Limits, Fits and Tolerances

Prof. S. S. Pande

Mechanical Engineering Department
Indian Institute of Technology, Bombay

Outline

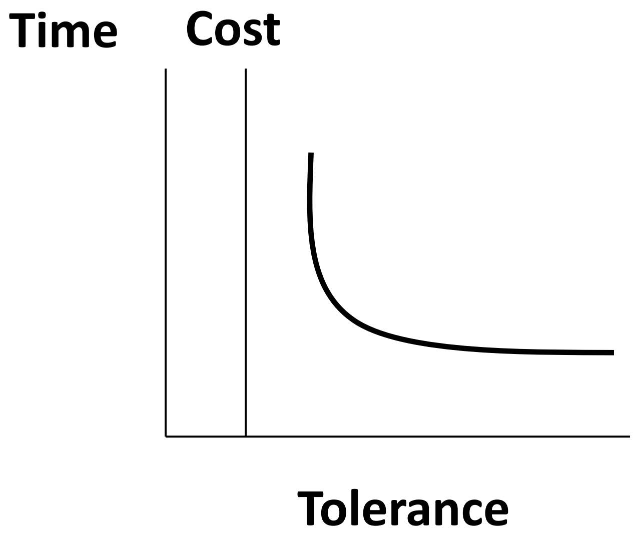
- Basic Definitions
- ISO system for Tolerance Specification
- Tolerance Design for assembly- Fits
- Design of Limit Gages
    - Taylor’s Principle

What is Tolerance ?

Permissible variation in the size (dimension) of a component to suit *Functional Requirements*

How to choose Tolerance?

- Part *Function*
- Cost of Production
- Productivity (Time)
- Availability of Manufacturing Resources



Tolerance Callout

Numeric

$25^{+0.020}_{+0.015}$ 25 0.010 $25^{+0.015}_{-0.010}$

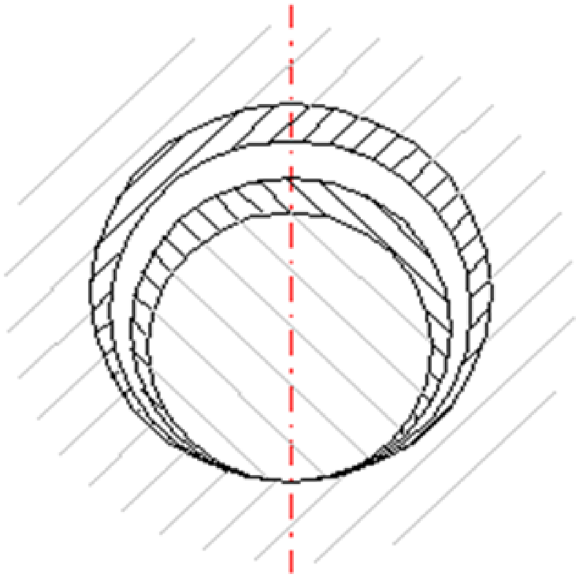
AlphaNumeric (ISO)

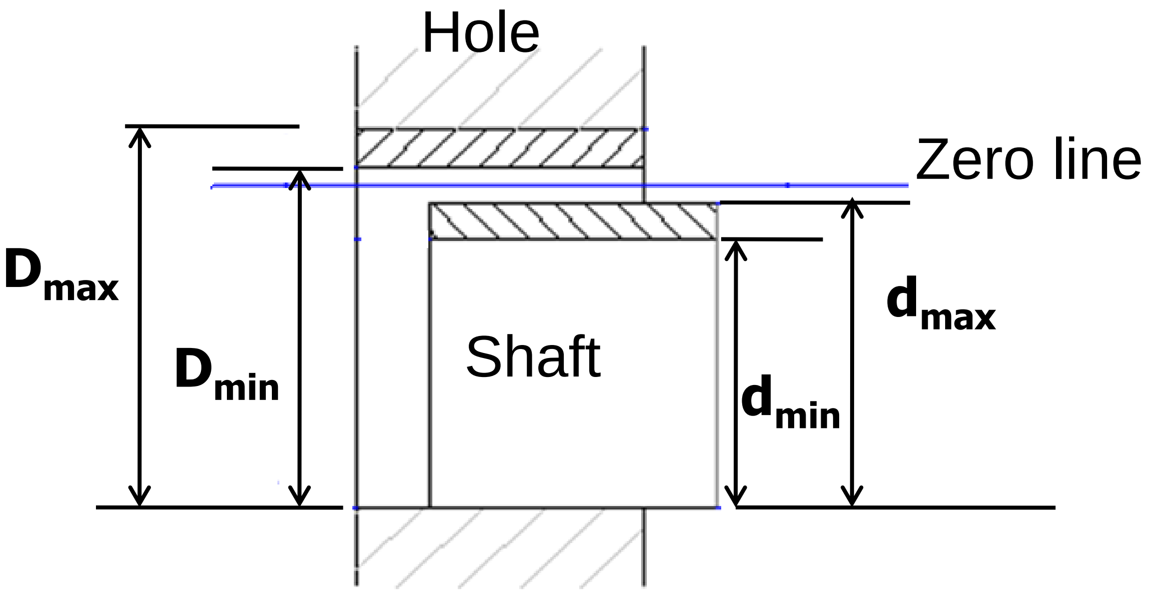
Hole : 25 H7

Shaft : 25 g6

Assembly : 25H7g6

Tolerance Zones – Shaft and Hole





Basic Definitions

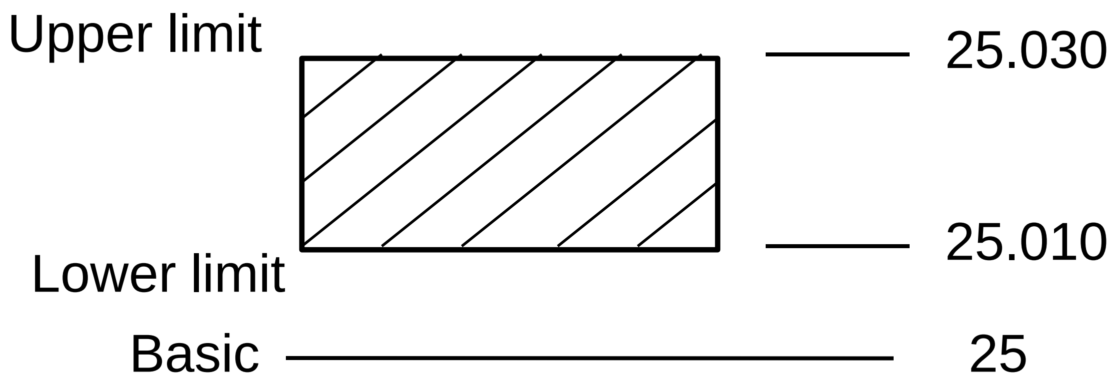
Hole : $25.0^{+0.030}_{+0.010}$ mm

Shaft/ Hole : External / Internal feature of a part
Basic Size : 25.00 mm
Upper Limit : 25.030 mm
Lower Limit : 25.010 mm
Tolerance : Upper limit – Lower limit
= 0.020 mm = 20 microns

Hole Designation : A, B, ……Z, Z_a, Z_b, Z_c – 25 Nos
Shaft Designation : a, b, ……z, z_a, z_b, z_c – 25 Nos

Tolerance Zone and Limits

Hole : $25^{+0.030}_{+0.010}$



Tolerance = 0.020 mm

= 20 µm

Tolerance Zone Location

Hole : $25.0^{+0.030}_{+0.010}$ mm

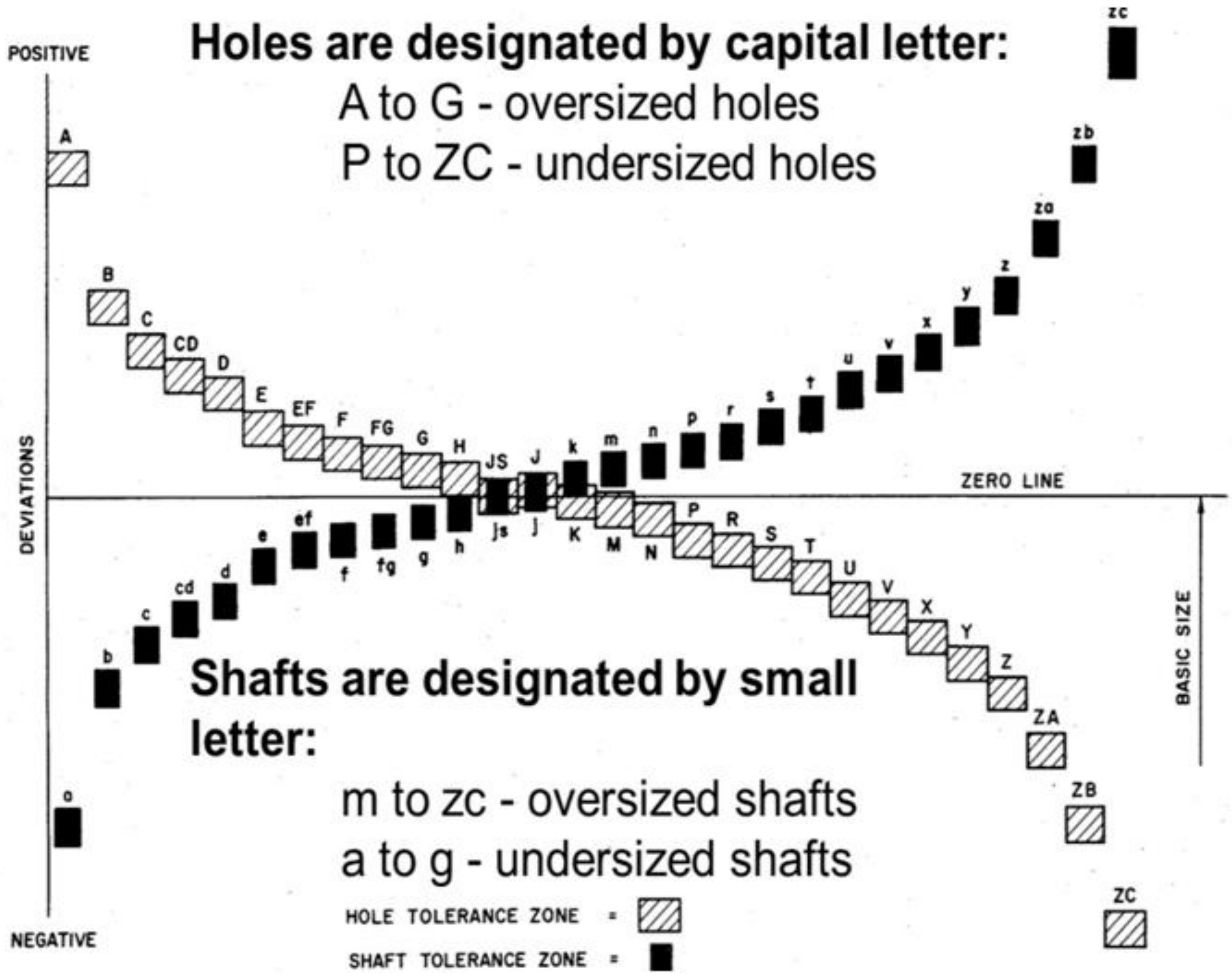
Upper Deviation : Upper limit – Basic size
= 0.030 mm

Lower Deviation : Lower limit – Basic size
= 0.010 mm

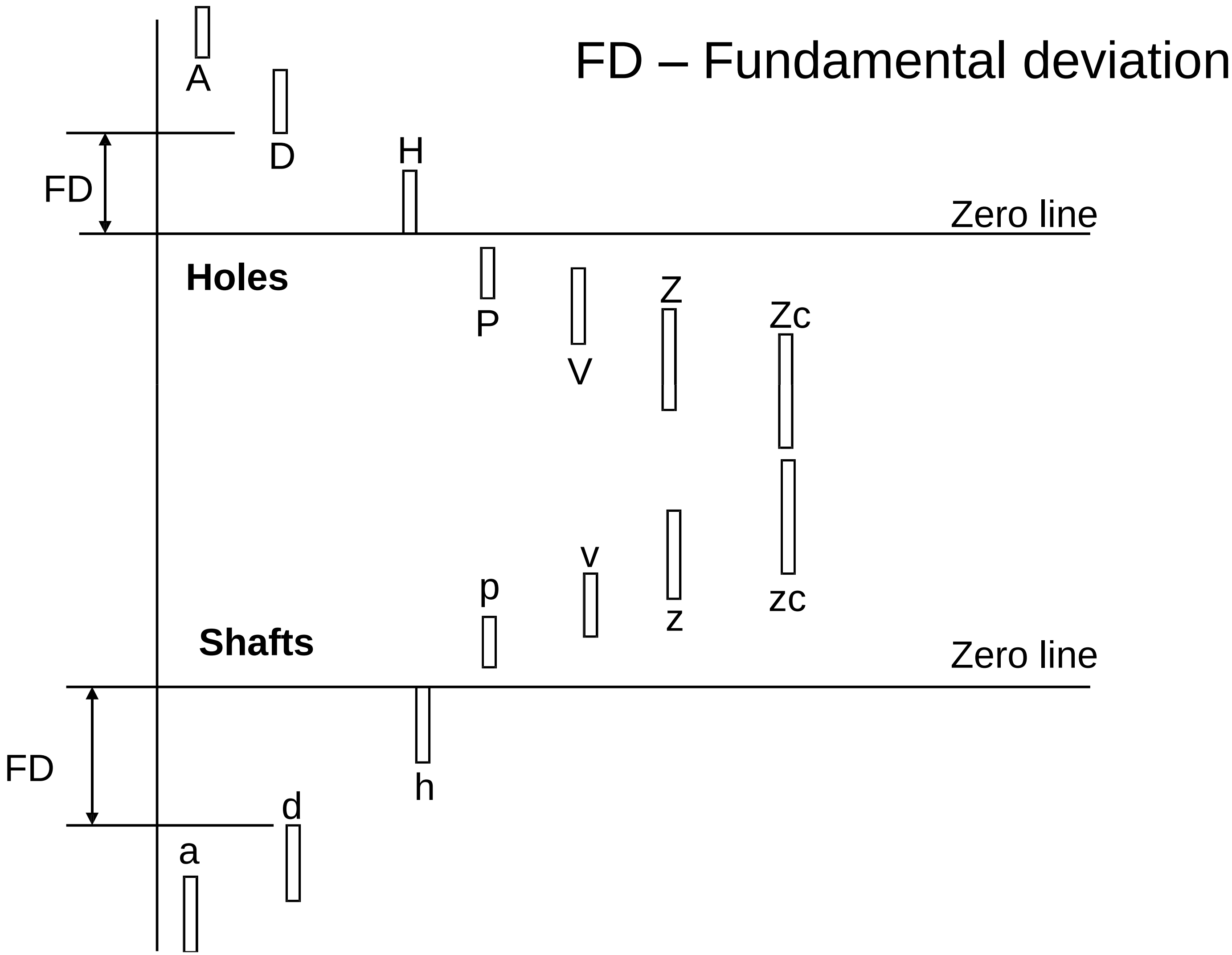
Fundamental Deviation = 0.010 mm
Locates Tolerance zone

Basic Shaft : h | Fundamental Deviation
Basic Hole : H | is zero

ISO Tolerance Grades for Shafts and Holes



Tolerance zones - Shafts and Holes



Grades of Tolerance

There are 18 grades of tolerances

IT01, IT0, IT1 to IT16

IT01 to IT4 – Gauges, measuring instrument

IT5 to IT7 – Precision Engg applications

IT8 to IT11 – General Engineering

IT12 to IT14 – For Sheet metal working

IT15 to IT16 – Casting, General cutting work

Tolerance Allocation

Standard Tolerance Unit i

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

D (mm) : Geometric mean of the lower and upper limits of a diameter step in which the dimension lies.

Diameter steps

1-3	**3-6**	**6-10**	**10-18**	**18-30**
30-50	**50-80**	**80-120**	**120-180**	**180-250**
250-315	**315-400**	**400-500**		

Tolerance Values

Tolerance has parabolic relationship with the size of parts.

Tolerance values are

IT01 $0.3 + 0.008D$

IT0 $0.5 + 0.012D$

- - - - - - - - - -

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

D in mm, Tolerance in μms.

Fundamental deviations of shafts

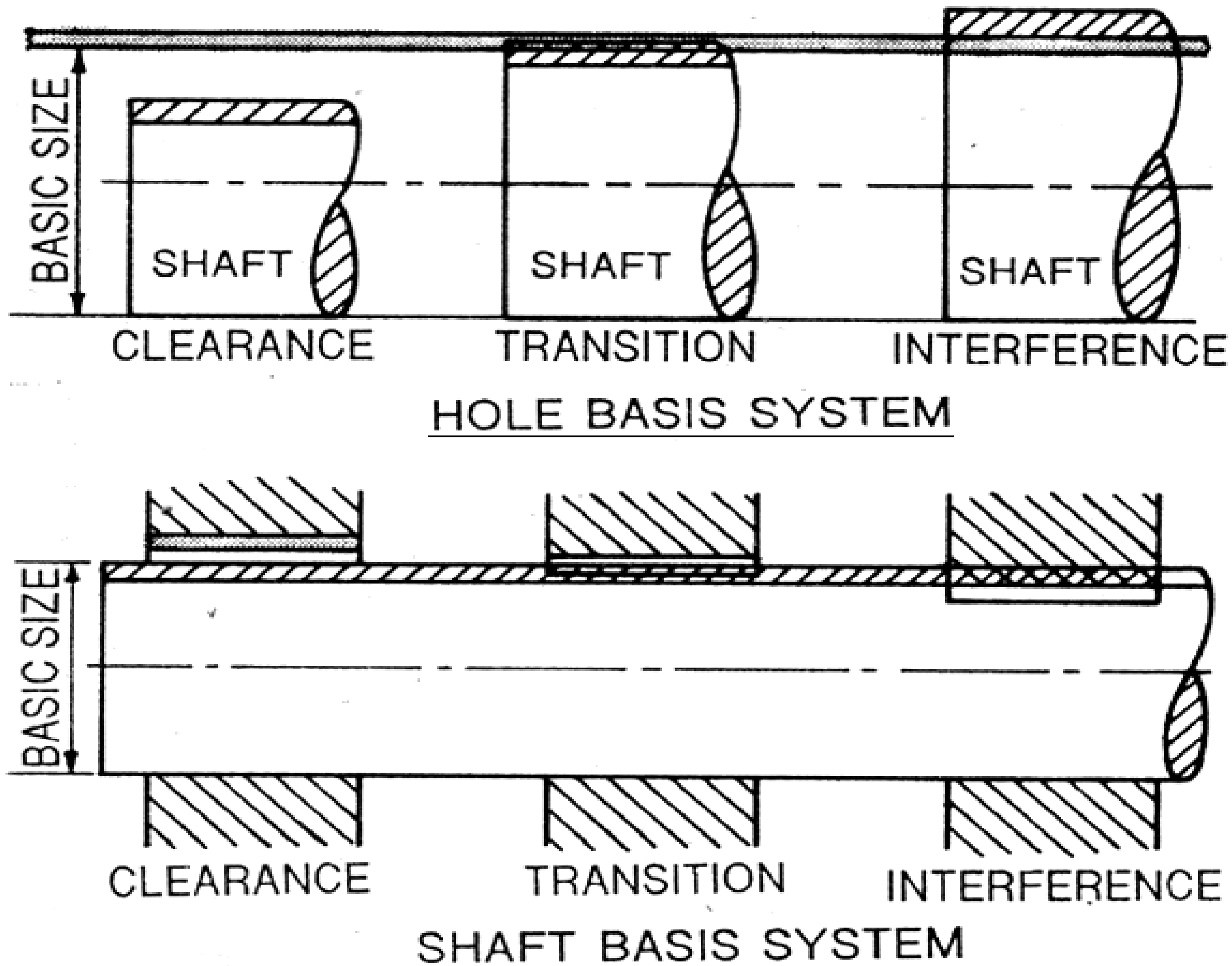
Shaft Designation	Upper Deviation(μms)	
a	$= -(265+1.3D)$	for $D \leq 120$
	$= -3.5D$	for $D > 120$
d	$= -16D^{0.44}$	
g	$= -2.5D^{0.34}$	
h	= Zero	

D in mm

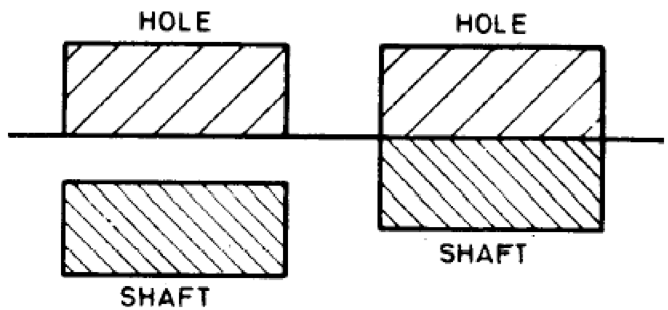
What is a *Fit*?

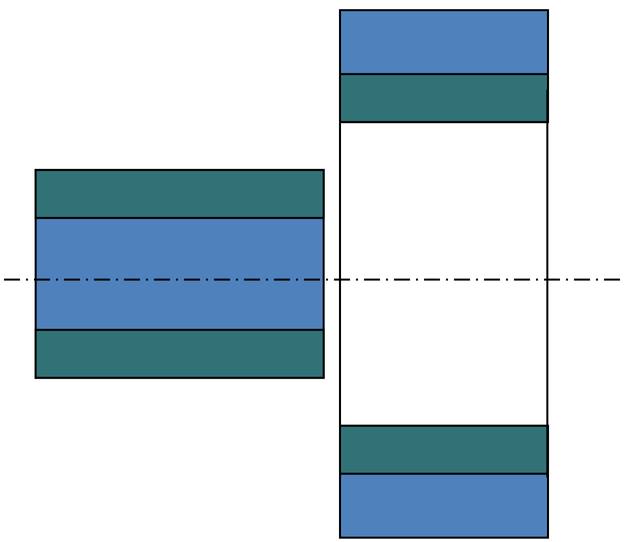
- Relationship between the mating parts <u>before</u> assembly
- *Clearance, Transition, Interference* Fits
- Hole Basis/ Shaft Basis system

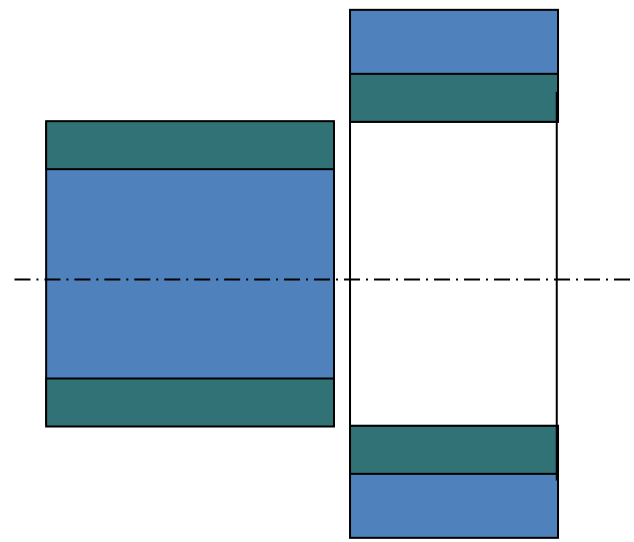
Types of Fits



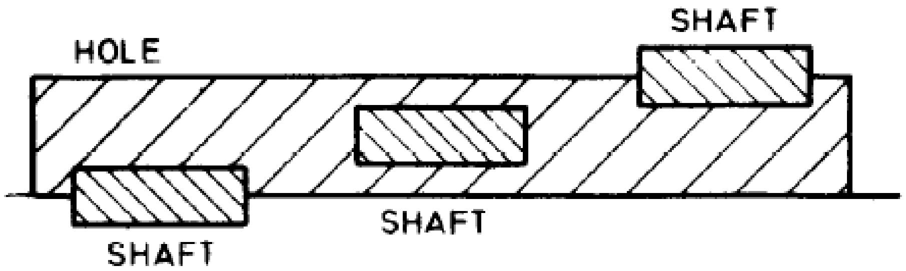
Clearance Fit - Hole Basis

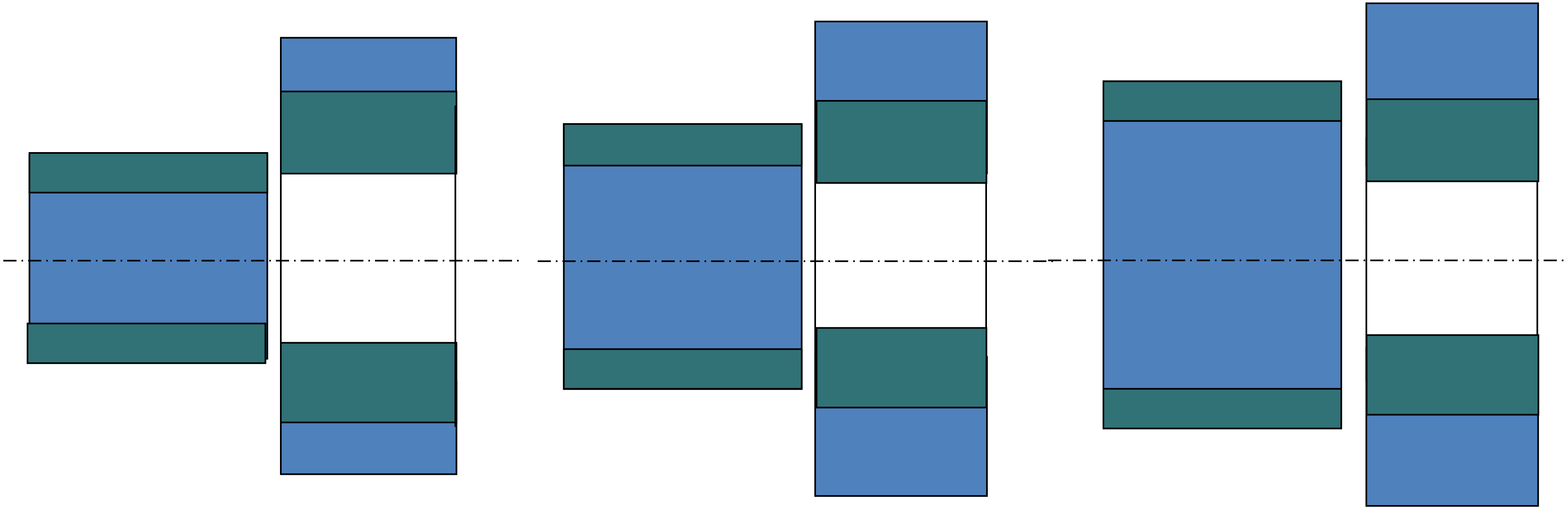




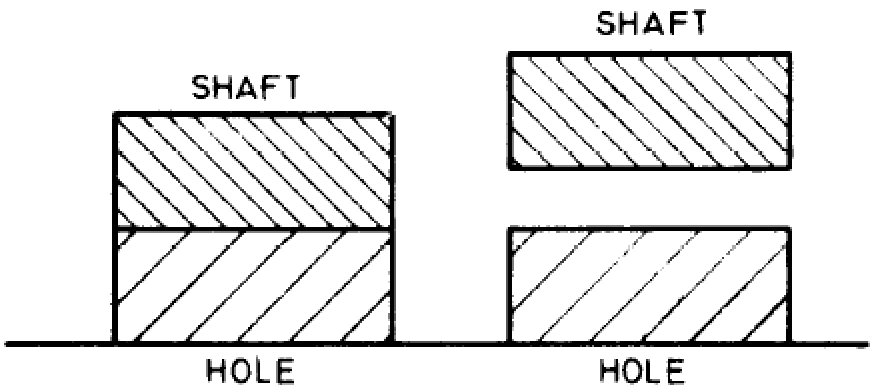


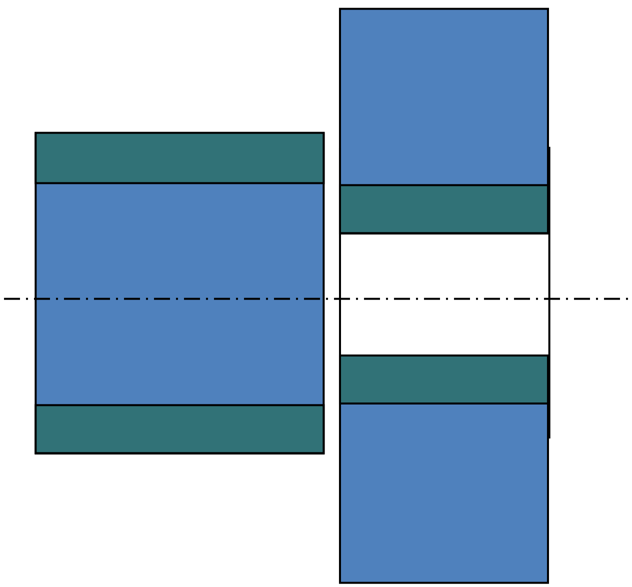
Transition Fit –Hole Basis

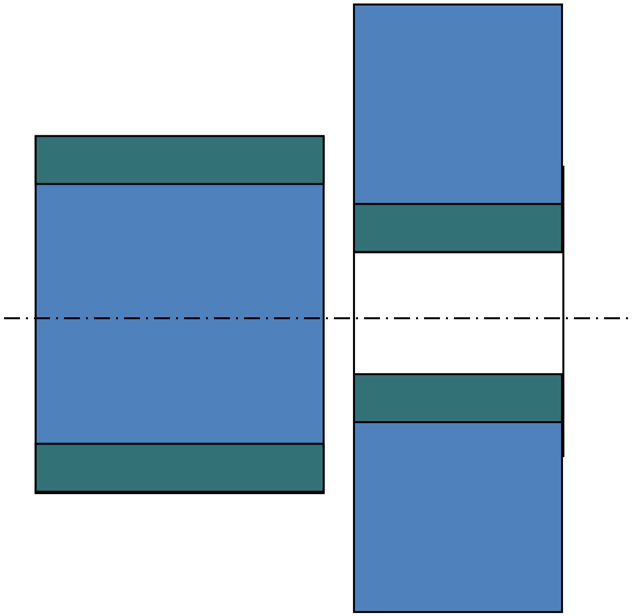




Interference Fit – Hole Basis







Typical Recommended Fits

Clearance Fits

H7/h6 : Sealing rings, bearing covers
H7/g6 : Sleeve shafts, clutches
H7/f7 : High speed bearings, machine tool spindles

Transition Fits

H7/n6 : Gears and bearing bushes, shaft and wheel
H7/m6 : Gears belt pulleys, couplings

Interference Fits

H8/u8 : Worm wheel hubs, couplings
H7/r6 : Coupling of shaft ends, valve seats, gear wheels

Example

Evaluate limits and fits for an assembly pair **6 H7/ g6** mm

<u>Solution:</u>

The size 6 mm lies in the diameter step of 3-6.

$$D = \sqrt{3 \times 6} = 4.24 \text{ mm}$$

The Fundamental tolerance unit is

$$i = 0.45\sqrt[3]{D} + 0.001D$$

$$= 0.7327 \ \mu m$$

Tolerance for hole H7

Tolerance = 16i = 12 μm

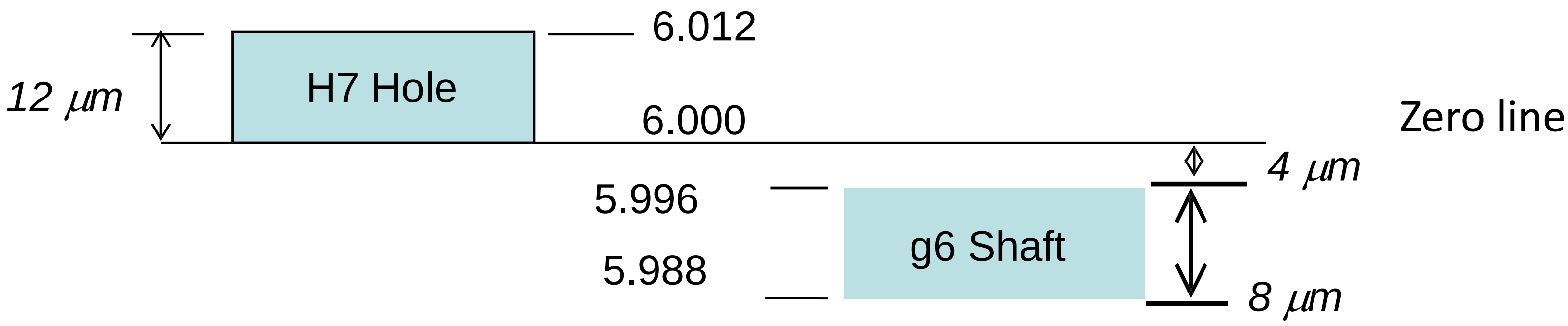
The fundamental deviation H hole = Zero

Tolerance for g6 shaft

Tolerance = 10i = 8 μm

The fundamental deviation for g shaft = -2.5 $D^{0.34}$ = - 4 μm

Tolerance Diagram 6 H7 g6



Fit

Maximum clearance = Maximum size of hole - Minimum size of shaft

= 6.012 – 6.988 = 0.024 mm = **24 µm**

Minimum clearance = Minimum size of hole - Maximum size of shaft

= 6.000 - 6.996 = 0.004 mm = **4 µm**

The type of fit is Clearance.

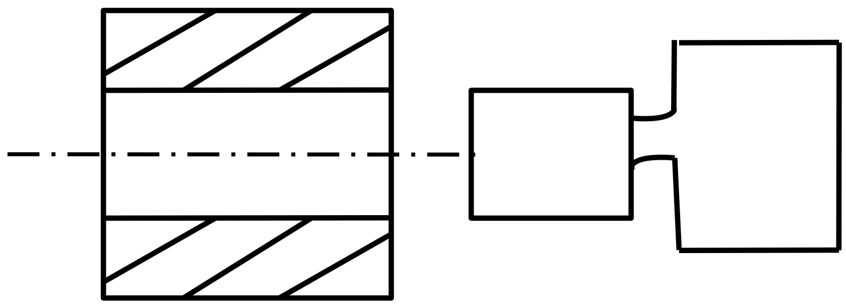
Go-NoGo Limit Gages

Objective

- Check if the part size is within the *Upper* and *Lower* size Limits
- Go gage should always go (into the part).
- NoGo gage should NOT go.
- Go gage should check both part Form and Dimension.

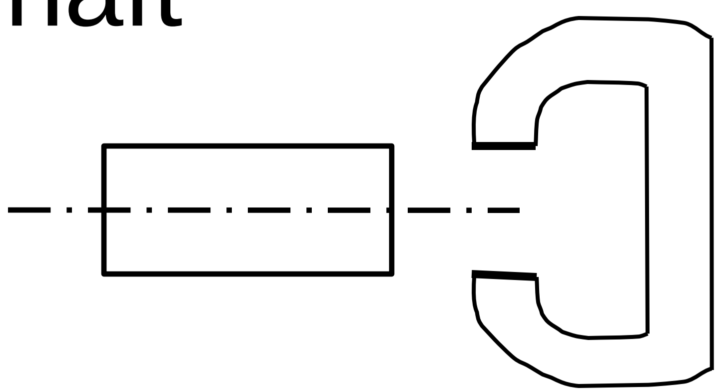
Types of Limit Gages

Hole



Plug Gage

Shaft



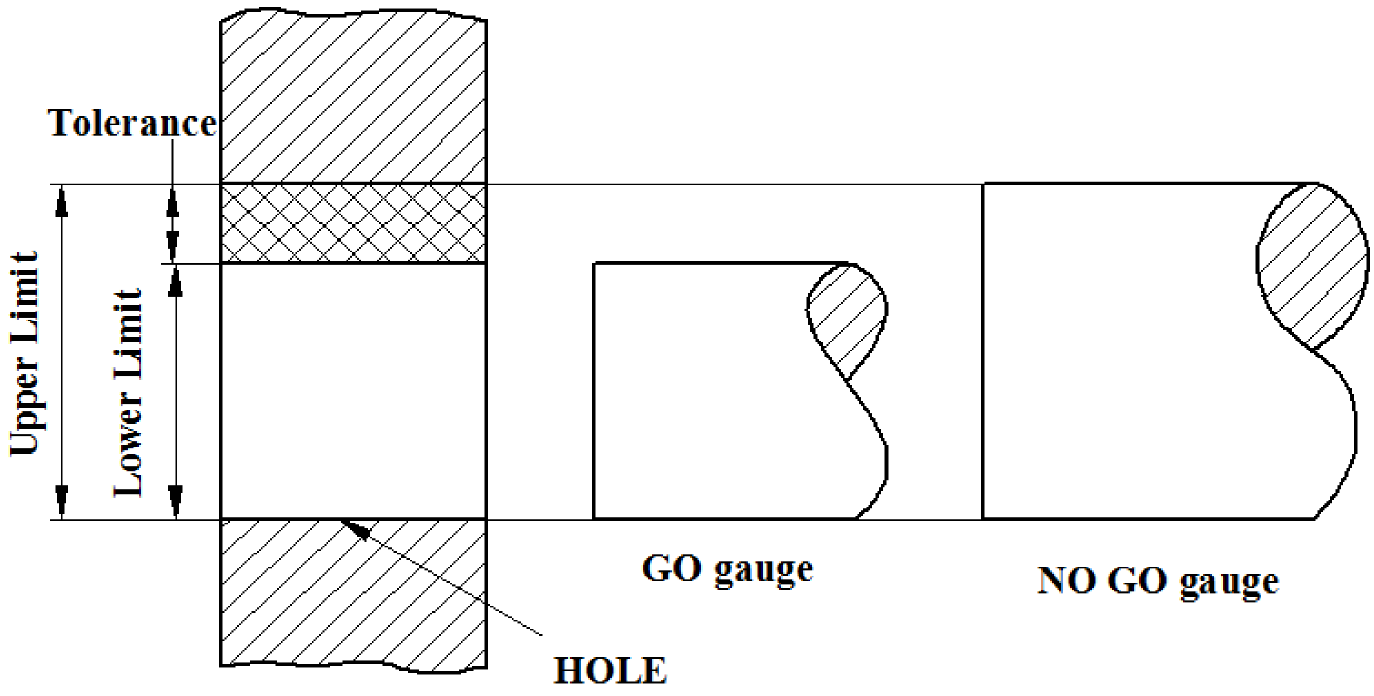
Ring Gage

Taylor's Principle for Gage Design

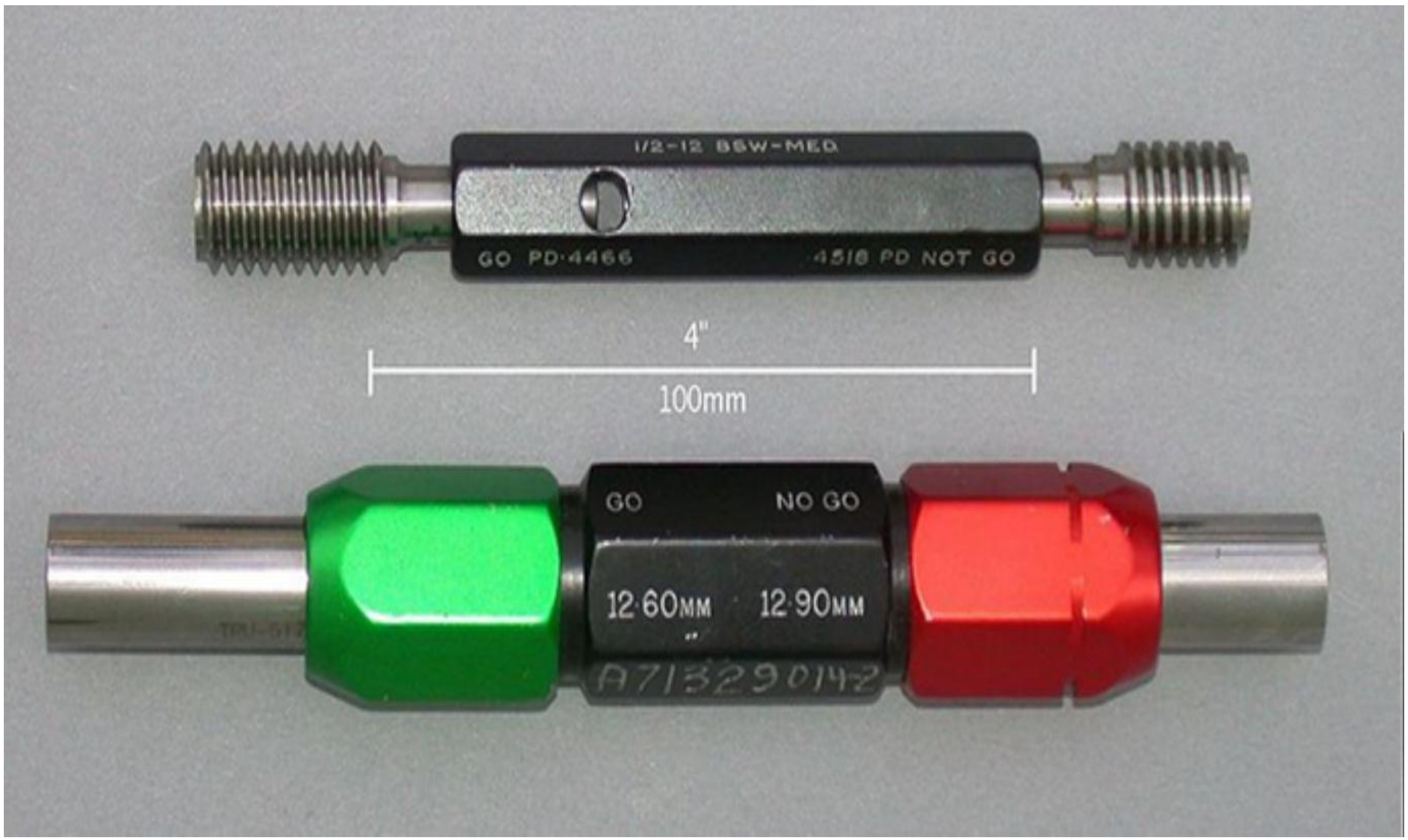
Go gage size corresponds to the *Maximum Material Condition* (MMC) of the Part.

- Upper size limit for Shaft
- Lower size limit for Hole

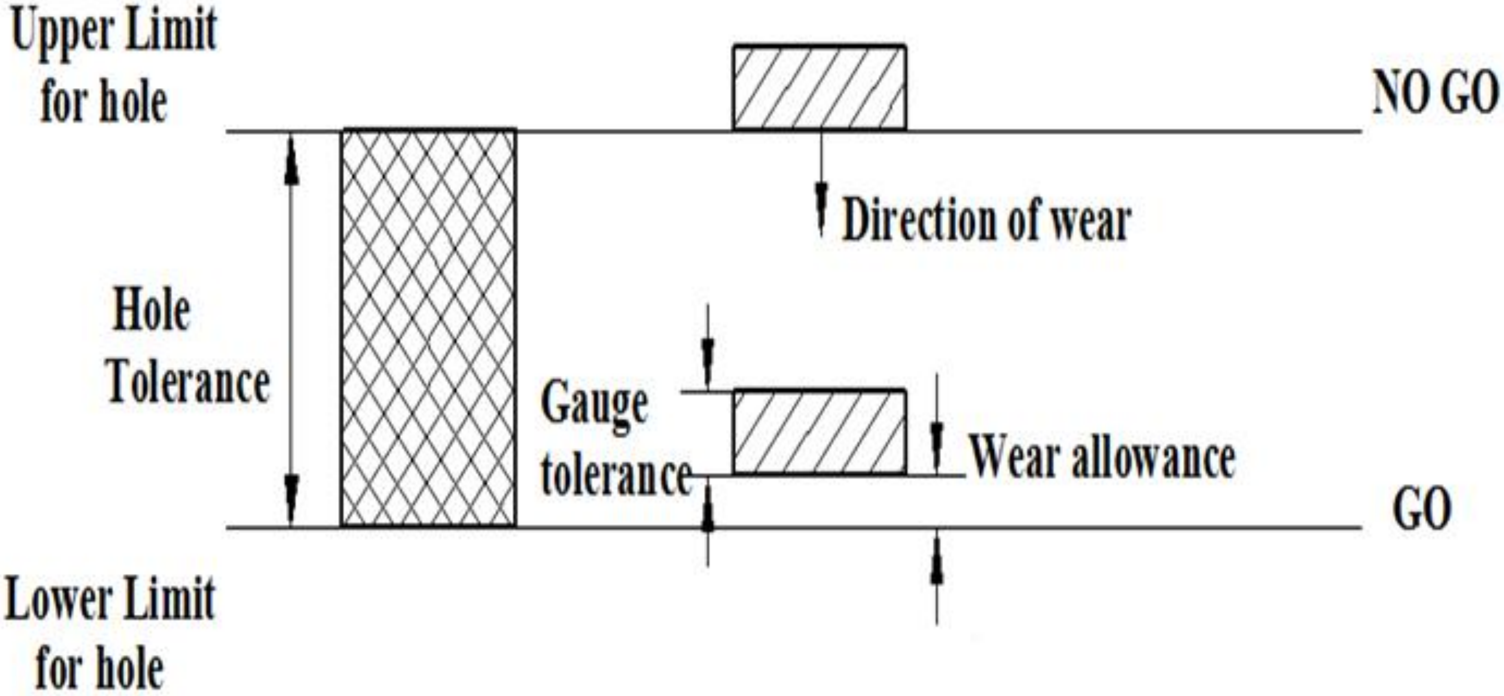
Plug Gages : Go – NoGo



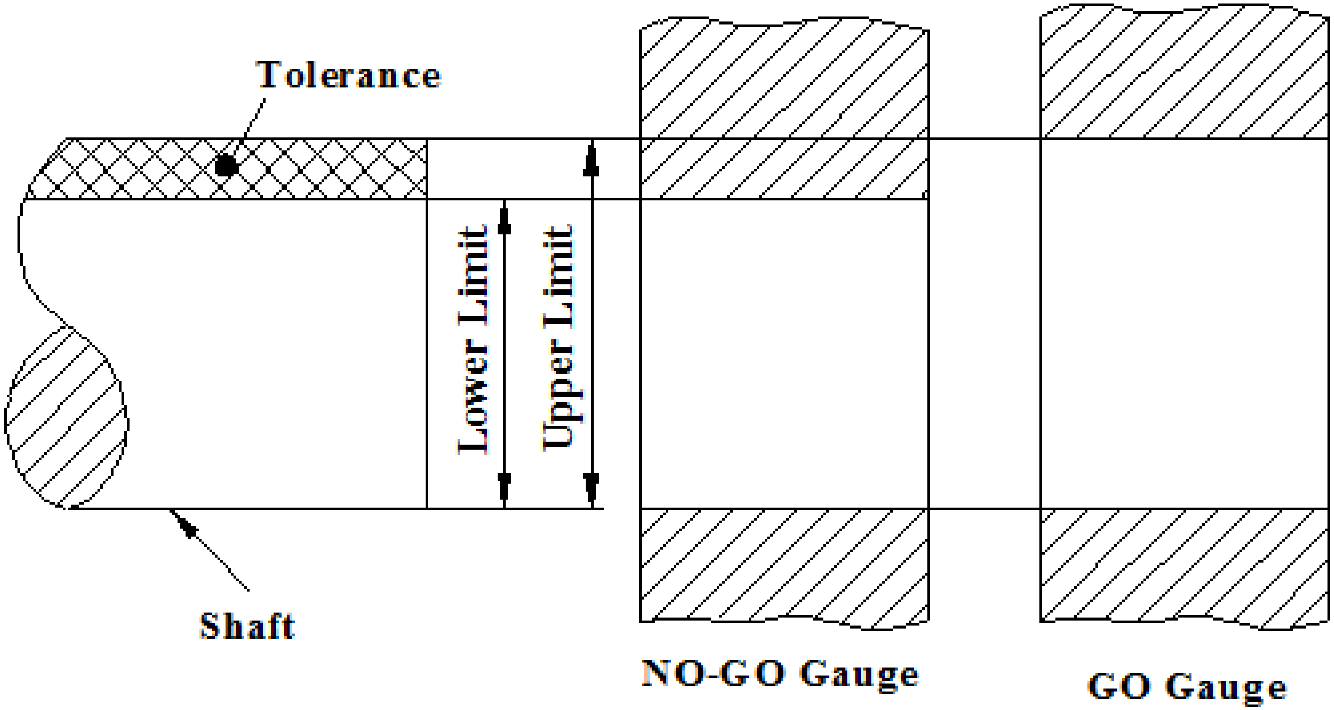
Plug Gages : Go – NoGo



Gage Tolerances – Plug Gages



Ring Gages : Go – NoGo



Ring Gages : Go – NoGo