DESIGN OF MACHINE ELEMENTS

Module-I

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Poor Design??

Ref:http://www.boredpanda.com/poor-design-decisions-fails/

Machine Design

- Definition
  - Machine Design is defined as the use of scientific principles, technical information and imagination in the description of a machine or a mechanical system to perform specific functions with maximum economy and efficiency
  - Design is an innovative and highly iterative process

The Design Process

- Market survey

Contd…

Ref: https://www.carwale.com/rollsroyce-cars/

Ref:http://www.lamborghinila.com/

Ref:https://www.cardekho.com/Tata/Tata_Nano

Product Specification

Contd…

Selection of Mechanism

Contd…

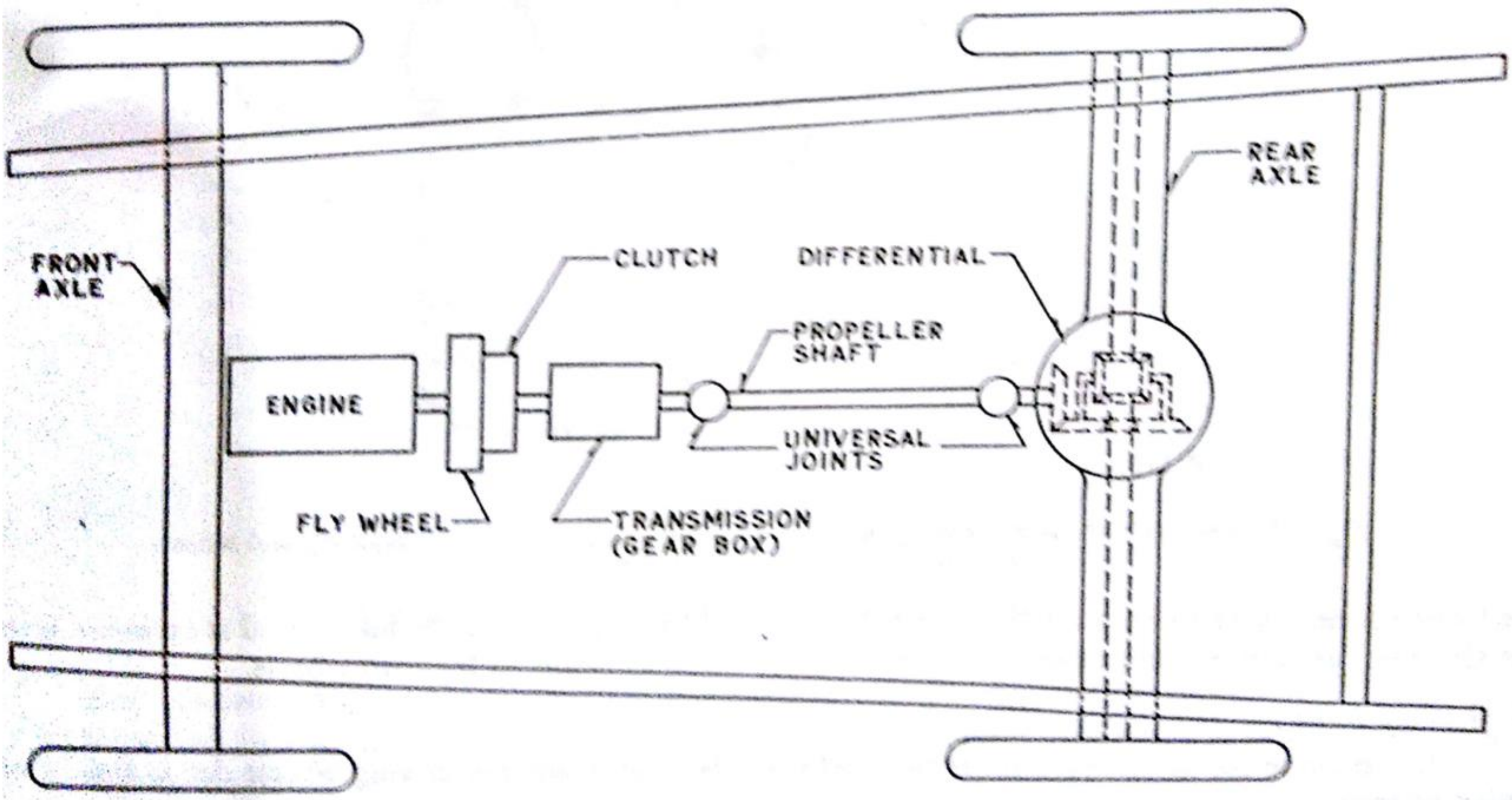

Fig. 1.4. Layout of complete transmission system of an automobile.

Layout of configuration and selection of joining methods

Ref. Automobile Engineering, Vol-1, Dr. Kirpal SIngh

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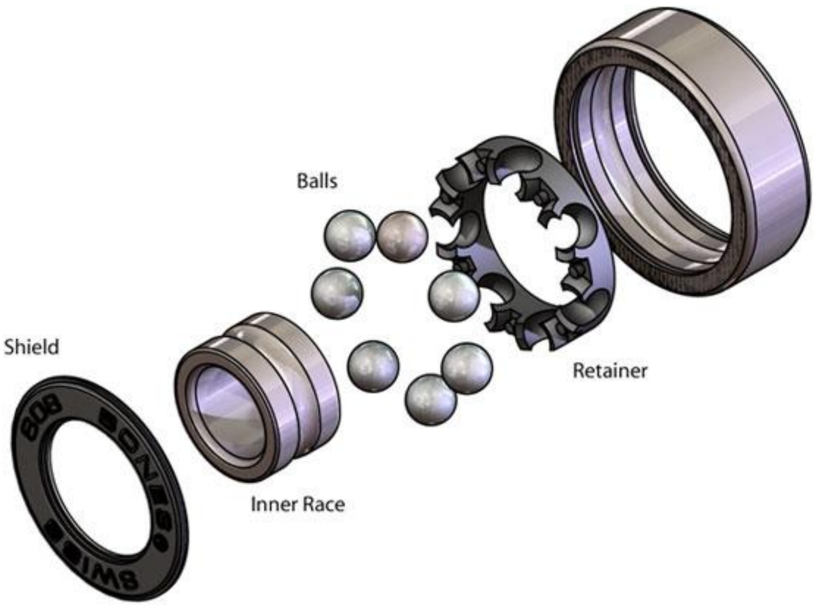

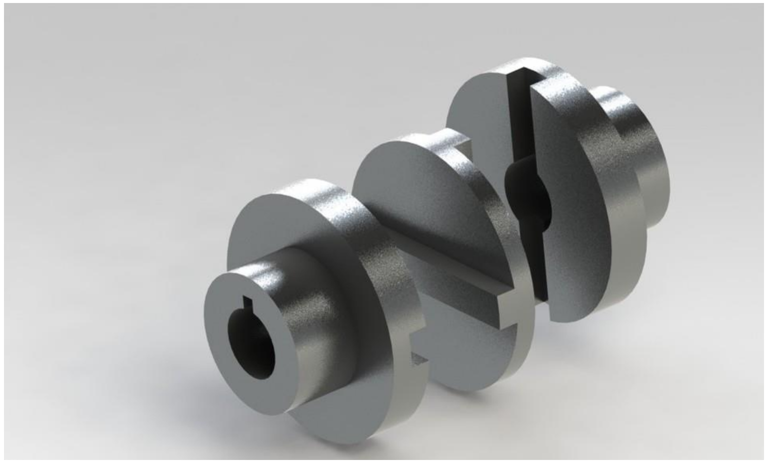

Design of Individual Components

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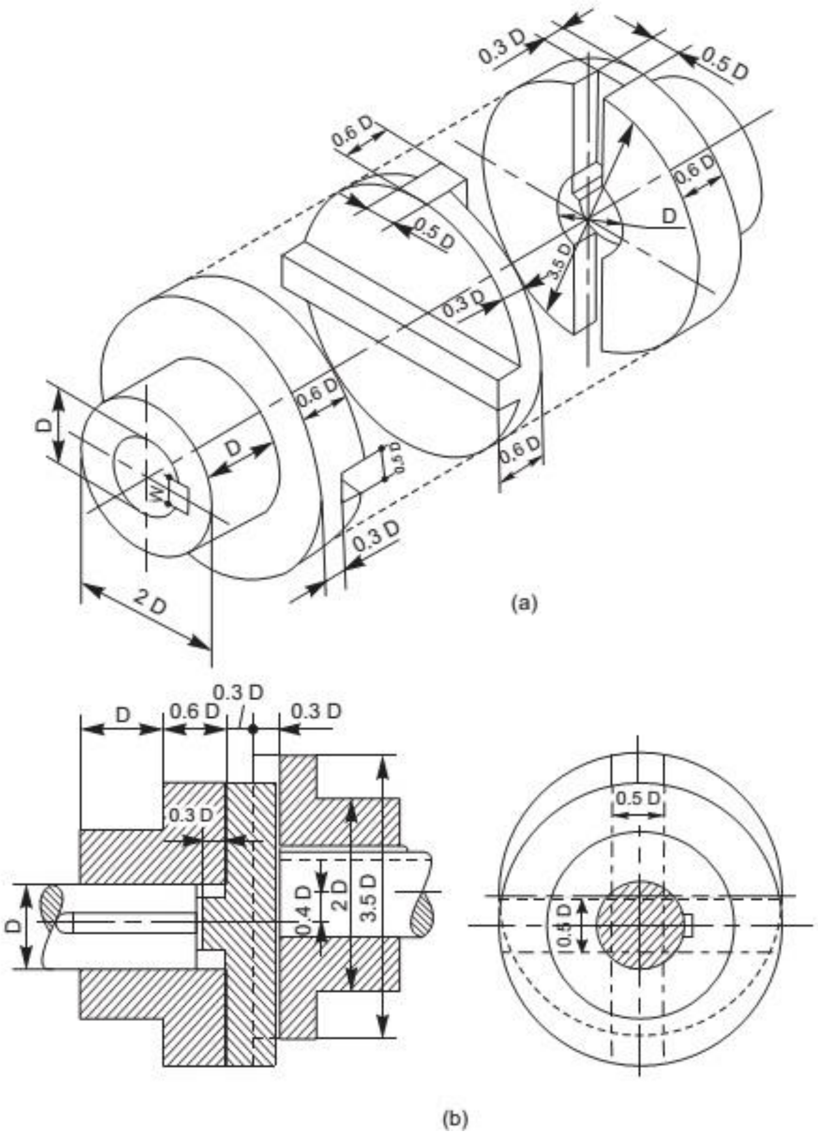
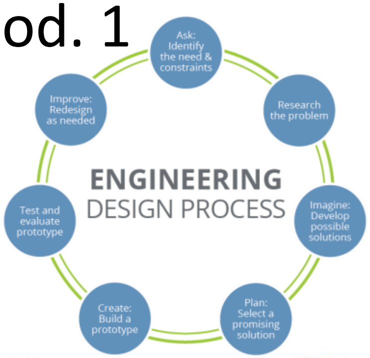


- Prepare Assembly and detail drawing
- Modify drawings after testing prototype

Ref: https://blogpuneet.wordpress.com/2013/10/08/oldhams-coupling/

Course Contents

Mod. 1



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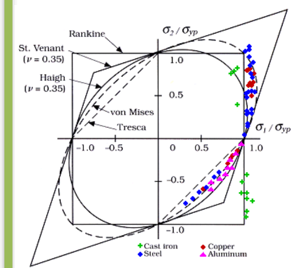
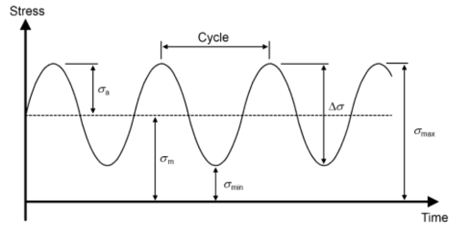
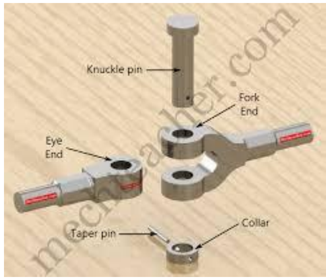
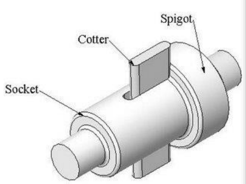




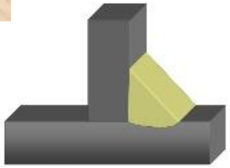
Mod. 3

Mod. 4





Butt weld



Fillet weld

Mod. 5

Mod. 6

Basic Requirement

TRADITIONAL DESIGN METHODS

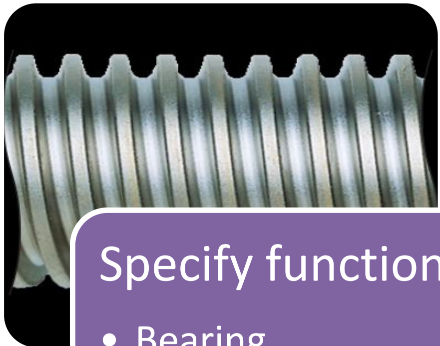
- Design by craft evolution

Ref:https://www.123rf.com/stock-photo/bullock_cart.html

Ref:http://directboats.com/rowboats.html

- Design by drawing

PROCEDURE IN DME



Specify functions

- Bearing
- Spring
- Screw fastening

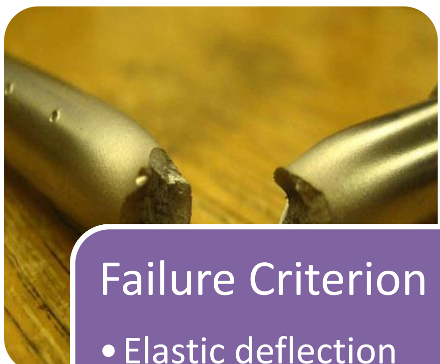
Force determination

- Free body diagram

Selection of Material

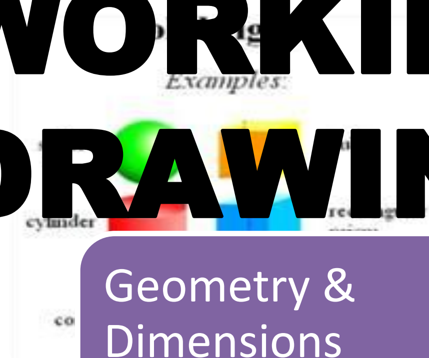
- Availability
- Man. Considerations
- Properties

WORKING DRAWING



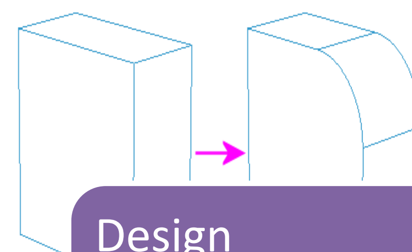
Failure Criterion

- Elastic deflection
- General yielding
- Fracture



Geometry & Dimensions

- Operating conditions
- Basis of failure criterion

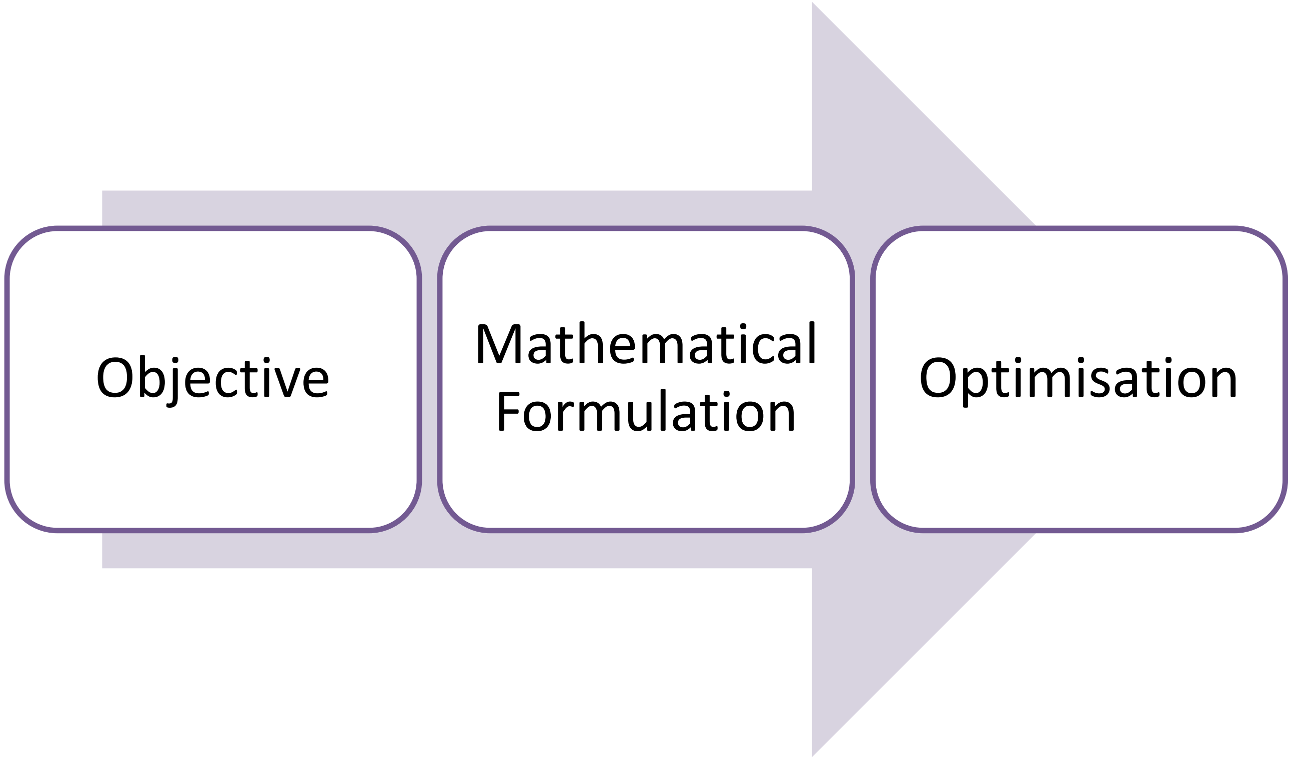


Design Modifications

- Assembly & manufacturing considerations

DESIGN SYNTHESIS

Design Synthesis is defined as the process of *creating* or *selecting* configurations, materials, shapes and dimensions for a product.



AESTHETIC CONSIDERATIONS

?????

ERGONOMIC CONSIDERATIONS

Ergonomics is defined as the relationship between man and machine and the application of anatomical, physiological and psychological principles to solve the problems arising from man-machine relationship

- Design of driver's seat
- Layout of instrument dials and display panels
- Design of hand levers and hand wheels
- Energy expenditure in hand and foot operations
- Lighting, noise and climatic conditions in machine environment

Contd….

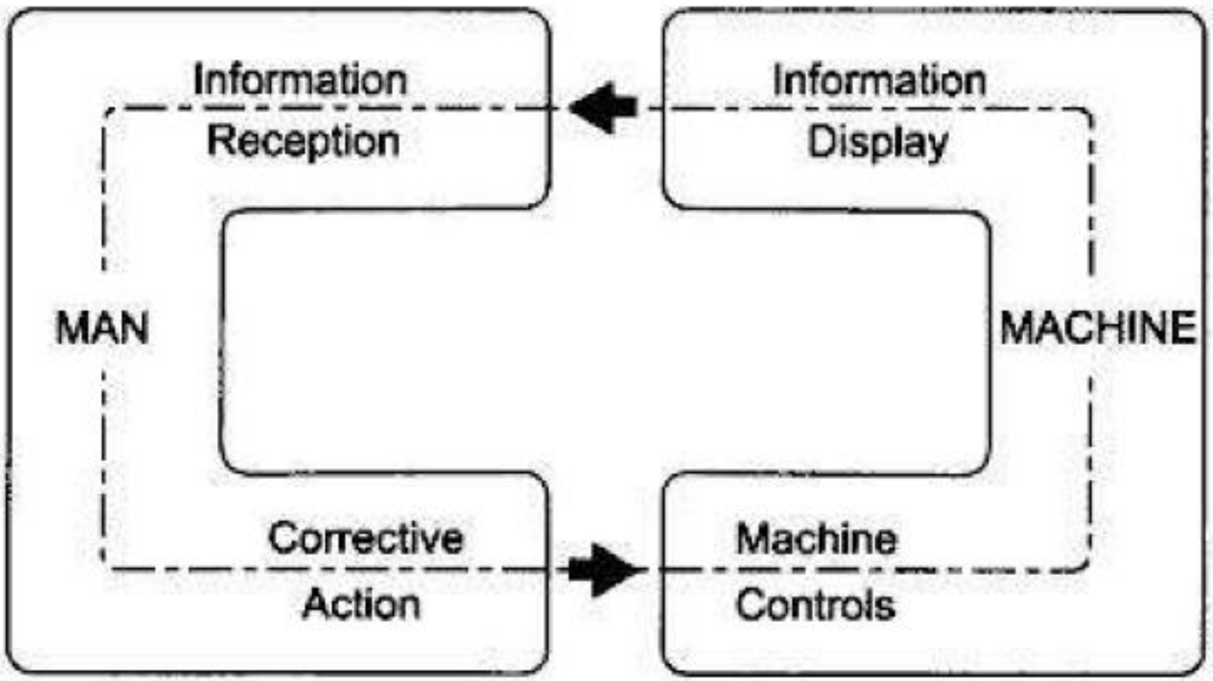


Fig. 1.6 *Man–Machine Closed-Loop System*

Display instruments	Control instruments
Quantitative measurement	Easily accessible and logically positioned
State of affairs	Conform to the anatomy of human parts
Predetermined settings	Proper colour

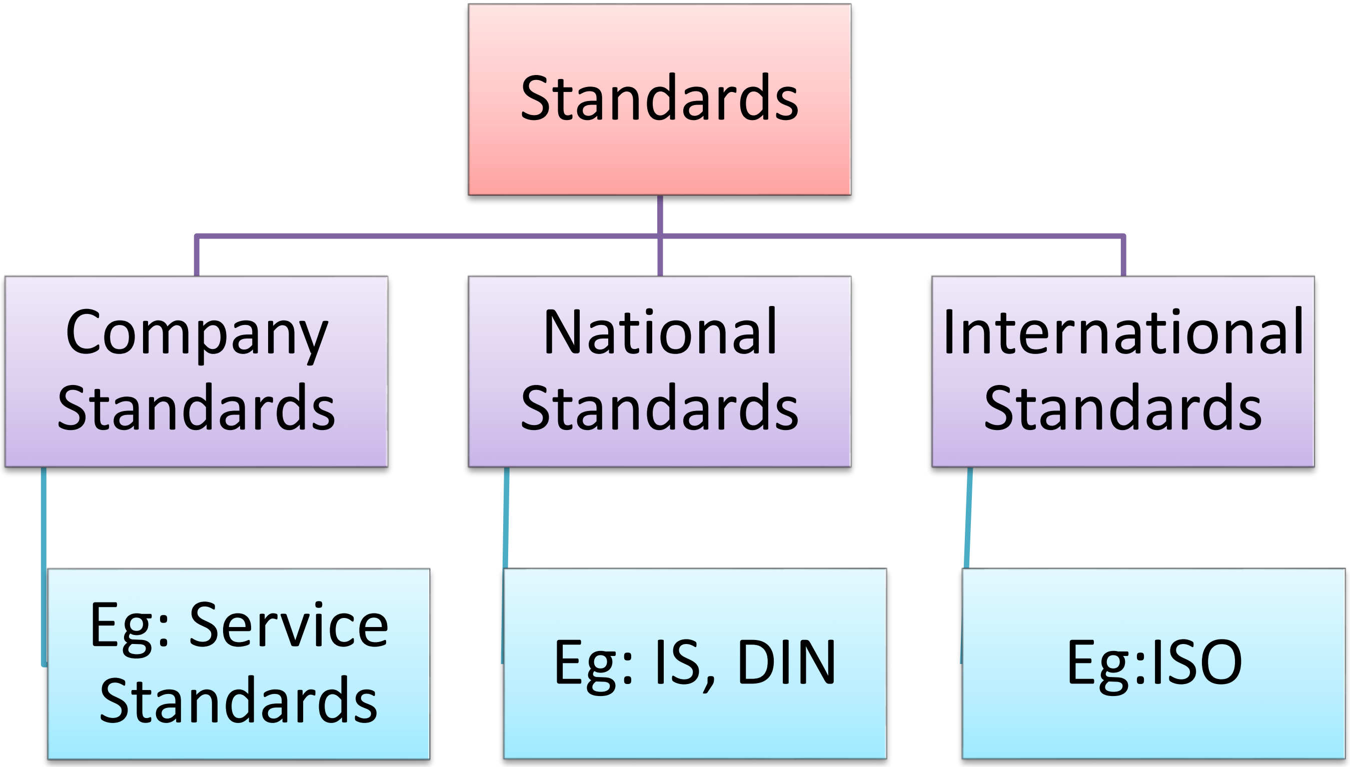
Overview

- Need of ……..
- Definition
- ????? Requirement
- Procedure
- Tradition
- Synthesis
- Design considerations

Standardization

The obligatory norms, to which various characteristics of a product should conform.

- Standards: Set of specifications for parts, materials or processes
- Codes: Set of specifications for analysis, design, testing



Standardization

The characteristics include materials, dimensions and shape of the component, method of testing and method of marking, packing and storing of the product.

- Standards for materials, their chemical compositions, Mechanical properties and Heat Treatment
  - FG 150, FG 200, FG 220- **(IS 210)**: Strength
  - 55Cr3- **(IS 570 Part 4)**: Chemical composition
- Standards for shapes and dimensions of commonly used machine elements
  - Dimension and cross section of V belts **(IS 2494)**

Standardization

- Standards for fits, tolerances and surface finish of component
  - Fit **IS 2709** (Guide for selection of fits)
  - Tolerances **IS 919** (Recommendations for limits and fits for engineering)
  - Surface texture **IS 10719**

- Standards for testing of products
  - Testing of pressure vessels **IS 2825**

- Standards for engineering drawing of components
  - **SP46** by **BIS** for engineering drawings

Standardization: Advantages

- Reduction in types and dimensions of identical components
- Reduced manufacturing facilities required for individual organisation
- Easy replacement and availability
- Reduced designer tasks
- Improved quality and reliability

Selection of Preferred sizes

- Size of the machine element with preferred sizes

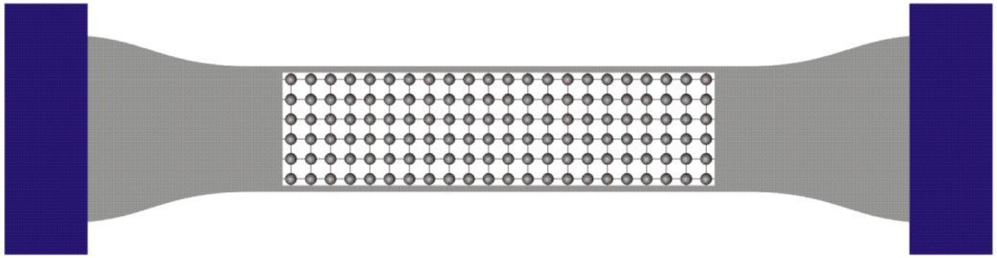
R5	$\sqrt[5]{10}$	1.58
R10	$\sqrt[10]{10}$	1.26
R20	$\sqrt[20]{10}$	1.12
R40	$\sqrt[40]{10}$	1.06
R80	$\sqrt[80]{10}$	1.03

Preferred Numbers

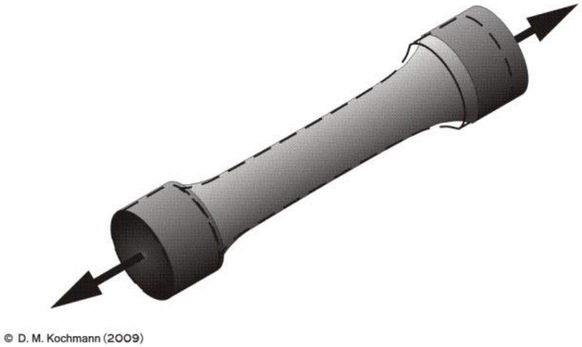
R5	*R10*	*R20*	*R40*
1.00	1.00	1.00	1.00
			1.06
		1.12	1.12
			1.18
	1.25	1.25	1.25
			1.32
		1.40	1.40
			1.50
1.60	1.60	1.60	1.60
			1.70
		1.80	1.80
			1.90
	2.00	2.00	2.00
			2.12
		2.24	2.24
			2.36
2.50	2.50	2.50	2.50
			2.65
		2.80	2.80
			3.00

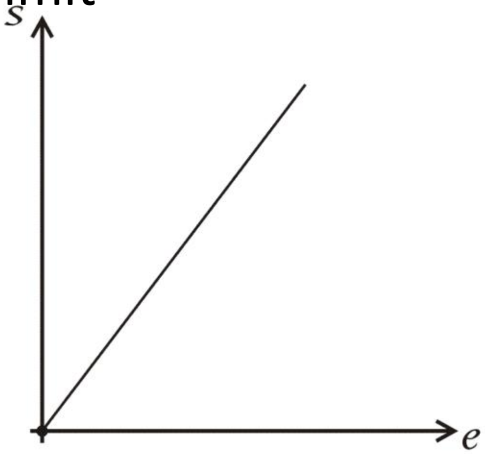
Elasticity

- Elasticity is defined as the ability of the material to regain its original shape and size after the deformation, when the external forces are removed



- Steel is perfectly elastic within a certain limit



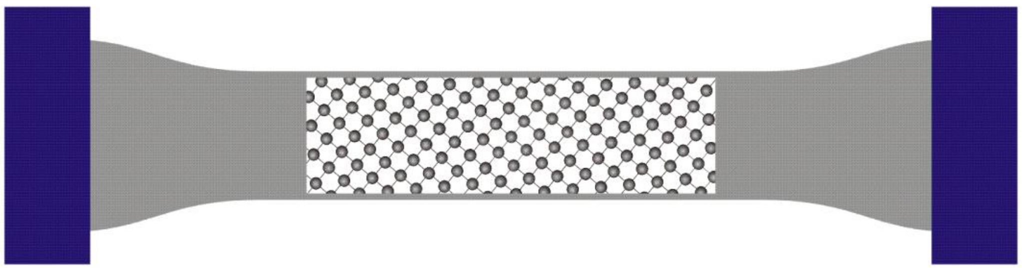


- Amount of deformation a metal undergoes is small

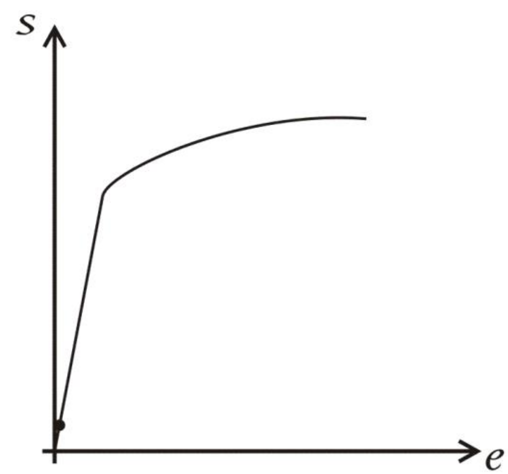
- Atoms are displaced from their original positions but they don't take up new positions

Plasticity

- Plasticity is defined as the ability of the material to retain the deformation produced under the load on permanent basis



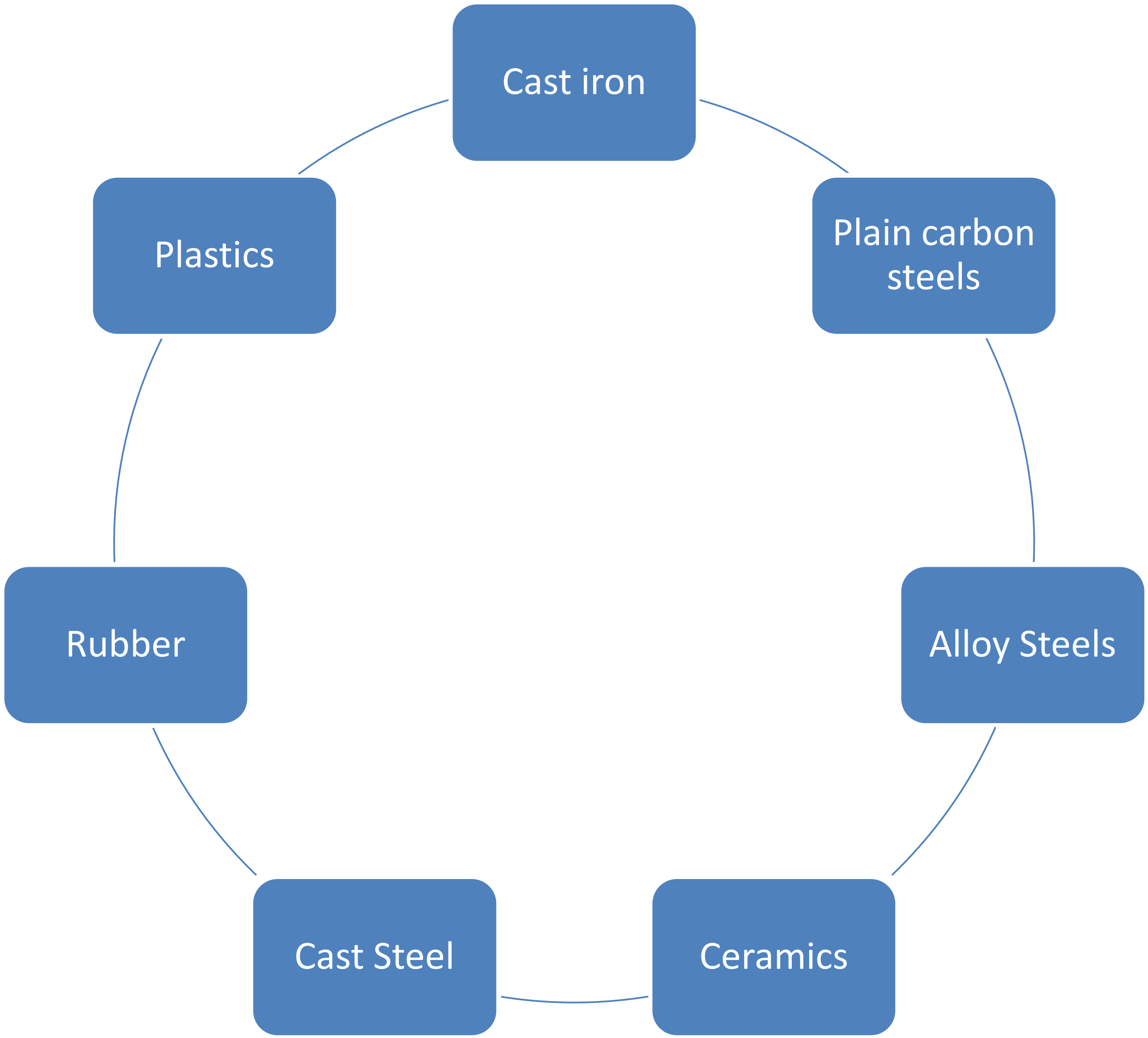
- External force deforms the metal to such an extent it cannot fully recover



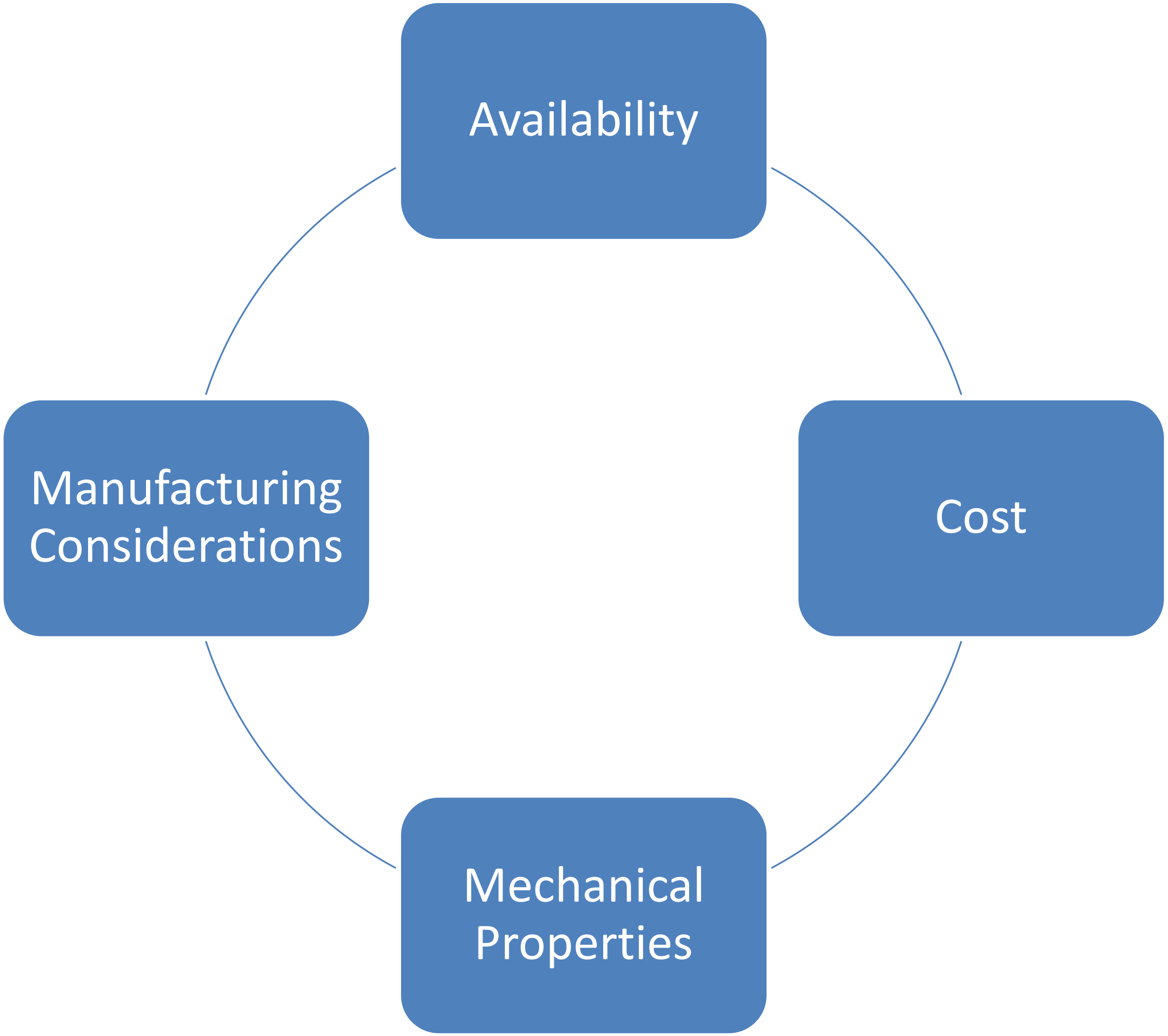
- Some metals take up extensive deformations without fracture

- Atoms are permanently displaced to take up new positions

Types of Materials



Factors for selection



Weighted Point Method

1
- Study of application and preparing a list of desirable properties

2
- Desirable properties are assigned values

3
- Go-no-go parameters
- Discriminating parameters

4
- Weightage is provided

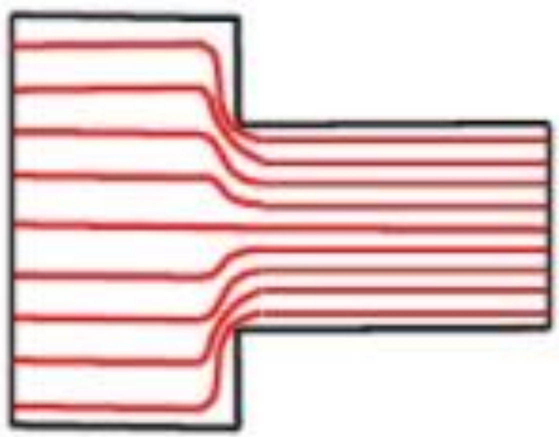
Weighted Point Method: Eg

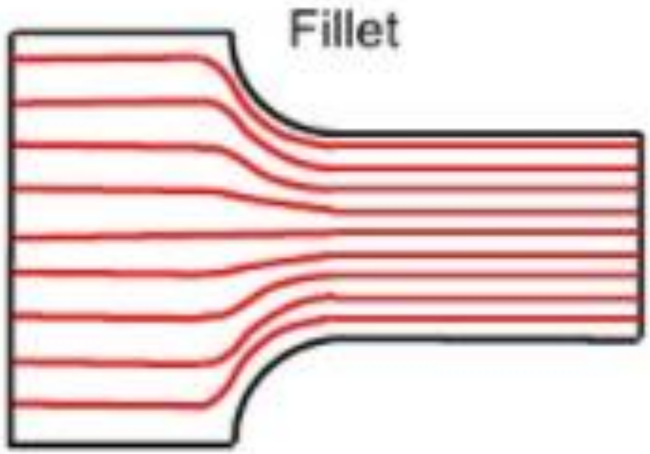
S. No.	Property	Low alloy steel	Plain carbon steels	Stainless steel	Chromium steels
1	Ultimate tensile strength (N/mm^2)	850	850	1200	950
2	Hardenability Index	60	80	30	100

- Points for ultimate tensile strength
  - Sum=850+850+1200+950=3850
  - Rating strength= 850/3850= 0.22
  - Weightage index=0.22*5=1.1
- Points for hardenability
  - Sum=60+80+30+100=270
  - Rating hardenability index= 60/270=0.222
  - Weightage index= 0.22*3=0.666

Stress Concentration

$$\sigma_t = \frac{P}{A} \qquad \sigma_b = \frac{M_b y}{I} \qquad \tau = \frac{M_t r}{J}$$

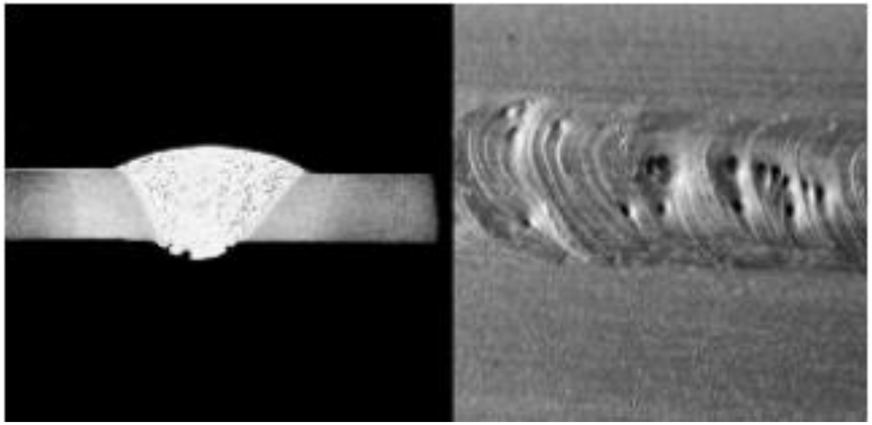


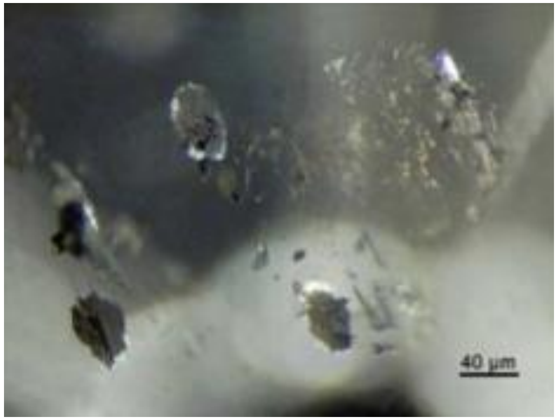


The localization of high stresses due to the irregularities present in the component and abrupt changes of cross-section

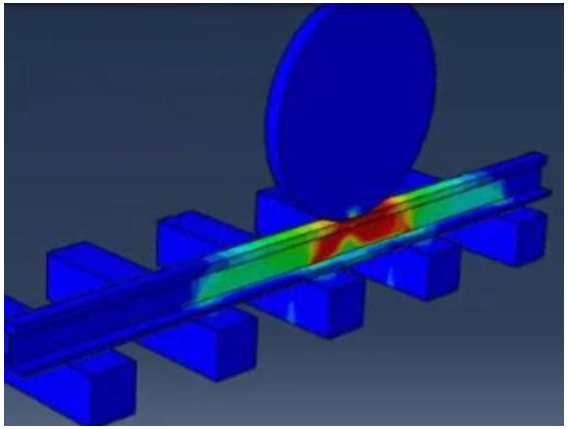
Causes of stress concentration

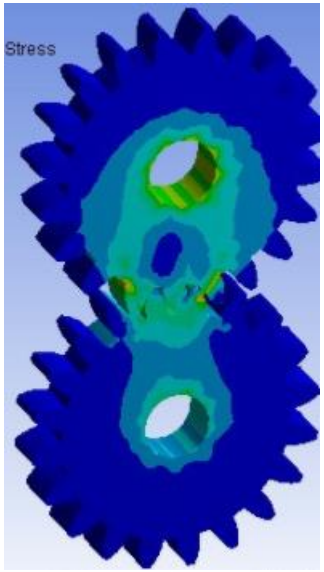
- Variation in properties



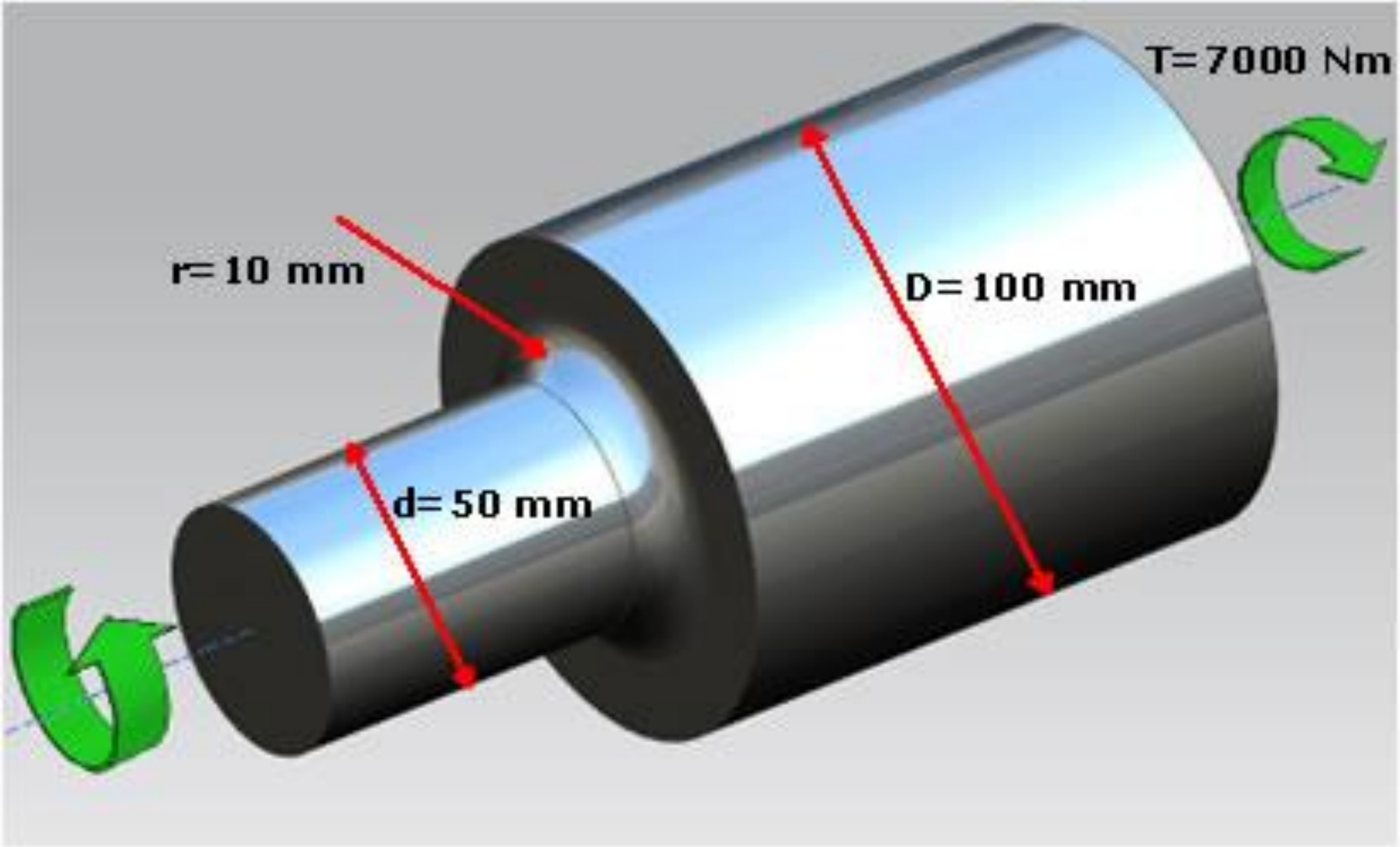


- Load application





- Abrupt changes in dimension



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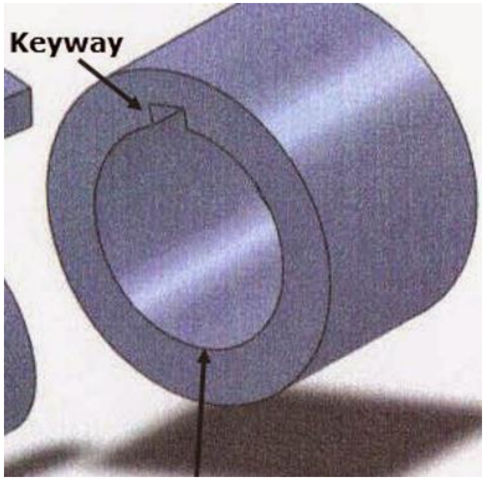
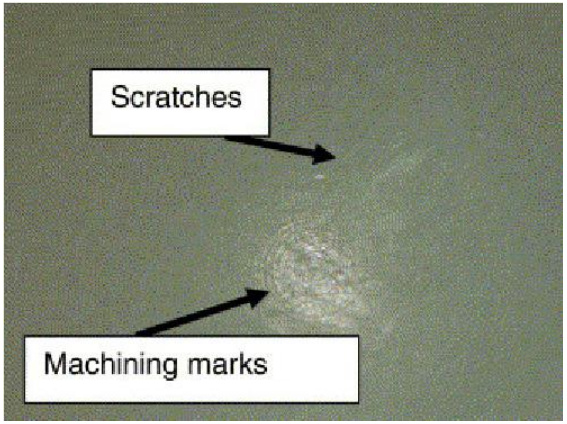
- Discontinuities in the component



- Machining Scratches

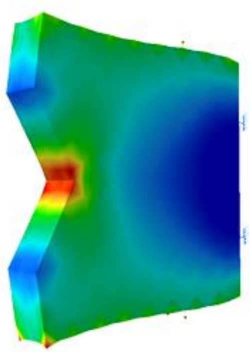


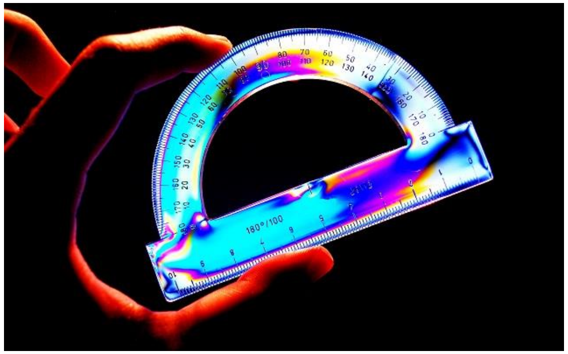
Stress Concentration Factor (K_t)

$$K_t = \frac{\sigma_{max}}{\sigma_o} = \frac{\tau_{max}}{\tau_o}$$

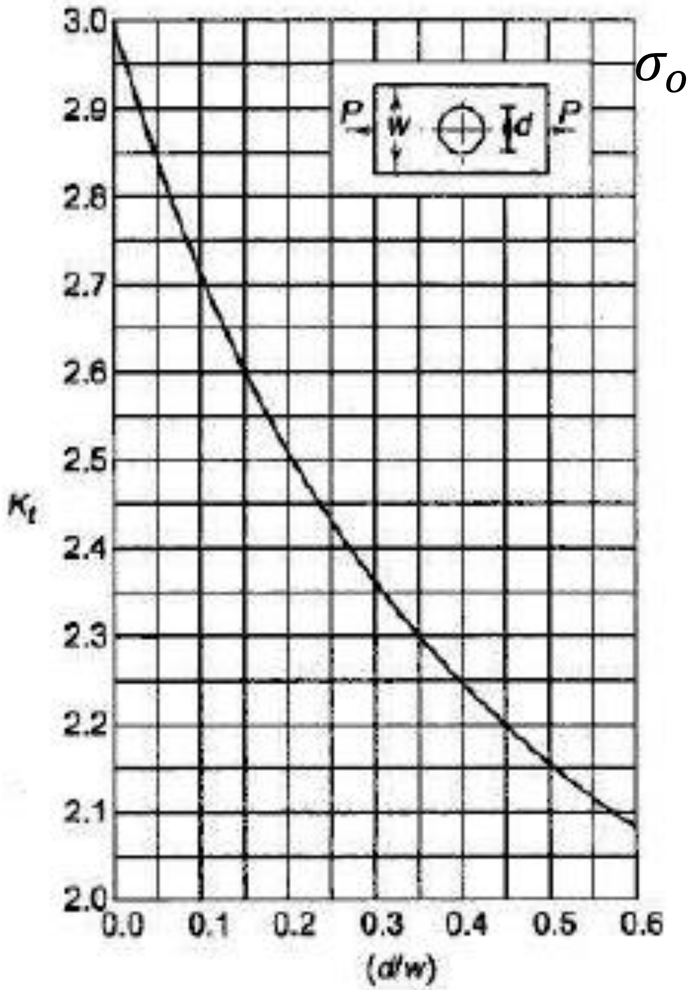
Mathematical method

Experimental methods



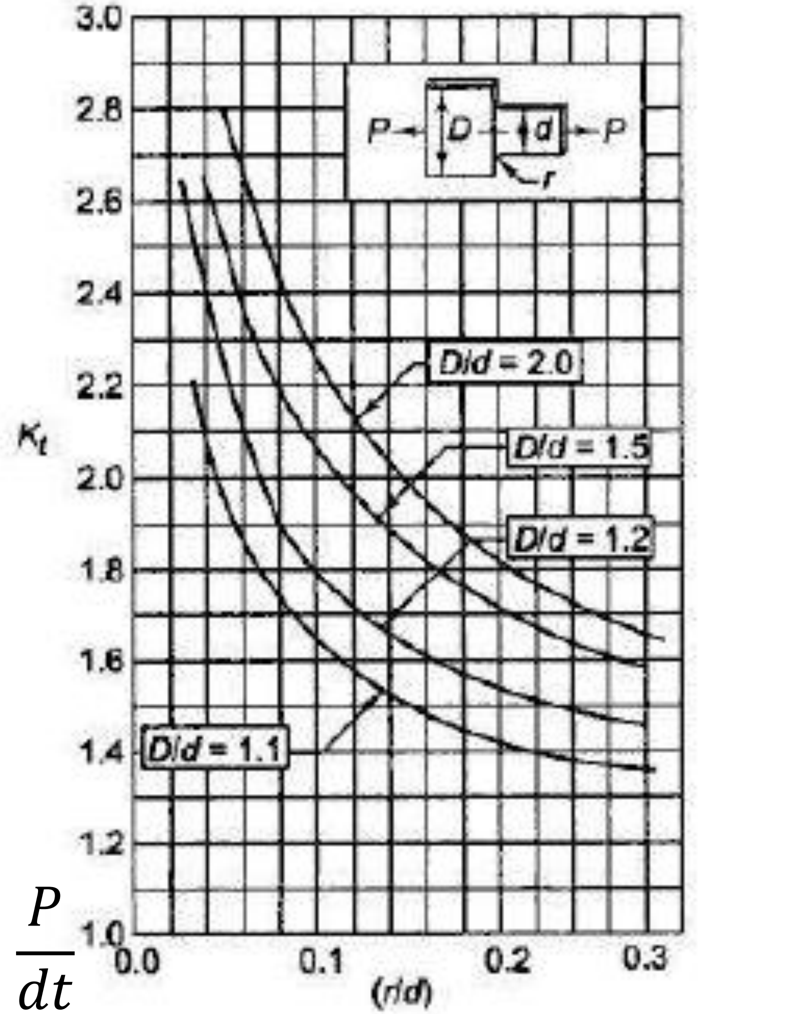


Stress Concentration factors



$$\sigma_o = \frac{P}{(w-d)t}$$

Fig. 5.2 *Stress Concentration Factor (Rectangular Plate with Transverse Hole in Tension or Compression)*



$$\sigma_o = \frac{P}{dt}$$

Fig. 5.3 *Stress Concentration Factor (Flat Plate with Shoulder Fillet in Tension or Compression)*

Stress Concentration factors

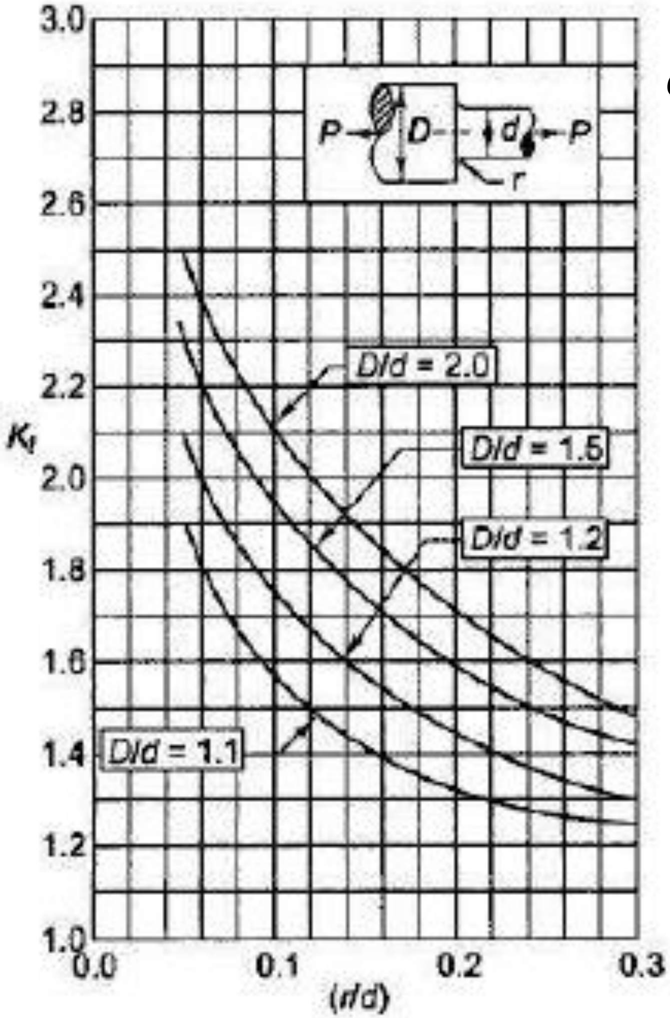
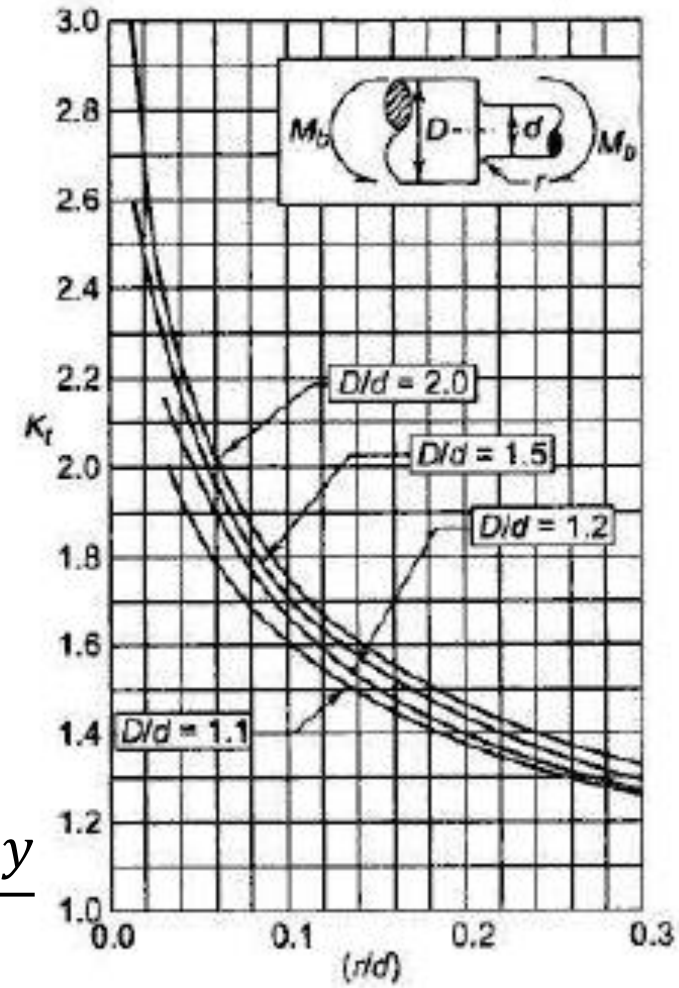


Fig. 5.4 *Stress Concentration Factor (Round Shaft with Shoulder Fillet in Tension)*

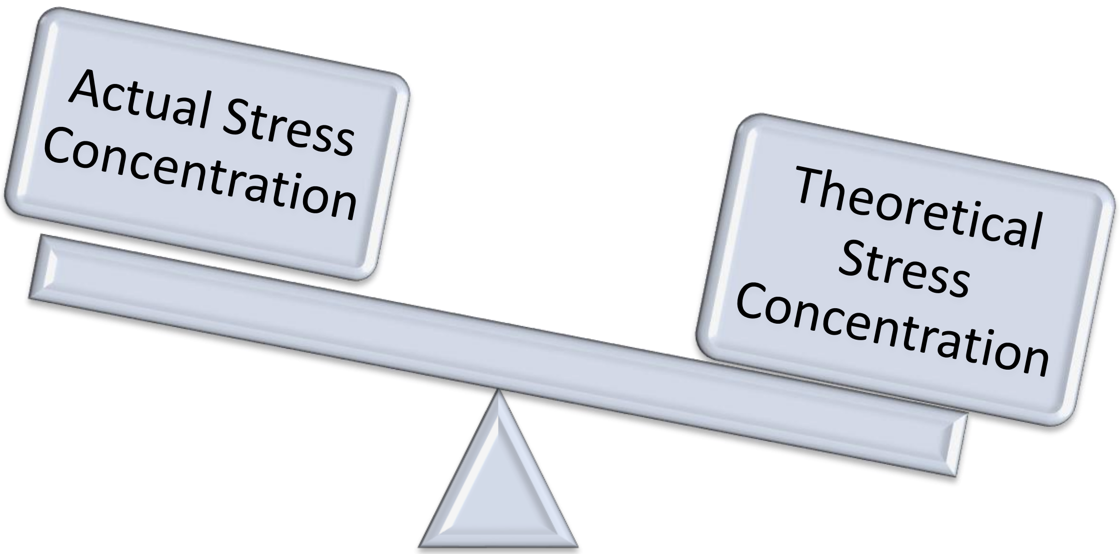
$$\sigma_o = \frac{P}{\left(\frac{\pi}{4} d^2\right)}$$



$$\sigma_o = \frac{M_b y}{I}$$

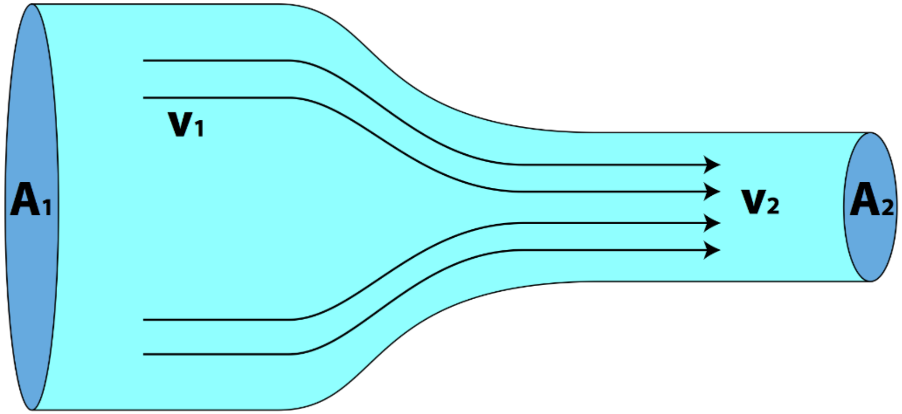
Fig. 5.5 *Stress Concentration Factor (Round Shaf with Shoulder Fillet in Bending)*

Stress Concentration factors

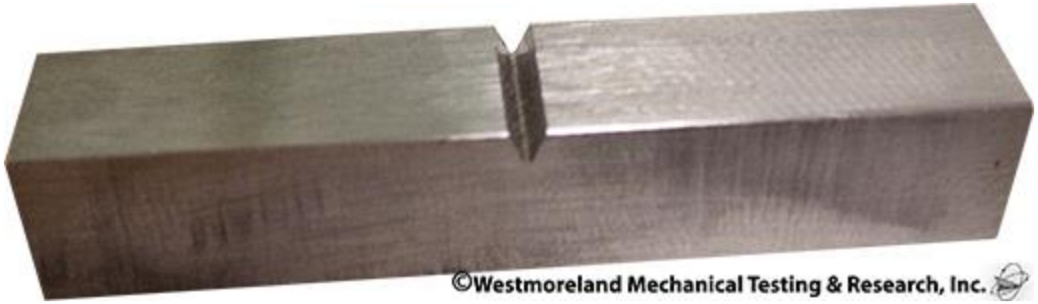


- Ductile materials under static load
- Ductile materials under fluctuating load
- Brittle materials

Reduction of Stress Concentration



- Additional Notches and Holes in Tension Member



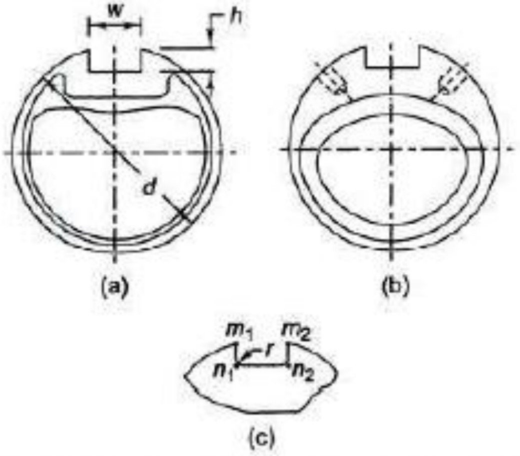
- Use of multiple notches
- Drilling additional holes
- Removal of undesired material

Reduction of Stress Concentration

- Fillet radius, undercutting and notch for member in bending

- Fillet
- Undercut
- Notch

- Drilling additional holes for shaft



- Fillet
- Symmetrical holes

Reduction of Stress Concentration

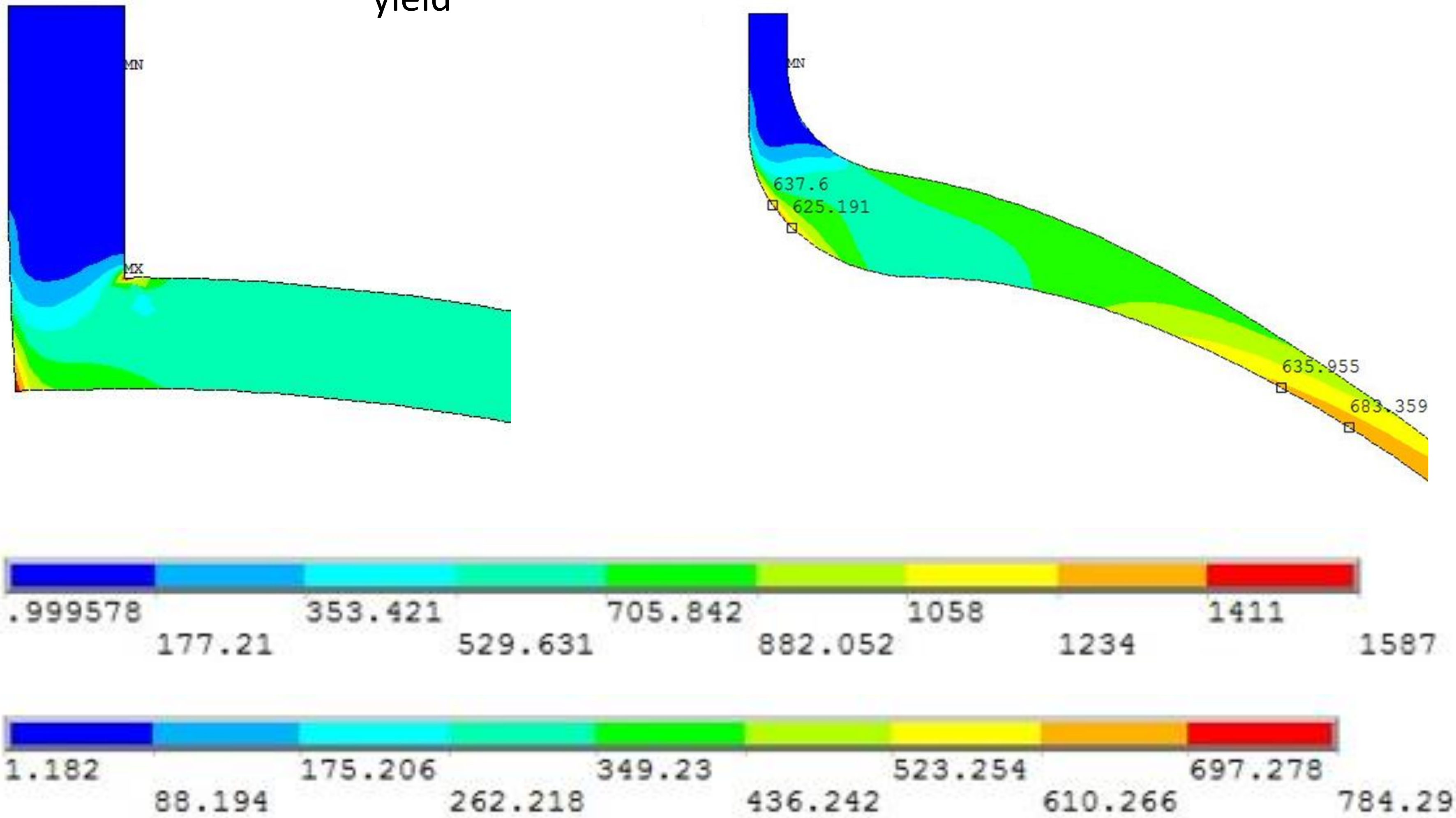
- Reduction of stress concentration in threaded members

- Undercut
- Reduction in Shank diameter

Simulation results

- Abrupt changes in section

σ_{yield}= 804.42MPa



Problem??

A flat plate subjected to a tensile force of 5 kN is shown in Figure. The plate material is of grey cast iron FG 200 and the factor of safety is 2.5. Determine the thickness of the plate.

Objective: Find t,

Given data (Check for consistency in units)

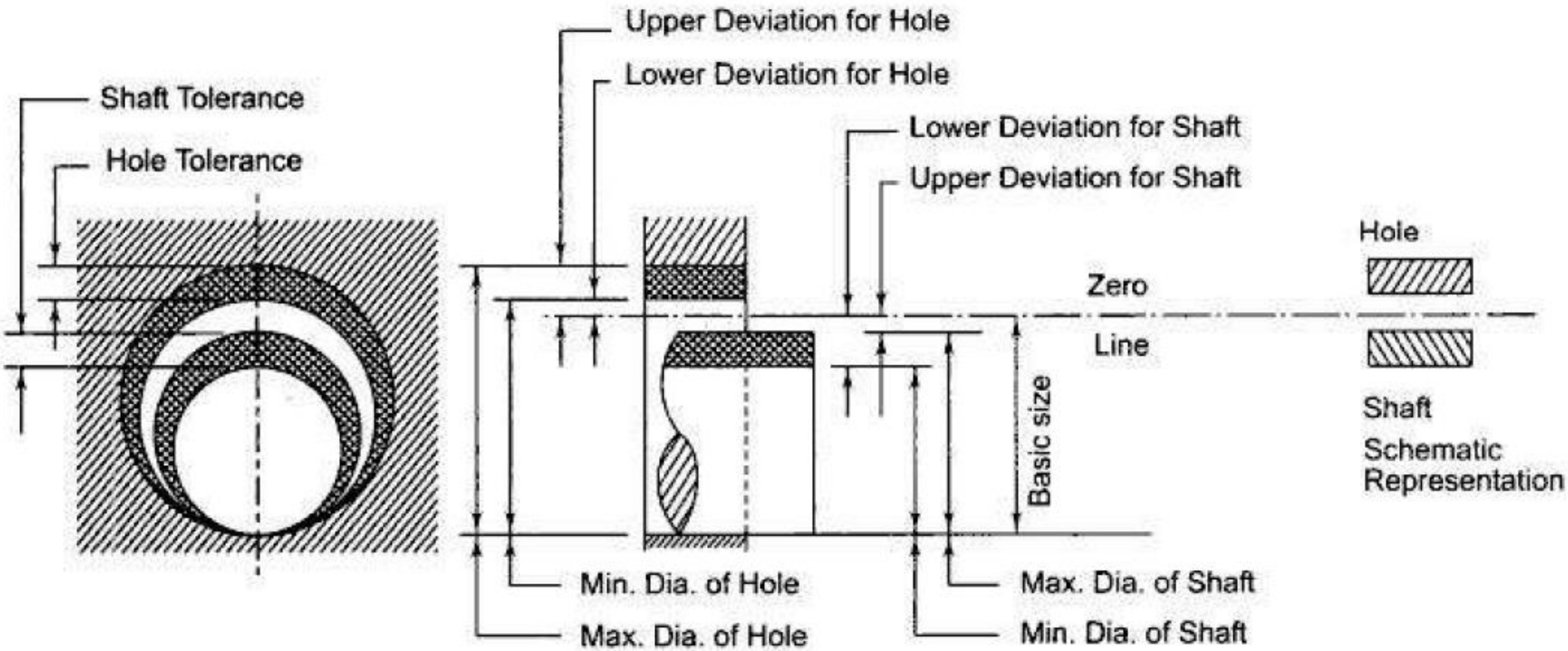
P=5kN S_{ut}=200 N/mm^2 (fs)=2.5

D=45mm, d=30mm, w=15mm, r= 5mm

$$\sigma_{max} = \frac{S_{ut}}{fs} \qquad \frac{D}{d} \qquad \frac{r}{d}$$

Tolerances

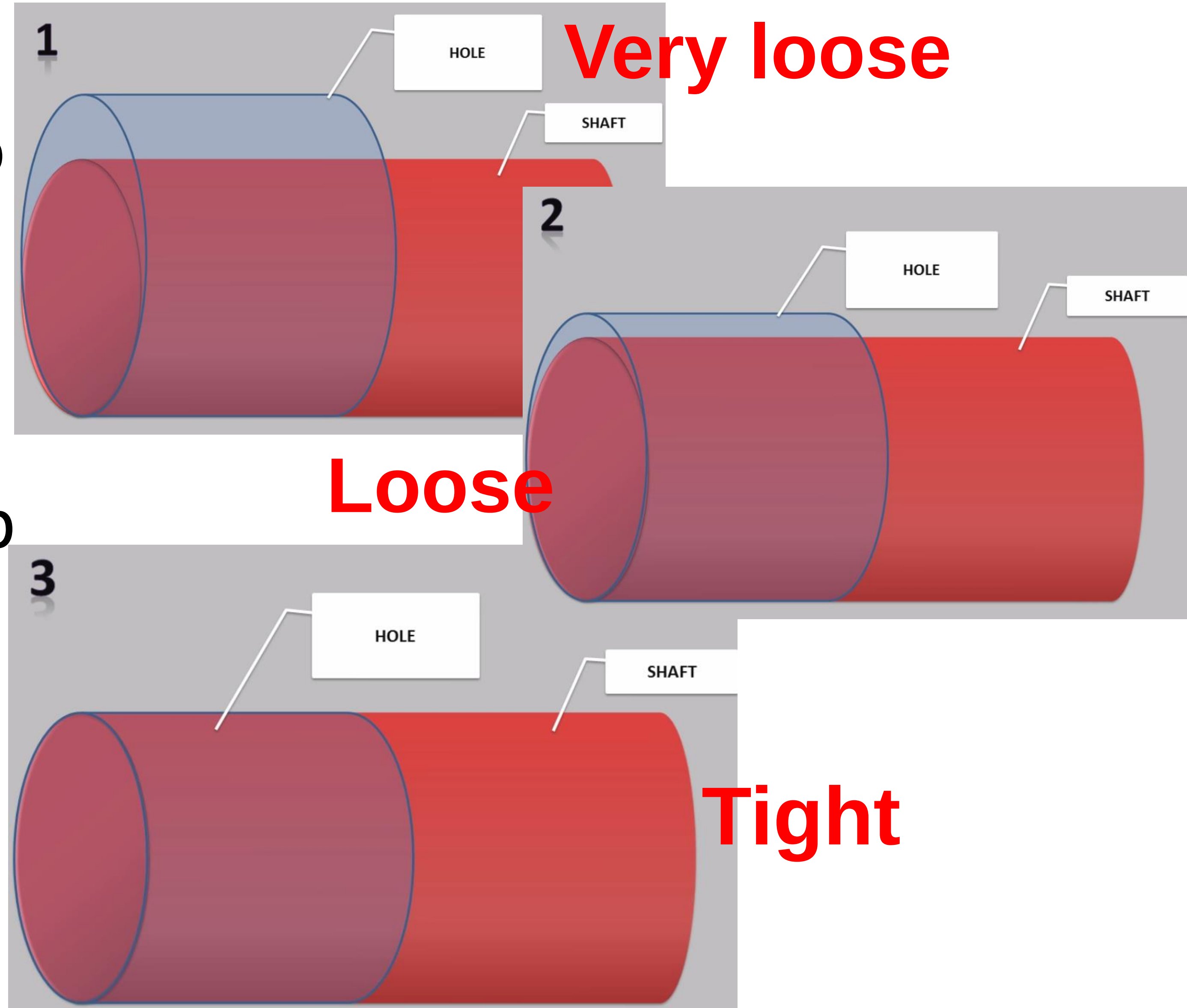
- Permissible variation in dimensions of the component
- Types: Unilateral and bilateral



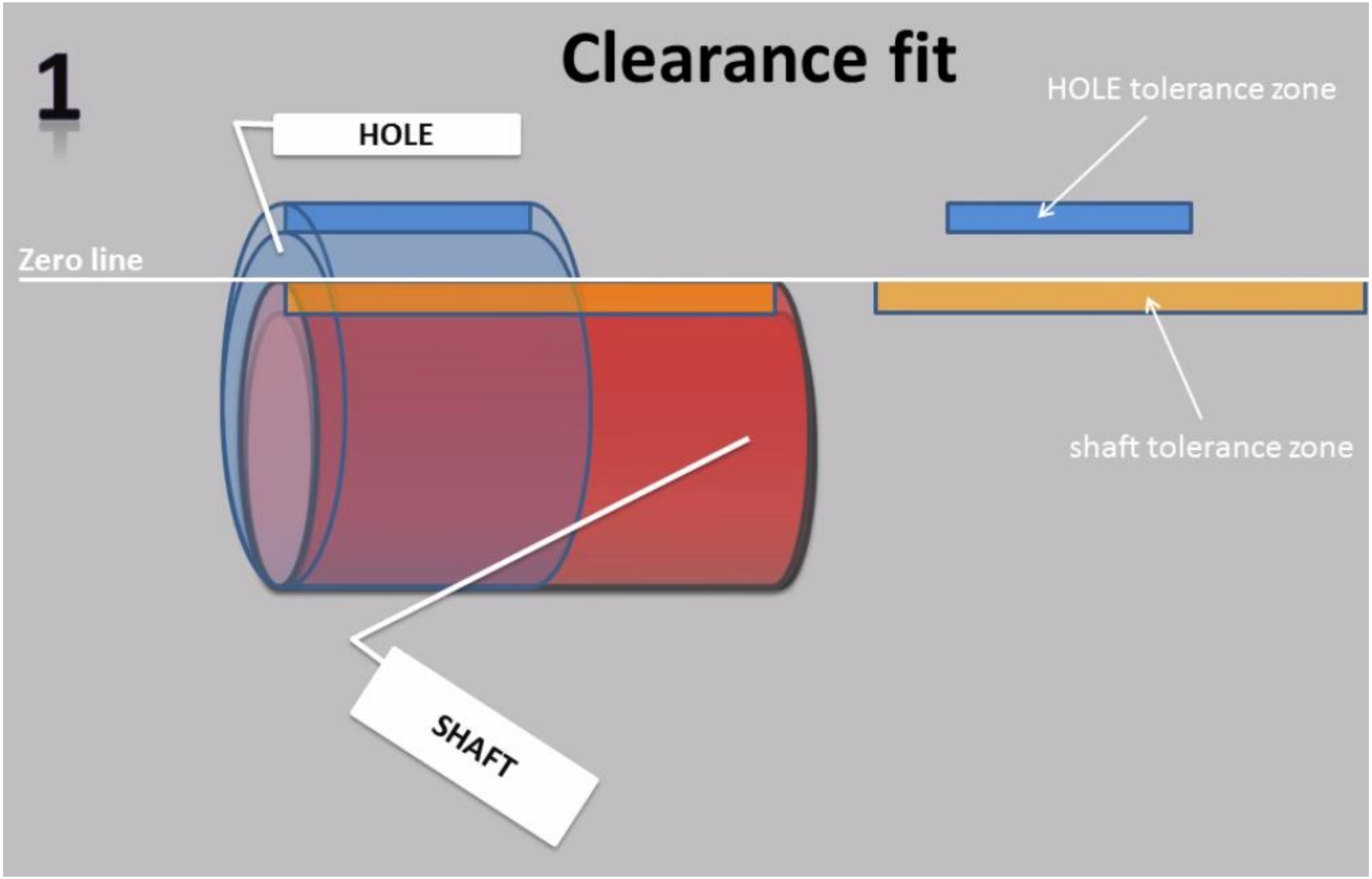
Ref. Design of Machine elements, Third edition, V B Bhandari

Fits

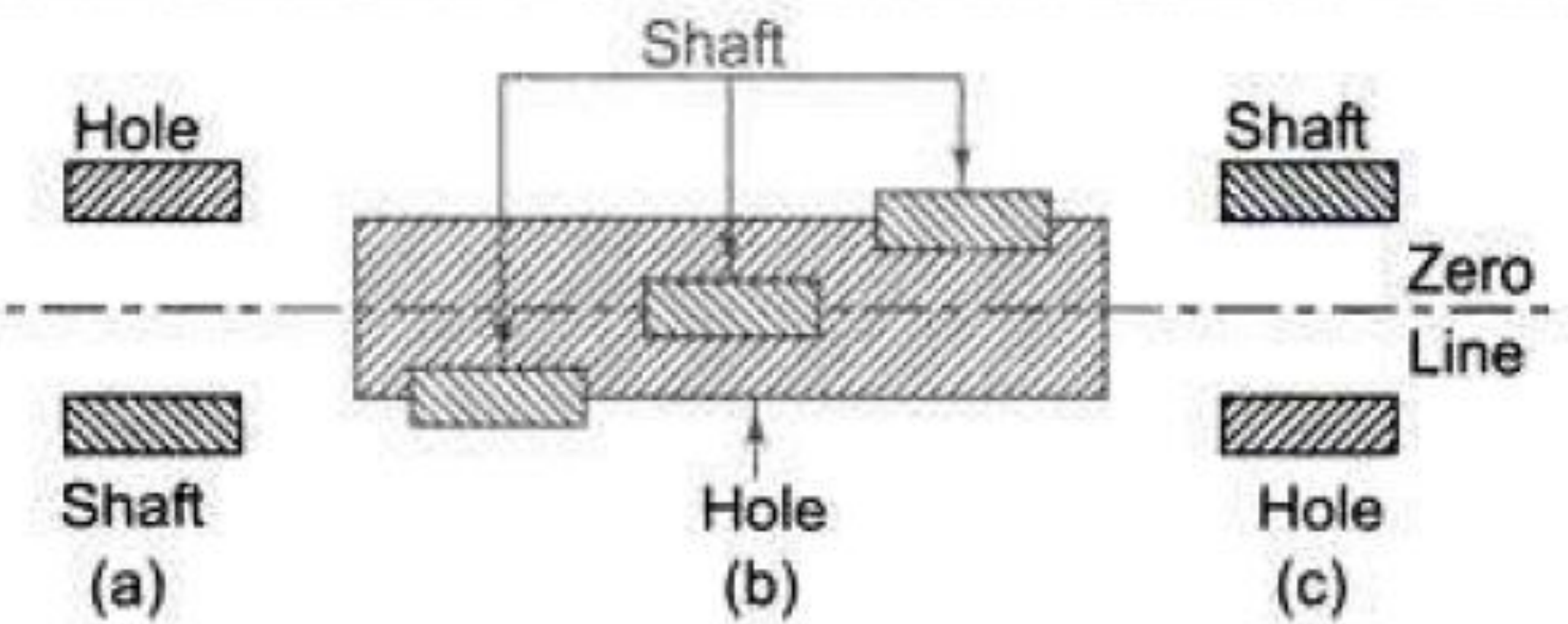
- When two parts are to be assembled, the relationship resulting between their sizes before assembly



Classification- Fits



Classification- Fits



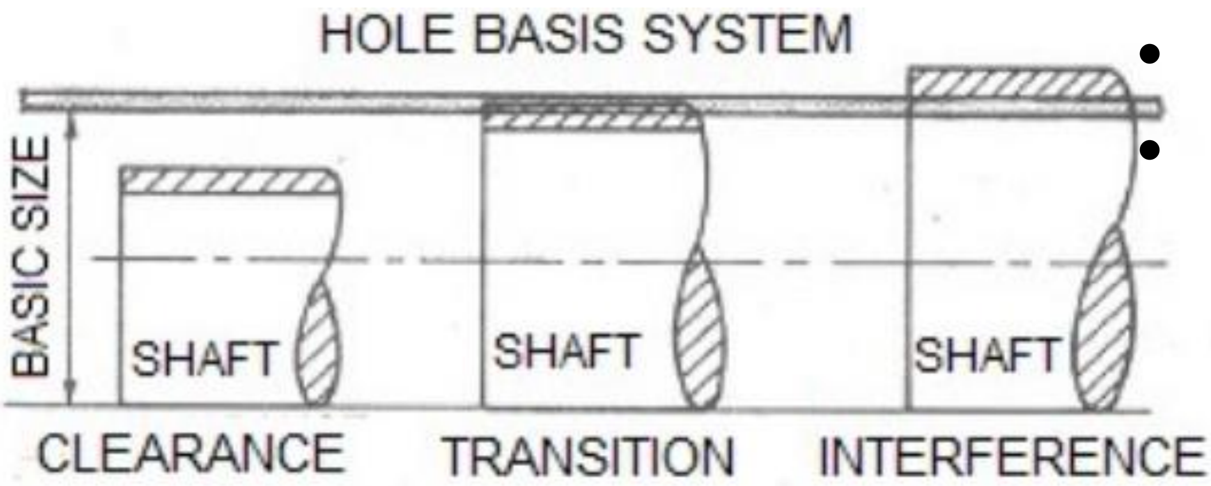
Clearance fit

Transition fit

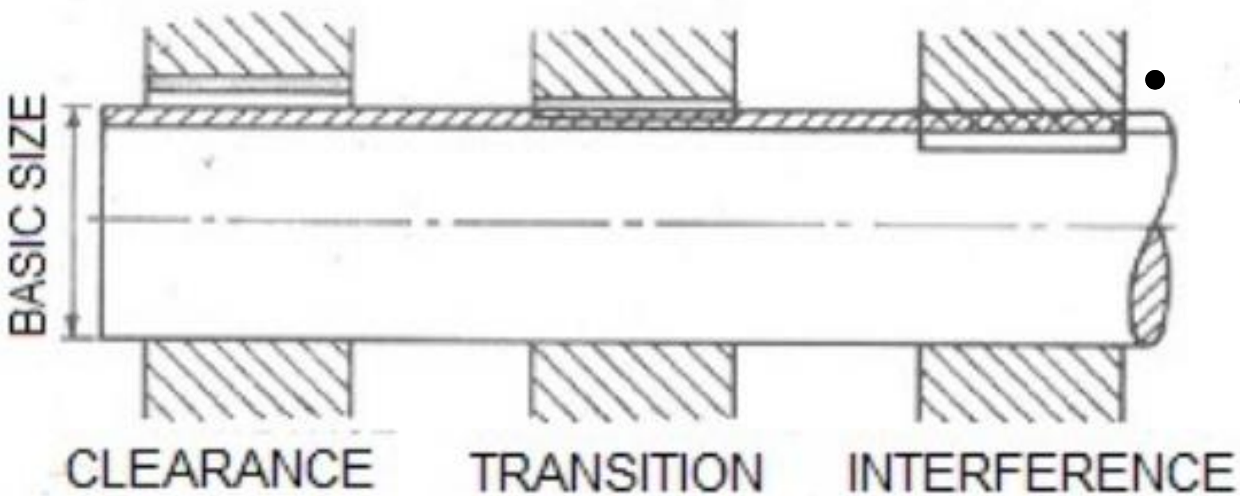
Interference fit

Ref. Design of Machine elements, Third edition, V B Bhandari

Classification- Fits

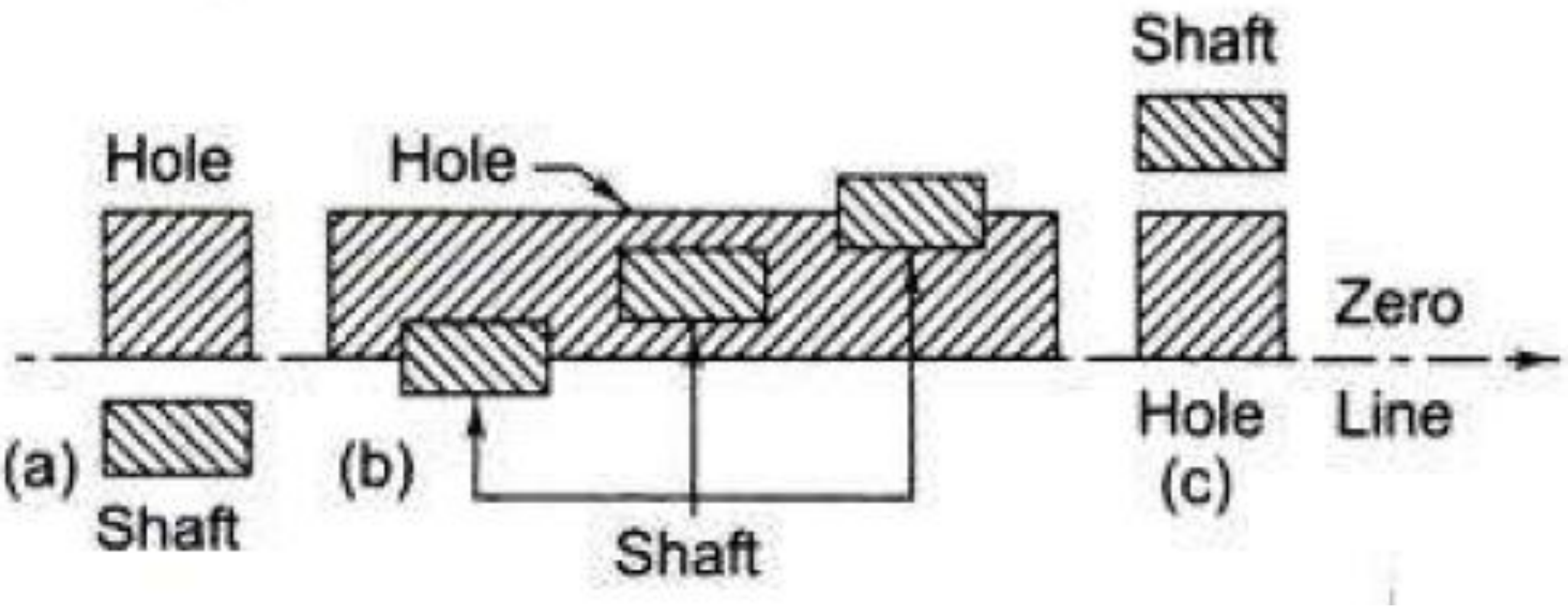


- Hole size: Constant
- Shaft size: Varying



- Hole size: Varying
- Shaft size: Constant

Classification- Hole basis tolerance system (H)



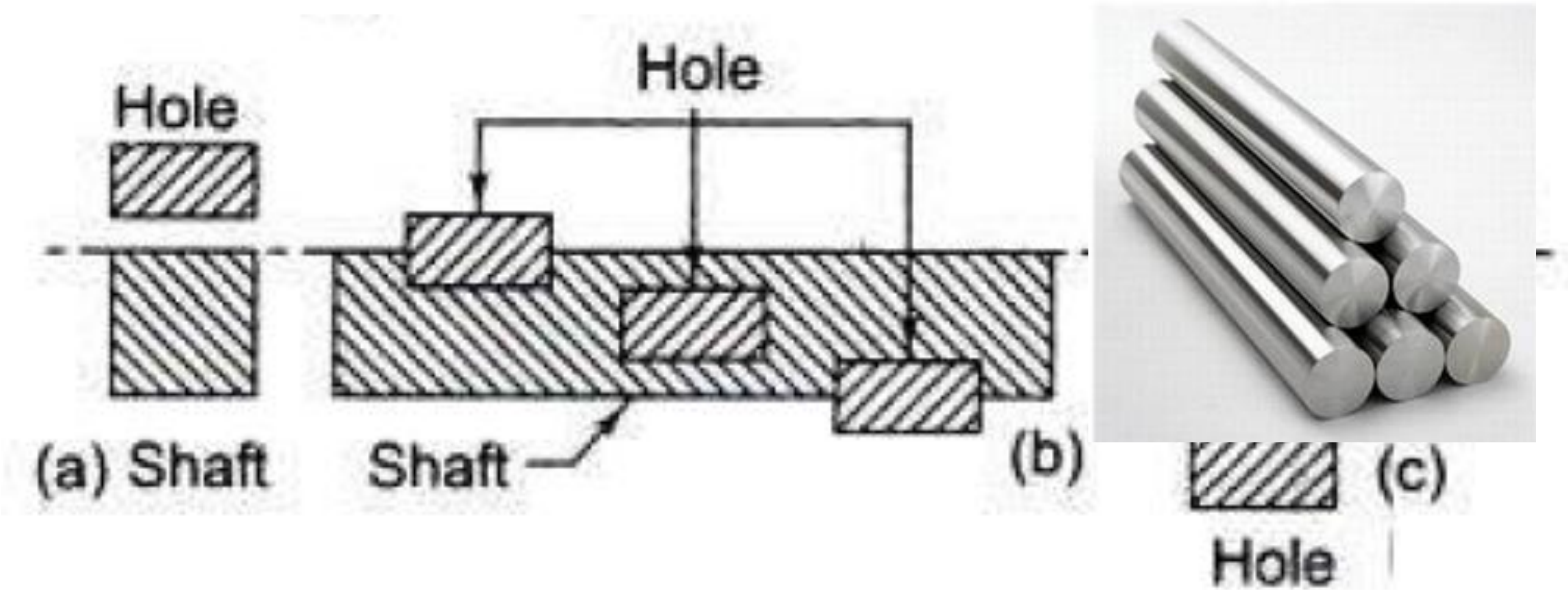
Clearance fit

Transition fit

Interference fit

Ref. Design of Machine elements, Third edition, V B Bhandari

Classification- Shaft basis tolerance system (h)



Clearance fit

Transition fit

Interference fit

Ref. Design of Machine elements, Third edition, V B Bhandari

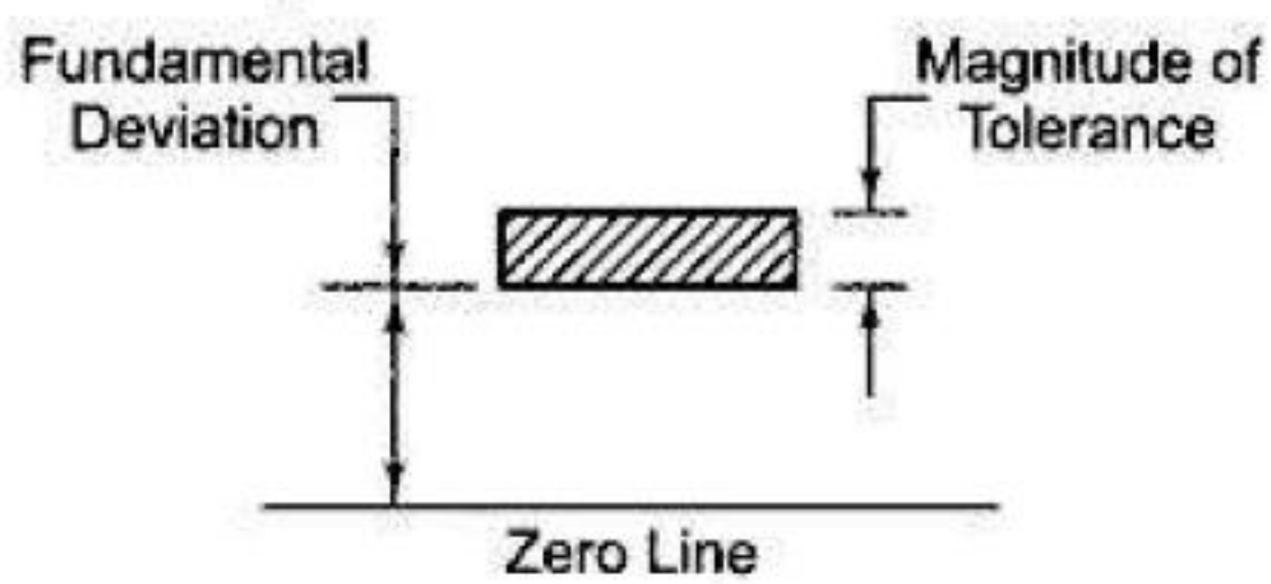
BIS SYSTEM: Tolerance

H7

- Fundamental deviation

g6

- Magnitude of tolerance



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BIS SYSTEM: Tolerance

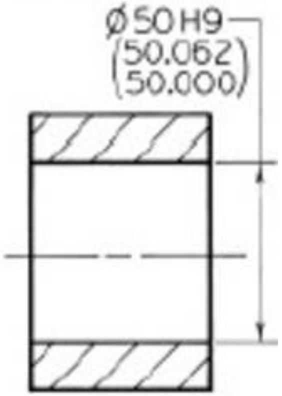


Table 3.2 *Tolerances for holes of sizes up to 100 mm (H5 to H11)*

Diameter steps in mm		H							
		5	6	7	8	9	10	11	5–11
over	to	es							ei
0	3	+4	+6	+10	+14	+25	+40	+60	0
3	6	+5	+8	+12	+18	+30	+48	+75	0
6	10	+6	+9	+15	+22	+36	+58	+90	0
10	18	+8	+11	+18	+27	+43	+70	+110	0
18	30	+9	+13	+21	+33	+52	+84	+130	0
30	50	+11	+16	+25	+39	+62	+100	+160	0
50	80	+13	+19	+30	+46	+74	+120	+190	0
80	100	+15	+22	+35	+54	+87	+140	+220	0

Ref. Design of Machine elements, Third edition, V B Bhandari

TOLERANCE GRADING

Grade of Tolerance: Group of tolerances, which are considered to have the same level of accuracy for all basic sizes.

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	—

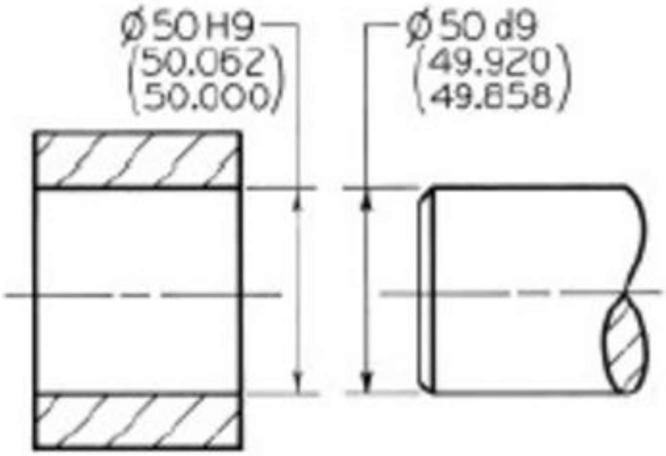
BIS SYSTEM:FITS

Basic size common to both components followed by symbols for tolerance of each component

$$50H9/d9$$

$$50H9-d9$$

$$50\frac{H9}{d9}$$



Selection of fit is based on the clearance required for the desired applications