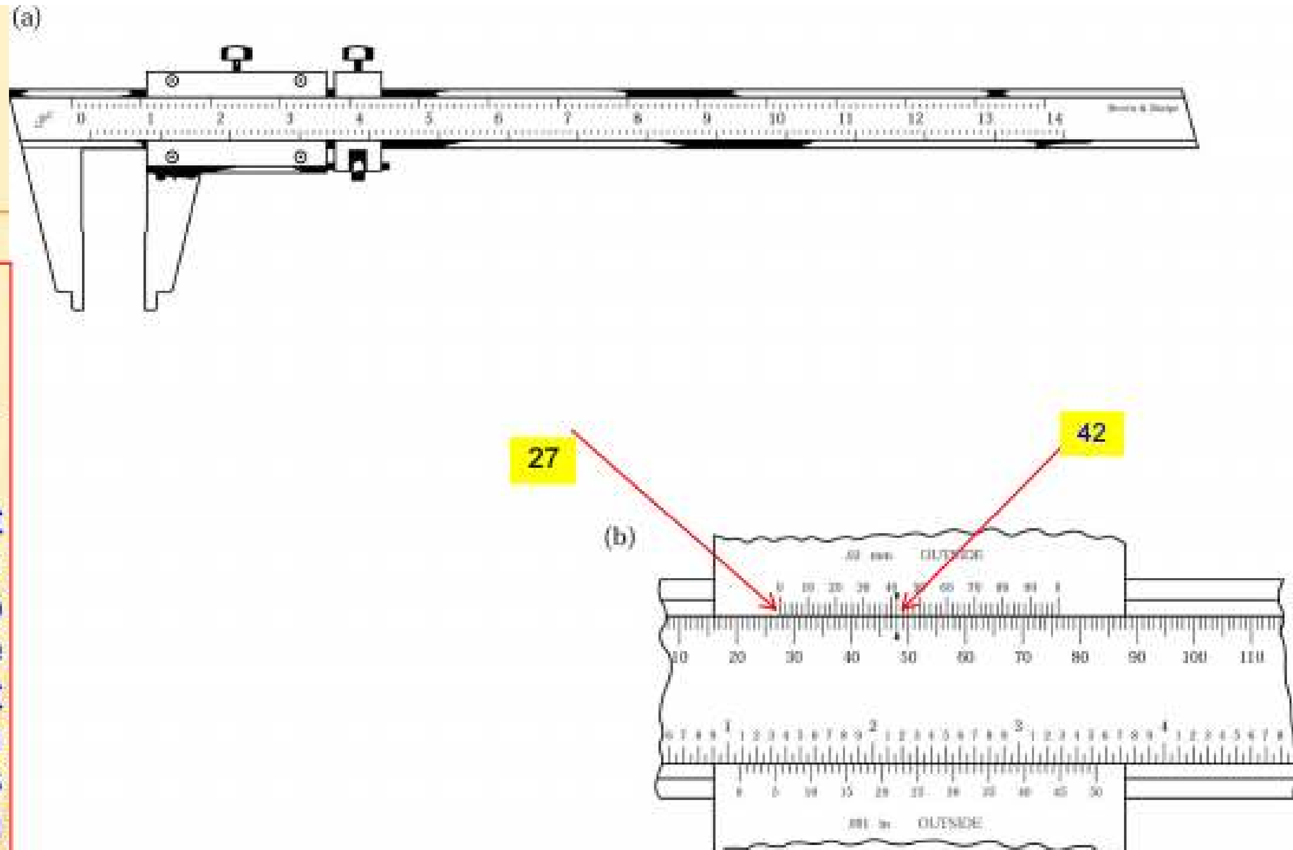
- Linear measurements
- Angular measurements
- Geometric form measurements
    - Roundness
    - Straightness
    - Cylindricity
    - Flatness, etc
- Geometric relationships
    - Parallel, perpendicular, etc.
    - Concentric, runout, etc.
- Controlled surface texture

Types of Measurement and Instruments Used

Measurement	Instrument	Sensitivity μm	Sensitivity μin.
Linear	Steel rule	0.5 mm	1/64 in.
	Vernier caliper	25	1000
	Micrometer, with vernier	2.5	100
	Diffraction grating	1	40
Angle	Bevel protractor, with vernier	5 min	
	Sine bar		
Comparative length	Dial indicator	1	40
	Electronic gage	0.1	4
	Gage blocks	0.05	2
Straightness	Autocollimator	2.5	100
	Transit	0.2 mm/m	0.002 in./ft
	Laser beam	2.5	100
Flatness	Interferometry	0.03	1
Roundness	Dial indicator Circular tracing	0.03	1
Profile	Radius or fillet gage		
	Dial indicator	1	40
	Optical comparator	125	5000
	Coordinate measuring machines	0.25	10
GO-NOT GO	Plug gage		
	Ring gage		
	Snap gage		
Microscopes	Toolmaker's	2.5	100
	Light section	1	40
	Scanning electron	0.001	0.04
	Laser scan	0.1	5

Basic Measurement Devices

CALIPER AND VERNIER



(a) A caliper gage with a vernier.

(b) A Vernier, reading 27.00 + 0.42 = 27.42 mm, (or 1.000 + 0.050 + 0.029 = 1.079 in.)

(c) We arrive at the last measurement as follows: First note that the two UPPER scales pertain to the millimeter units. We next note that the 0 (zero) mark on the upper mm scale has passed the 27 (mm) mark on the lower (mm) scale. Thus, we first record a distance of 27.00 mm.

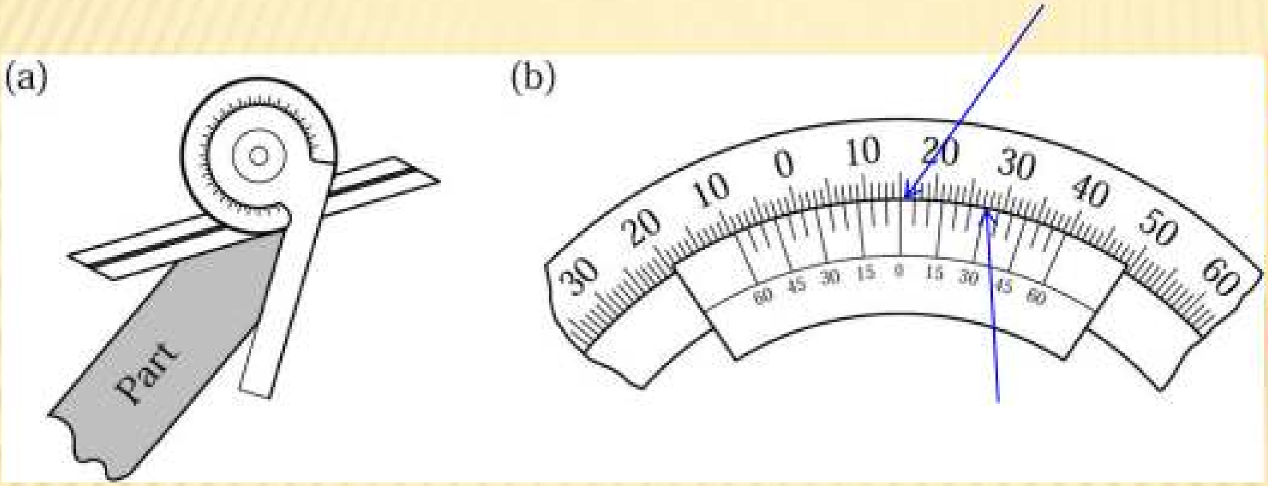
(e) Finally note that the marks on the two scales coincide at the number 42 (in fact 21 divisionx0.02=0.42). Each of the 50 graduations on the upper scale indicates 0.02 mm. (Given in this case but you should know how to get it). 0.02 is LEAST Count of the Vernier caliper.

(f) Thus, the total dimension is **27 mm+ 0.42 mm. = 27.42 mm.**

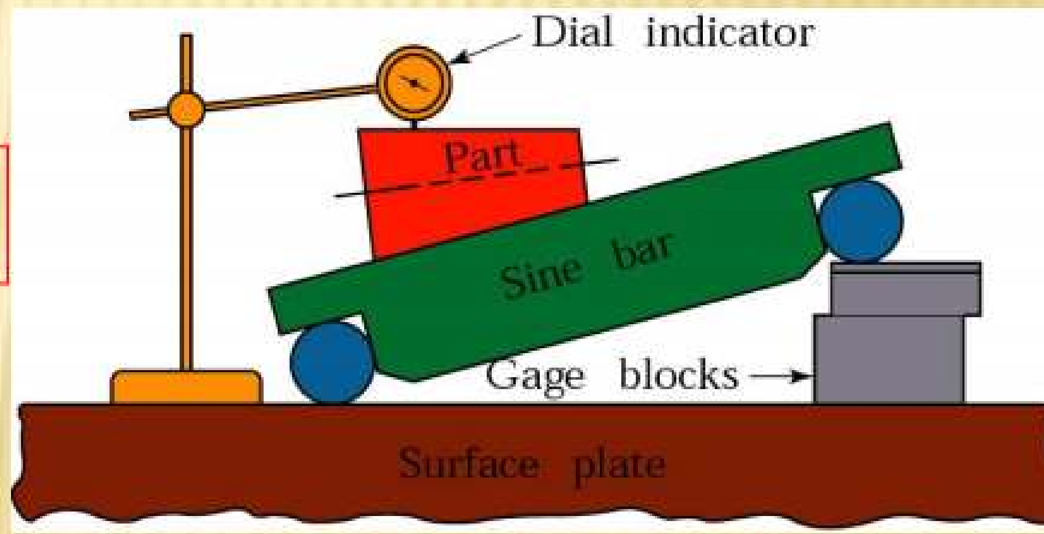
Analog and Digital Micrometers

(a) A vernier (analog) micrometer. (b) A digital micrometer with a range of 0 to 1 in. (0 to 25 mm) and a resolution of 50 μin. (1.25μm). It is generally easier to read dimensions on this instrument compared to the analog micrometer.

Angle Measuring Instruments



(A) SCHEMATIC ILLUSTRATION OF A BEVEL PROTRACTOR FOR MEASURING ANGLES. (B) VERNIER FOR ANGULAR MEASUREMENT, INDICATING 14° 30´.

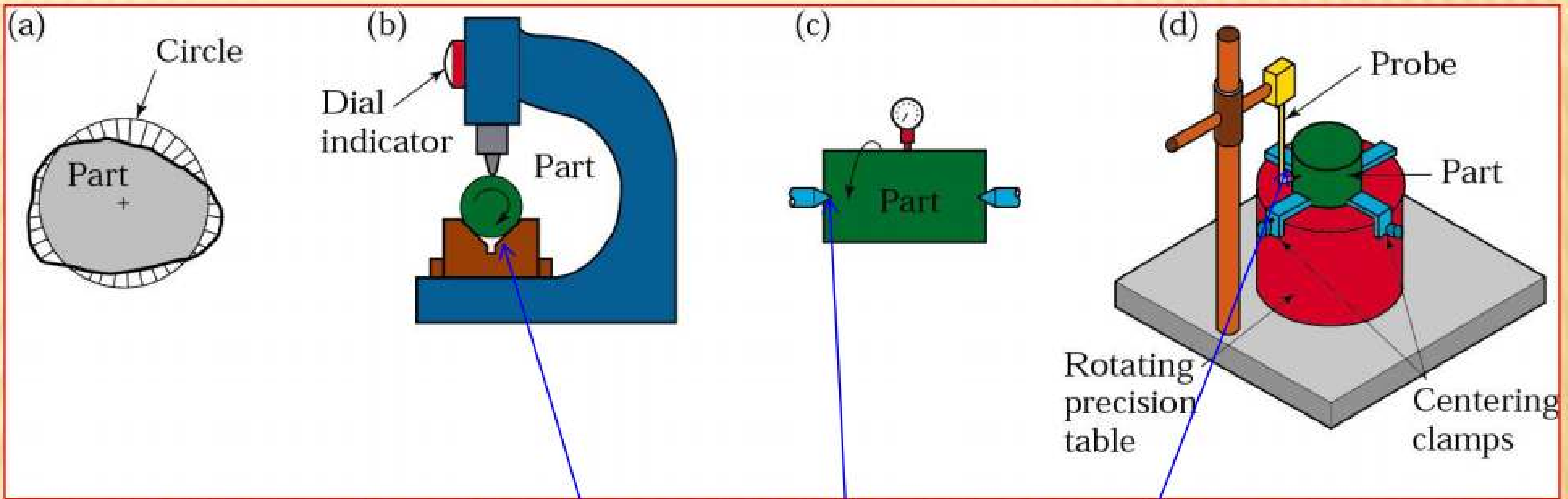


SETUP SHOWING THE USE OF A SINE BAR FOR PRECISION MEASUREMENT OF WORKPIECE ANGLES.

Gage Block Will Give The Height And Center To Center Distance Is Known In Advance.

You Can Find Angle Of Taper Of The Given Block In The Lab.

Measuring Roundness



(A) SCHEMATIC ILLUSTRATION OF "OUT OF ROUNDNESS" (EXAGGERATED). MEASURING ROUNDNESS USING

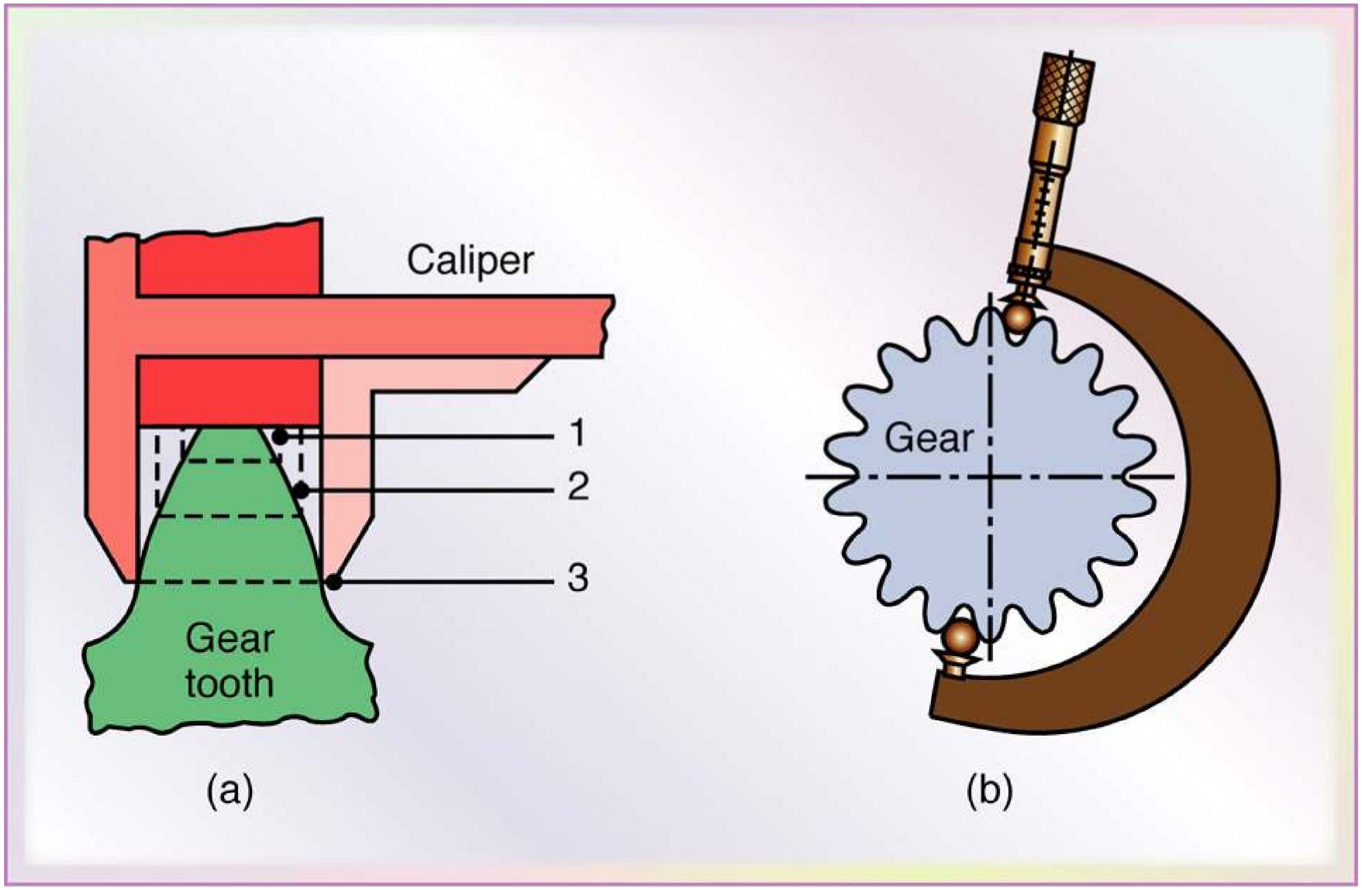
(B) V-BLOCK AND DIAL INDICATOR,

(C) PART SUPPORTED ON CENTERS AND ROTATED, AND

(D) CIRCULAR TRACING, WITH PART BEING ROTATED ON A VERTICAL AXIS.

***(E) SOURCE*: AFTER F. T. FARAGO.**

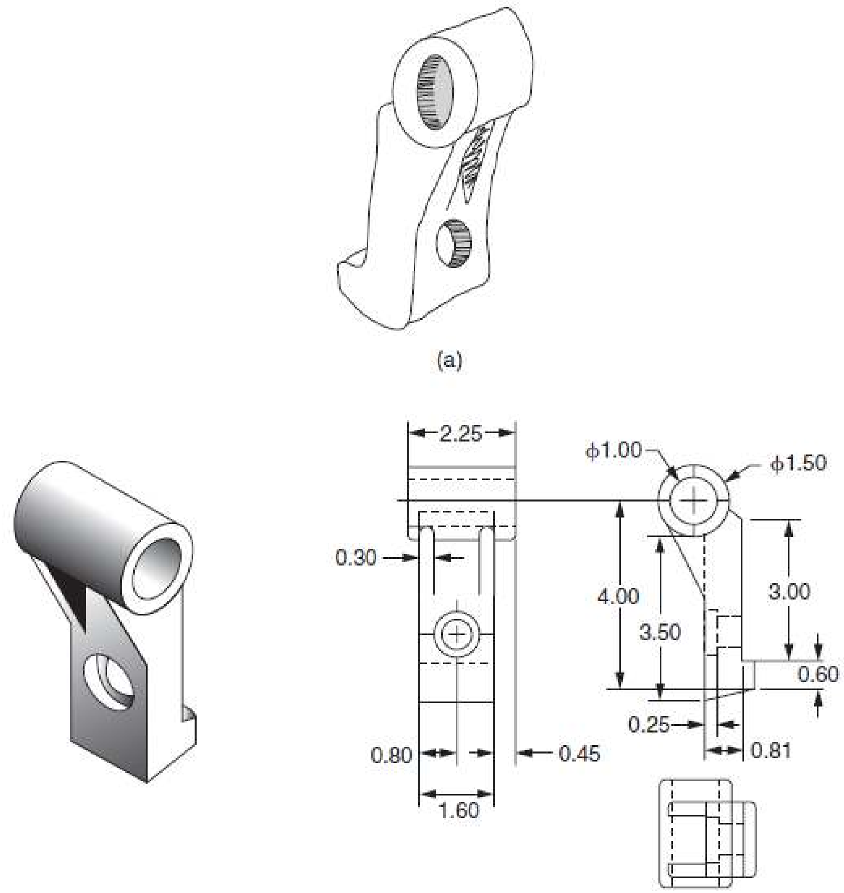
Profile Measurement



Measuring gear-tooth thickness and profile with (a) a gear-tooth caliper and (b) balls and a micrometer.

Source: American Gear Manufacturers Association.

Introduction to Tolerances



(a) (b) (c)

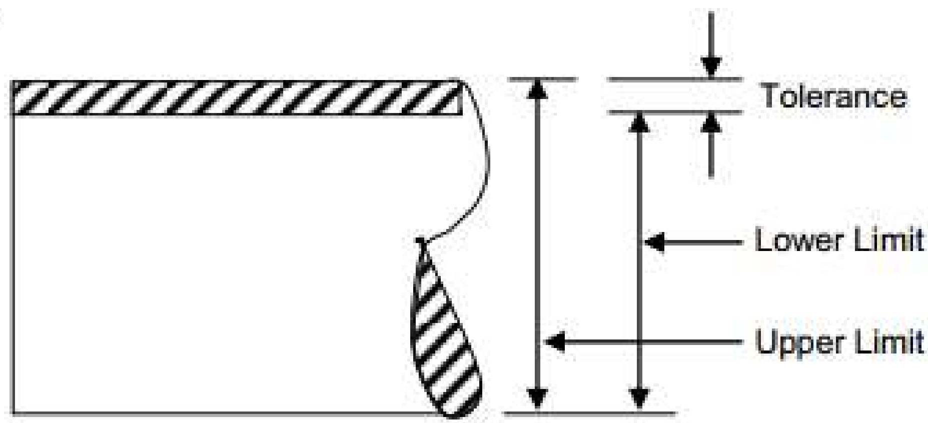
Can more than one or multiple parts be produced with exactly same dimensions?

Why?

Tolerance

"the allowable deviation from a standard, eg: the range of variation permitted in maintaining a specified dimension in a machined piece."

Webster



Why is it necessary?

- It is impossible to manufacture a part or component to an exact size or geometry.
- Since variation from the drawing is inevitable, acceptable degree of variation must be applied.
- Large variation may affect the functionality of the part.
- Small variations may affect the economy of the part.

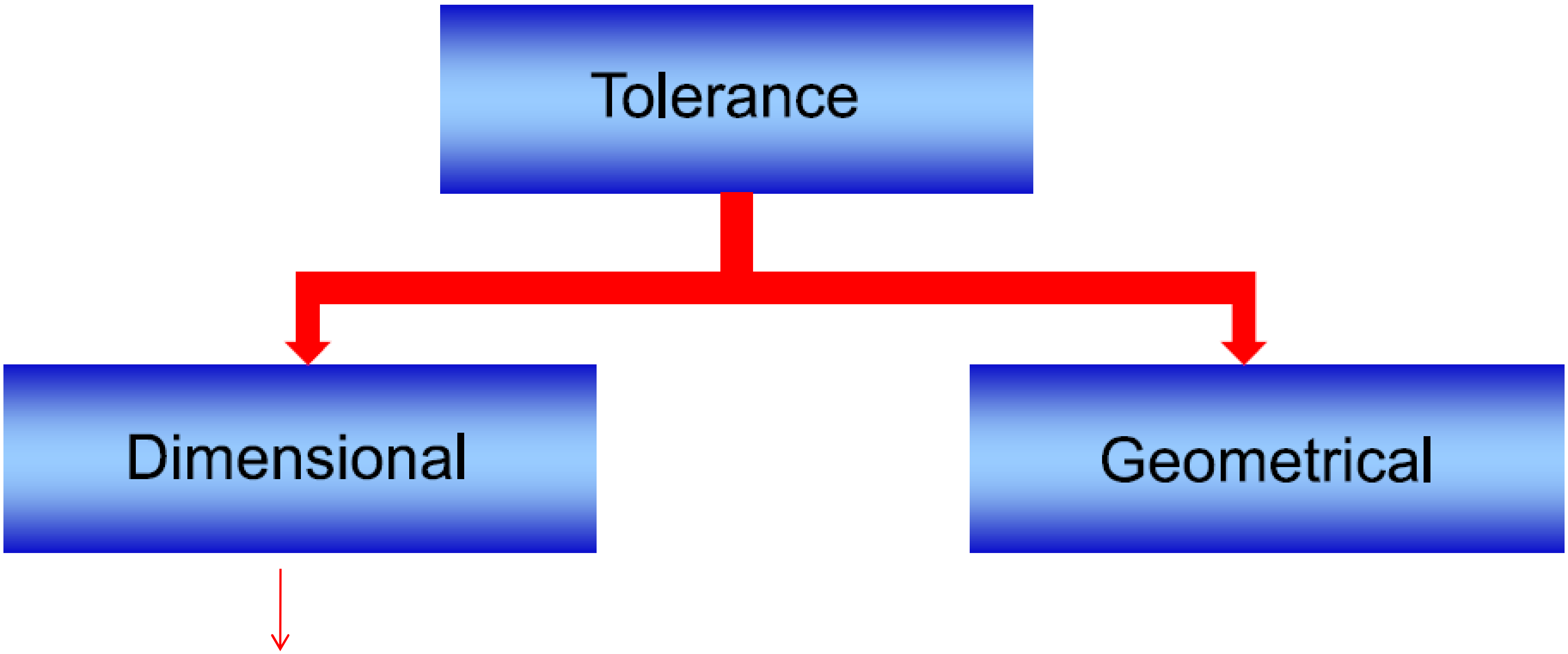
Consequences

- Cost generally increases with Smaller (tighter) tolerances.

- Parts with Smaller tolerances often require special methods of manufacture.

- Parts with Smaller tolerances often require greater inspection and call for rejection of parts .

Specification



" the total amount by which a specified dimension is permitted to Vary"

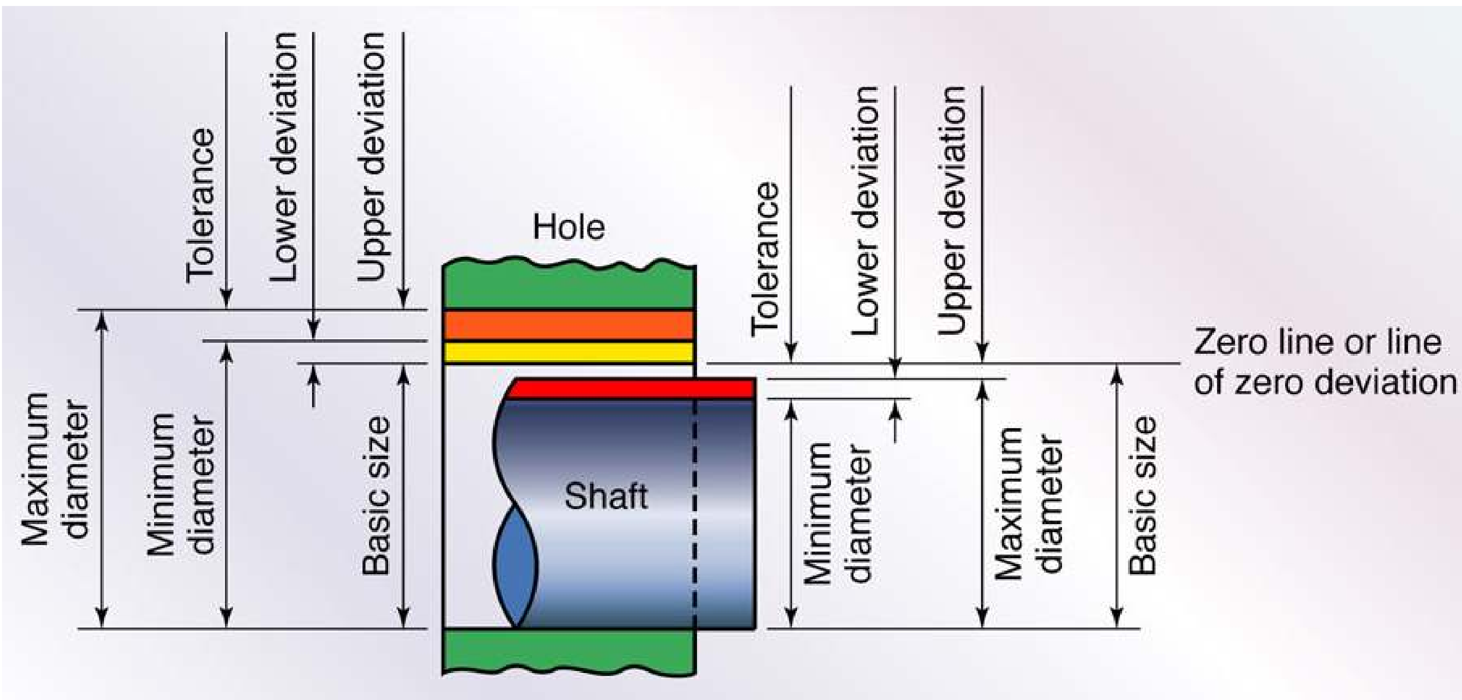
ANSI (**A**merican **N**ational **S**tandards **I**nstitute)

Some Definitions

Basic Size: The size with reference to which the limits of size are fixed.

Actual Size: Actual measured dimension of the part.

Zero Line: It is a straight line corresponding to the basic size. The deviations are measured from this line. The positive and negative deviations are shown above and below the zero line respectively.



Some Definitions

Limits of Size: The two extreme permissible sizes of a part between which the actual size should lie.

Maximum Limit of Size: The greater of the two limits of size.

Minimum Limit of Size: The smaller of the two limits of size.

Shaft: A term used by convention to designate all **external** features of a part, including those which are not cylindrical.

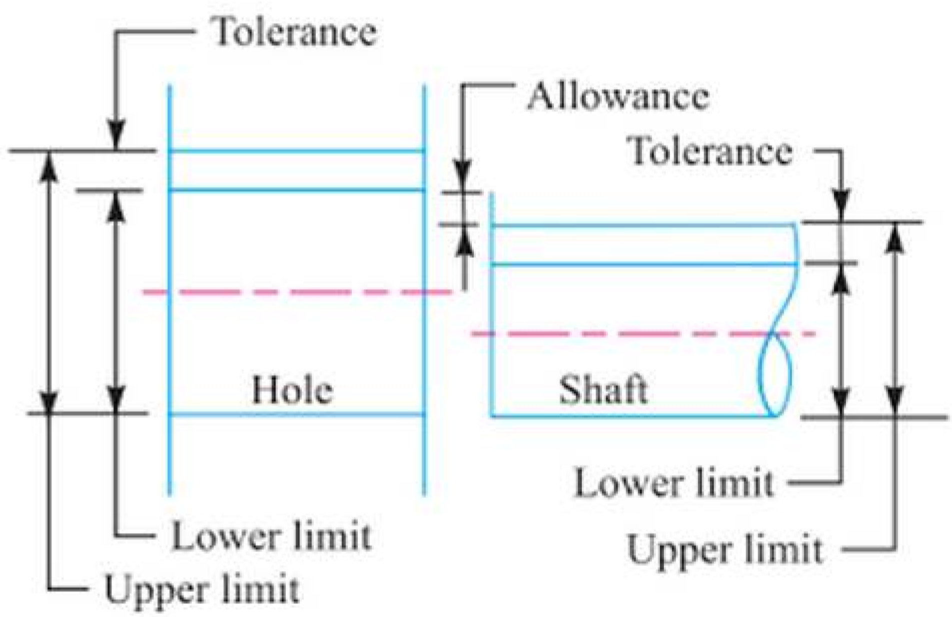
Hole: A term used by convention to designate all **internal** features of a part, including those which are not cylindrical.

Some Definitions

Allowance: It is the difference between the basic dimensions of the mating parts.

When the shaft size is less than the hole size, then the allowance is positive and when the shaft size is greater than the hole size, then the allowance is negative.

Tolerance: It is the difference between the upper limit and lower limit of a dimension.



Some Definitions

Tolerance Zone: It is the zone between the maximum and minimum limit size.

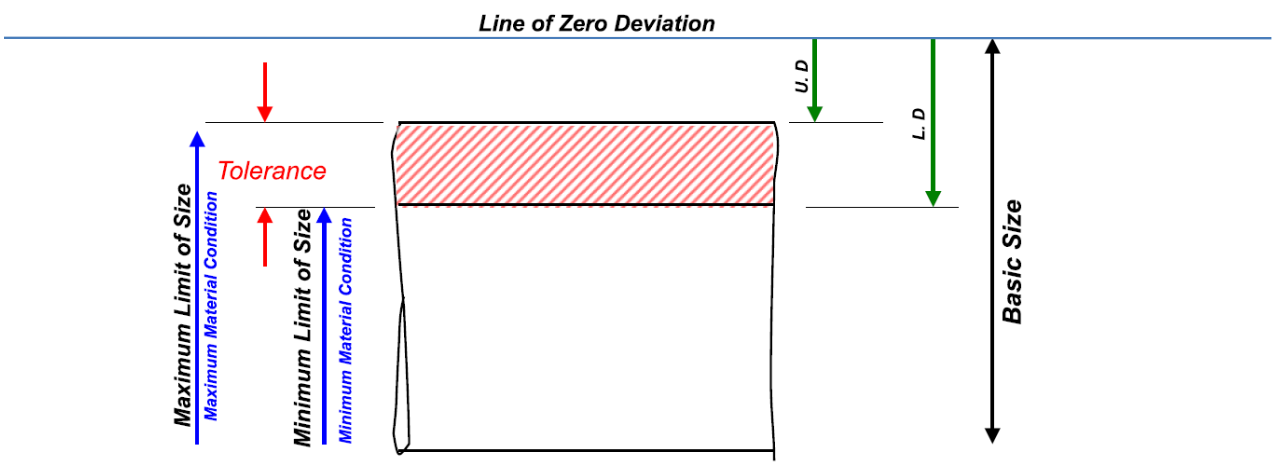
Upper Deviation: It is the algebraic difference between the maximum size and the basic size.

The upper deviation of a hole is represented by a symbol ES (Ecart Superior) and of a shaft, it is represented by es.

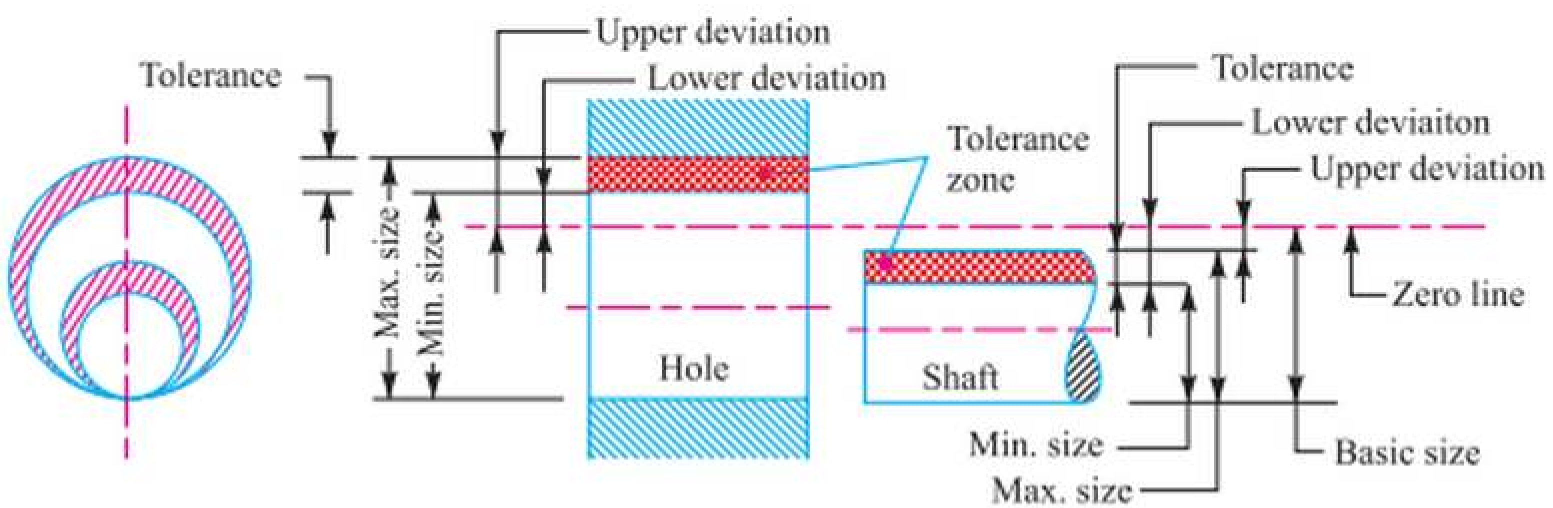
Lower Deviation: It is the algebraic difference between the minimum size and the basic size.

The lower deviation of a hole is represented by a symbol EI (Ecart Inferior) and of a shaft, it is represented by ei.

Shaft



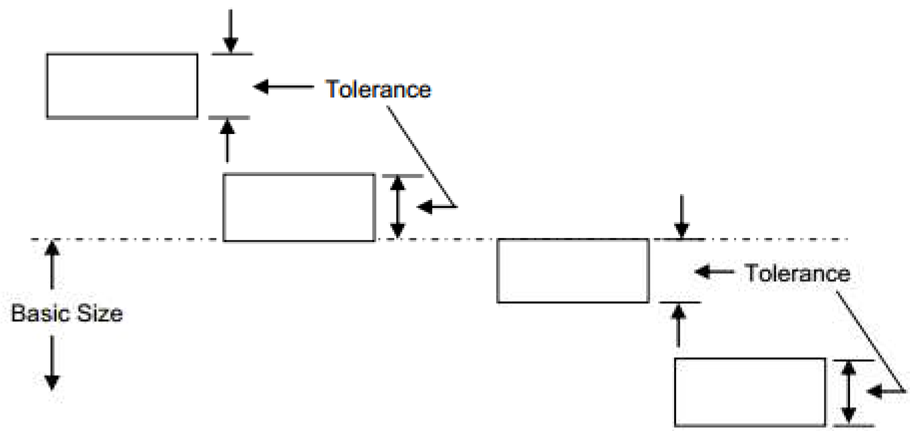
Some Definitions

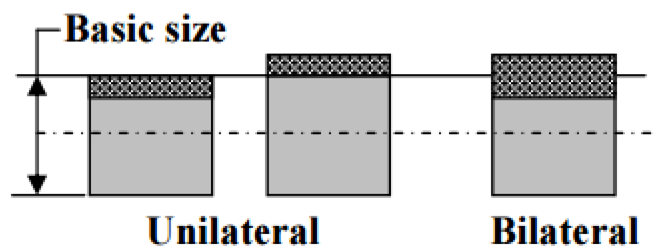


Specification of DT

Unilateral Tolerance

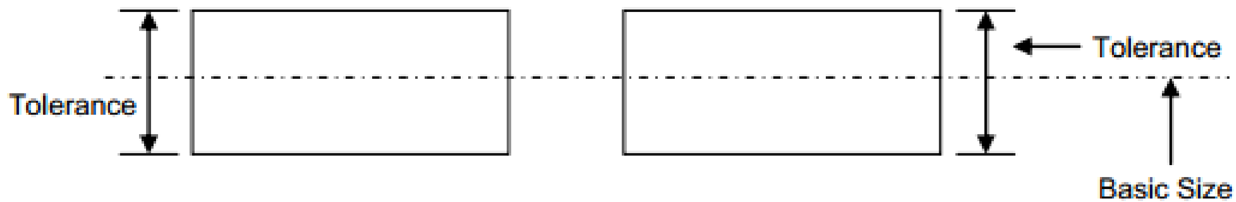
In this system, the dimension of a part is allowed to vary only on one side of the basic size, i.e. tolerance lies wholly on one side of the basic size either above or below it.





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.



Specification of DT

Bilateral

$$20 \pm 0.5$$

$$20^{+0.5}_{-0.5}$$

20.05
19.95

Unilateral

$$20^{+0.5}_{0}$$

20.05
20.00

Exercise

- $2.5^{+0.010}_{-0.005}$
- $2.5^{+0.0}_{-0.005}$
- $2.5^{-0.001}_{-0.005}$

Q1. Type?

Bilateral, Unilateral, Unilateral.

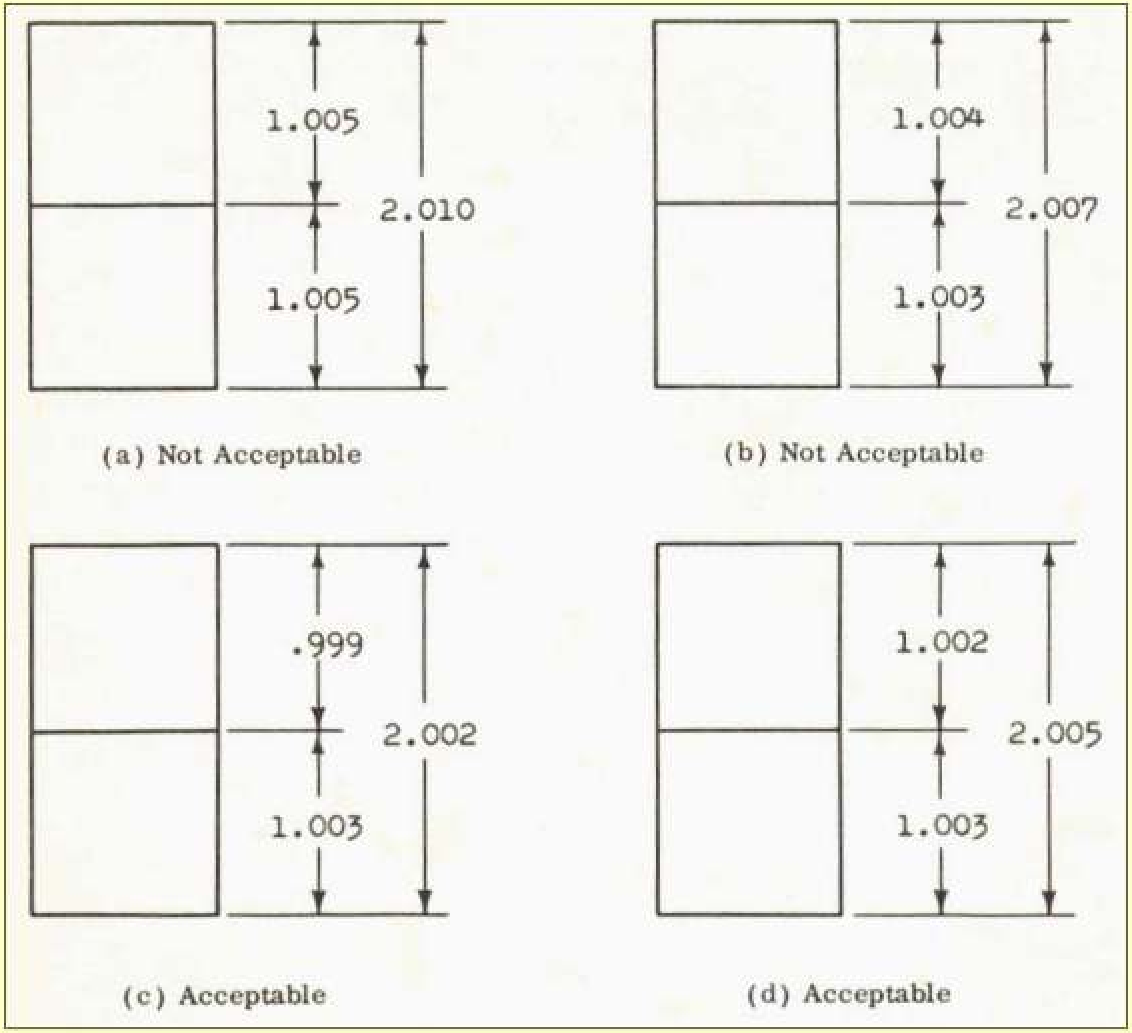
Q2. Tolerance?

0.015, 0.005, 0.004

Q3. Express in limit form?

In unilateral tolerance variation can be only in one direction. That is either Negative or Positive

Tolerance Stacks

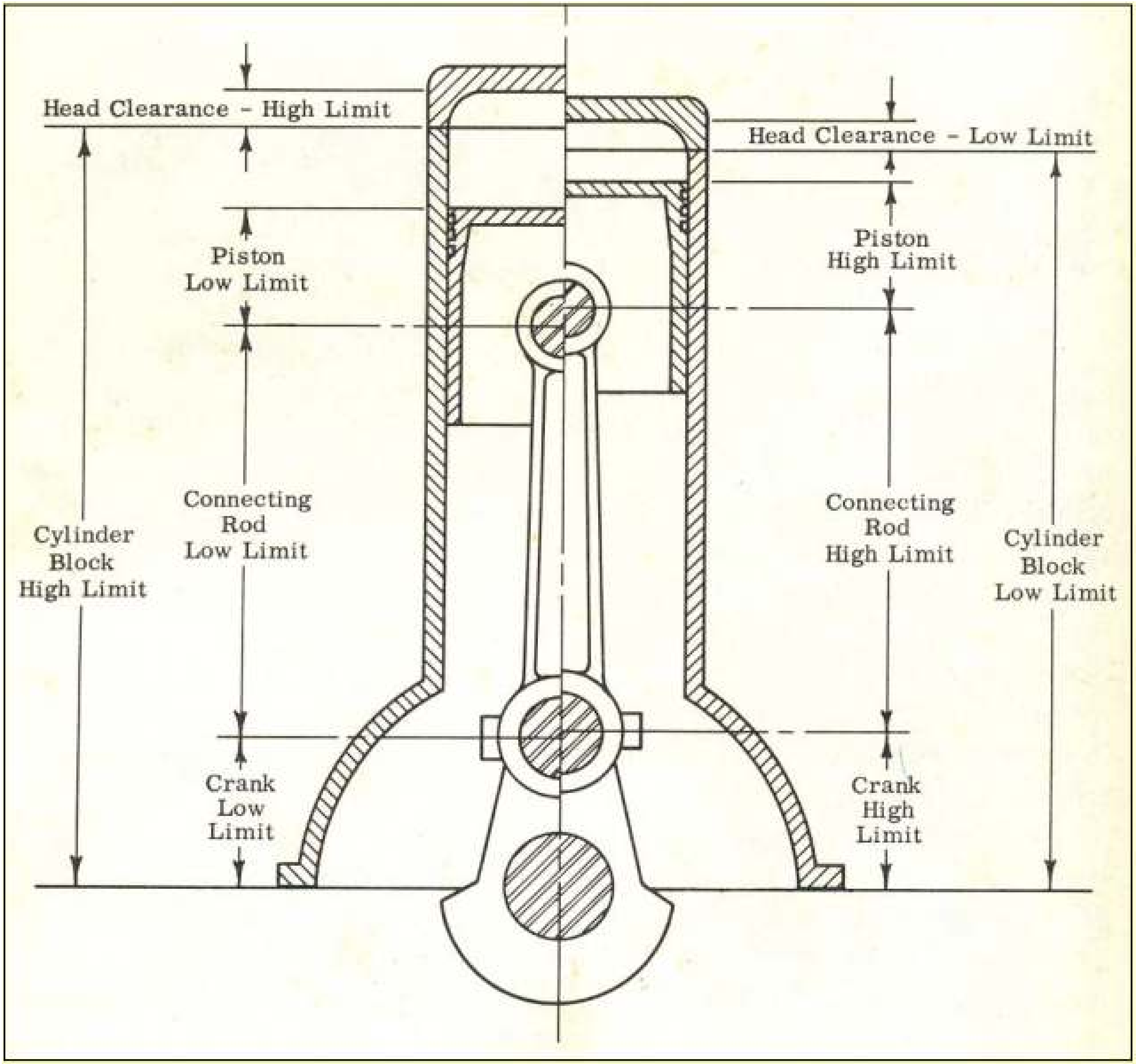


- Cubes are machined to 1.000±0.005
- If two cubes are stacked the desired height is 2.000±0.005

➢ Design tolerance stack

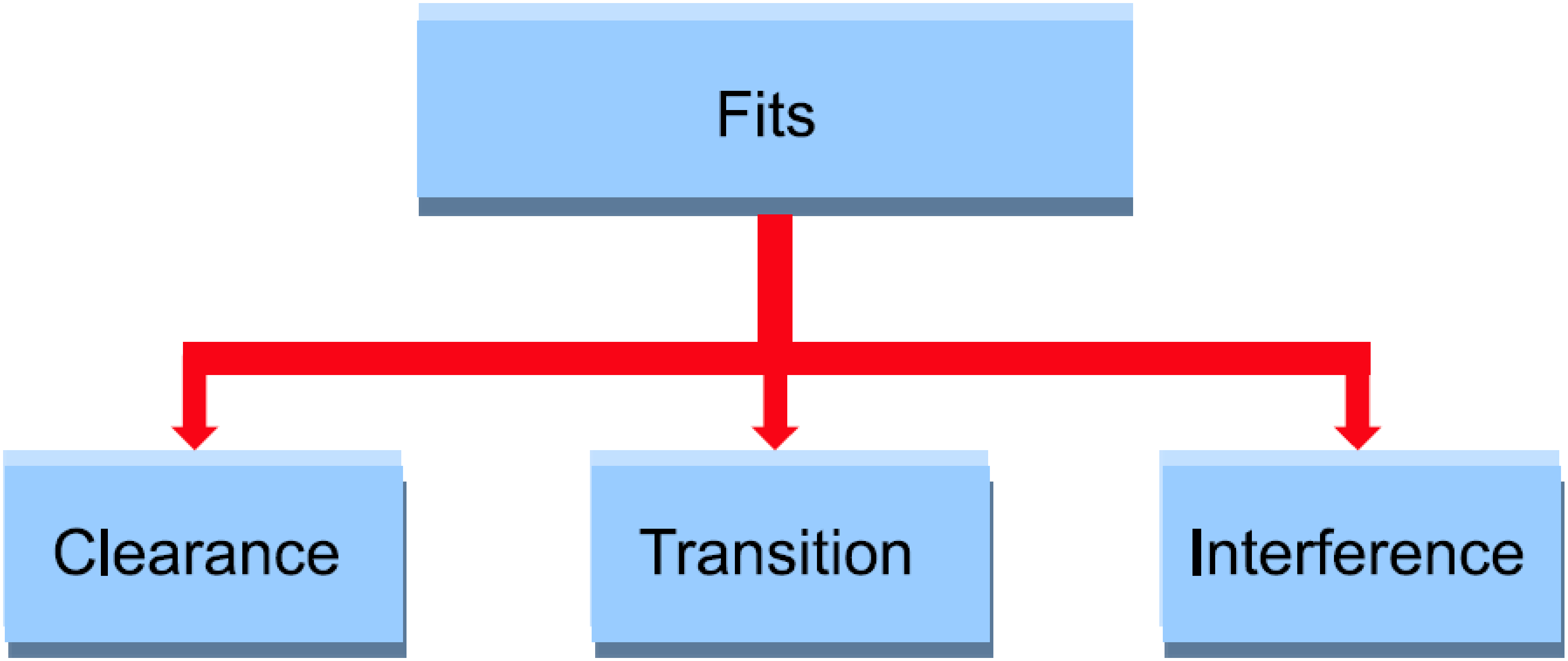
➢ Process tolerance stack

Effect of Tolerance Stacking



Fit

A fit may be defined as the degree of tightness and looseness between two mating parts.



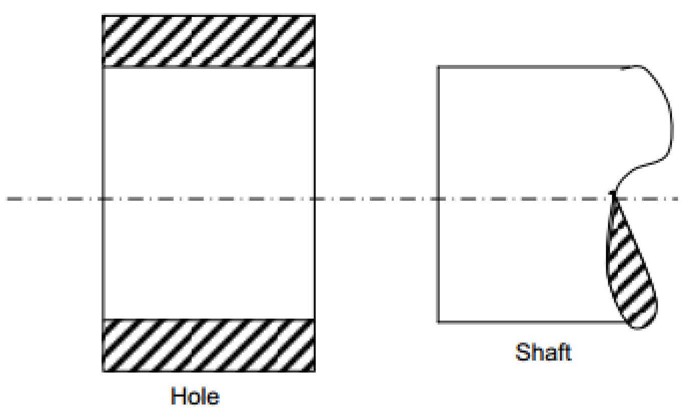
Clearance Fit

➢ In clearance fit, an air space or clearance exists between the shaft and hole.

➢ 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.

➢ Allows rotation or sliding between the mating parts.



- *Clearance = Hole - Shaft*
- *Hole - Shaft > 0*
- *Hole > Shaft*

Types of Clearance Fit

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.

Slide Fit or Medium Fit

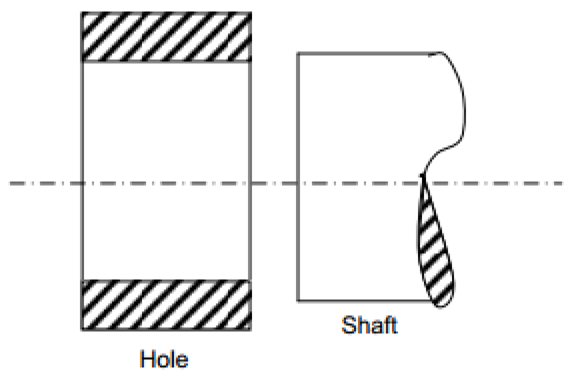
It is used on those mating parts where great precision is required. It provides medium allowance and is used in tool slides, slide valve, automobile parts, etc.

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.

➢ It used for components where motion, power has to be transmitted.



- *Interference = (- Clearance)*
- *Hole - Shaft < 0*
- *Hole < Shaft*

Interference exists between the high limit of hole and low limit of the shaft.

Types of Interference Fit

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 Force Fit

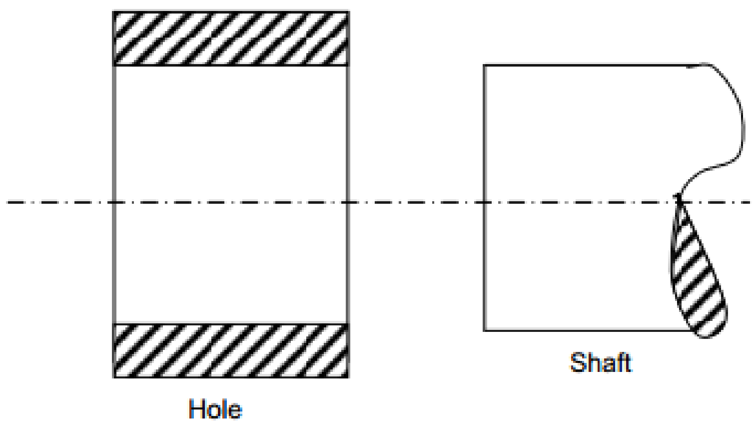
One part can be assembled into the other with a hand hammer or by light pressure. A slight negative allowance exists between two mating parts (more than wringing fit). It gives a semi-permanent fit and is used on a keyed pulley and shaft, rocker arm, etc.

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.



Types of Transition Fit

Push Fit or Snug Fit

It refers to zero allowance and a light pressure is required in assembling the hole and the shaft. The moving parts show least vibration with this type of 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.