Manufacturing Considerations in Design

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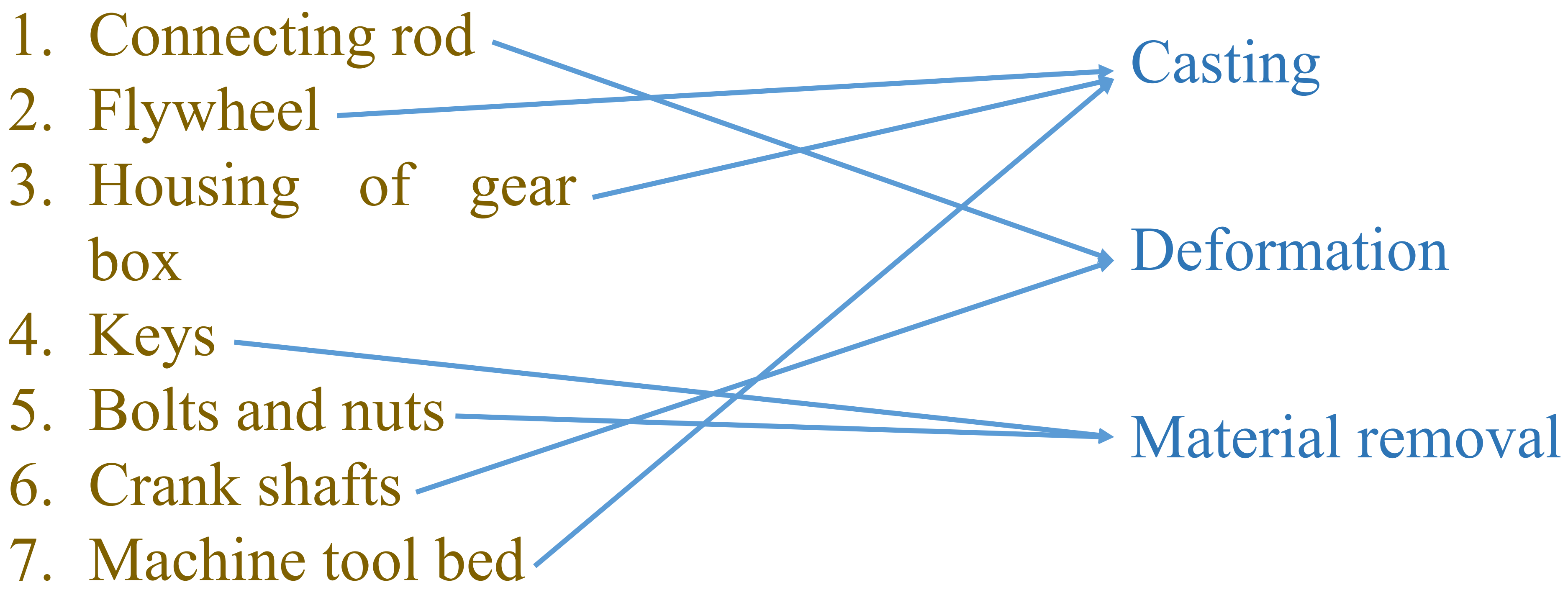
Manufacturing Considerations in Design

- Product design, selection of materials and processing the materials into finished components are closely related to one another.
- Manufacturing can be considered as processing the available materials into useful components of the product.
- Types of manufacturing processes:

  (i) Casting (ii) Deformation (iii) material removal (iv) Joining processes

Components made by different manufacturing processes



Selection of appropriate manufacturing method

- Material of the component
- Cost of manufacturing
- Geometric shape of the component
- Surface finish and tolerances required
- Volume of production

Types of Casting

- Sand casting
- Shell mould casting
- Permanent mould casting
- Die casting
- Centrifugal casting
- Investment casting

Advantages of Sand Casting

- Tooling required is relatively simple and inexpensive
- One of the cheapest method of manufacturing
- Almost any material can be casted
- There is no limit on the size of the component

Disadvantages of Sand Casting

- Not possible to achieve close tolerances
- Casted components require additional machining and finishing processes that increases the cost
- Casted components have rough surface finish
- Components with long and thin sections or projections can not be casted

Types of Forging processes

- Drop forging (80% share)
- Hand forging
- Press forging
- Upset forging

Advantages of Forging

- Forged components have inherent strength and toughness
- Optimum utilization of material
- Can be provided with thin sections without compromising on strength
- Close tolerances can be met that reduces material removal during final finishing
- Relatively rapid production rate and good reproducibility

Disadvantages of Forging

- Relatively costly mfg. process as equipments and tooling are costly
- Economical only when parts are manufactured on a large scale

Metal removal or Cutting processes

- Most versatile and common manufacturing methods
- Almost every component is subjected to some kind of machining operation in its final finishing stage
- Types: (i) metal cutting processes (ii) grinding processes (iii) un-conventional machining processes

Advantages of Machining Processes

- Almost any metal can be machined
- It is possible to achieve close tolerances
- Machined components have good surface finish

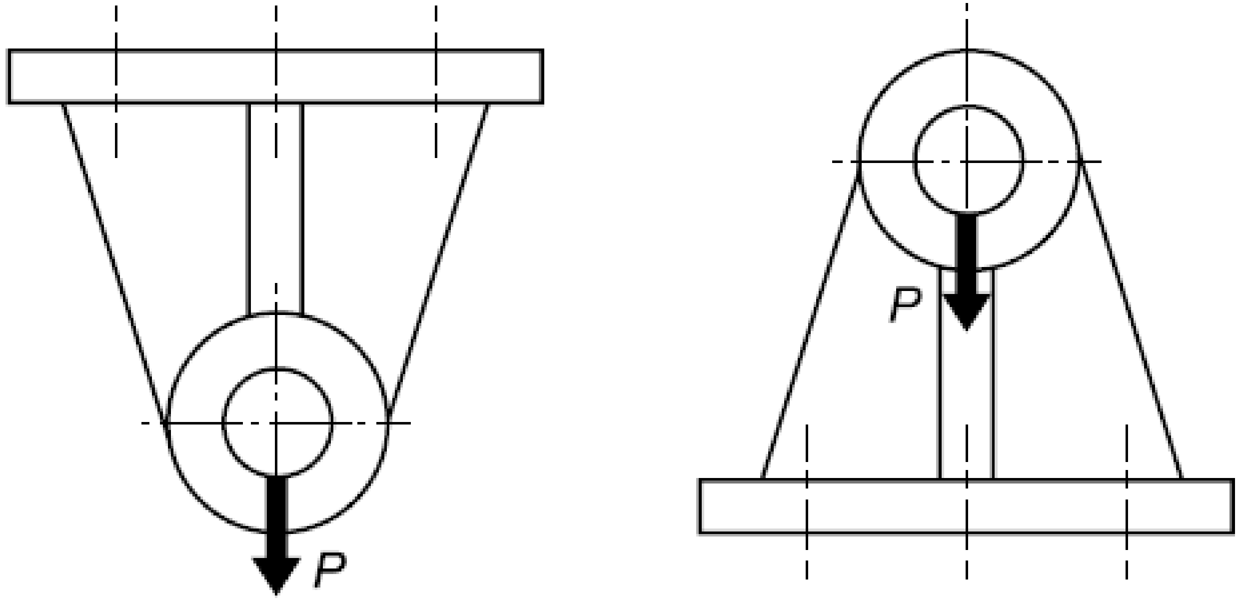
Disadvantages of Machining Processes

- Machining processes are costly
- Rate of production is low compared with casting or forging
- It is not possible to machine thin sections or projections
- There is significant wastage of material during material removal process

Design considerations of Castings

Poor shaping of casted components can adversely affect their strength. So designer should consult the foundry man and the pattern maker. General principles for design of castings are as follows:

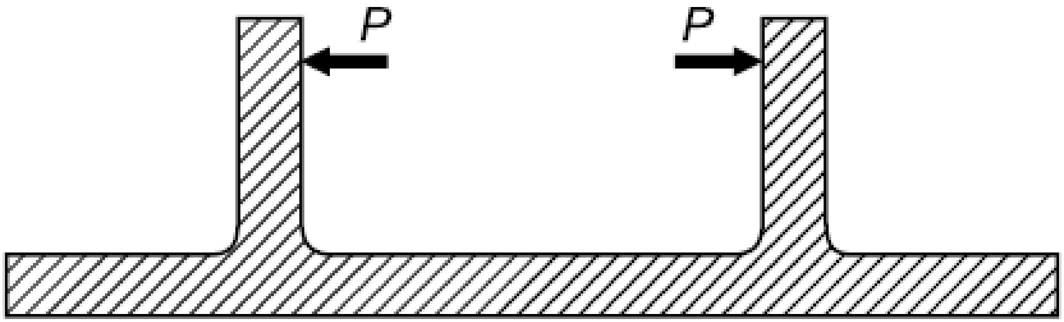
(a) Always keep stresses areas of the part in compression



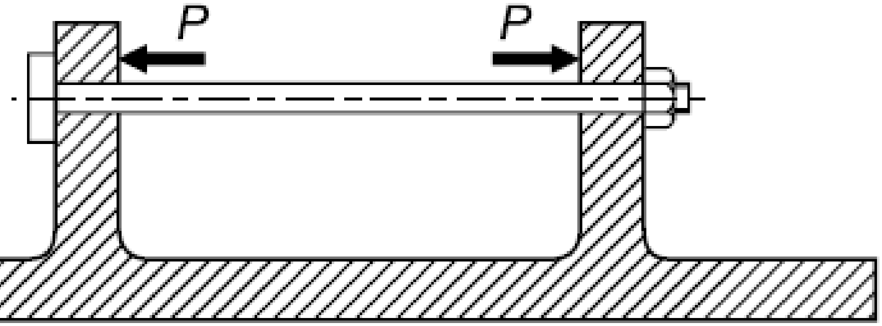
(a) (b)

Design considerations of Castings

When the tensile stresses are unavoidable, a clamping device such as ‘**tie rod**’ can be considered.



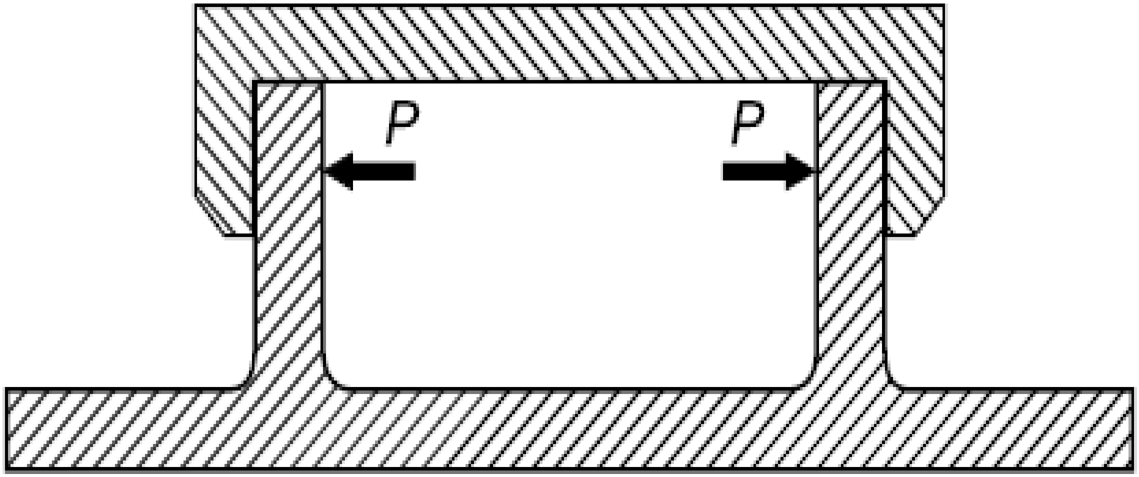
(a)



(b)

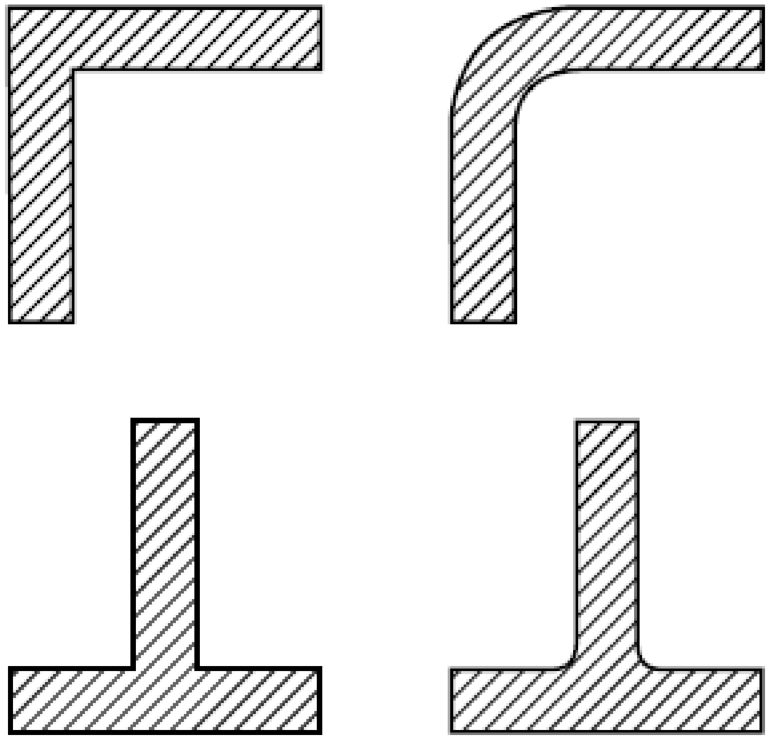
Design considerations of Castings

When the tensile stresses are unavoidable, a clamping device such as ‘**bearing cap**’ can be considered.



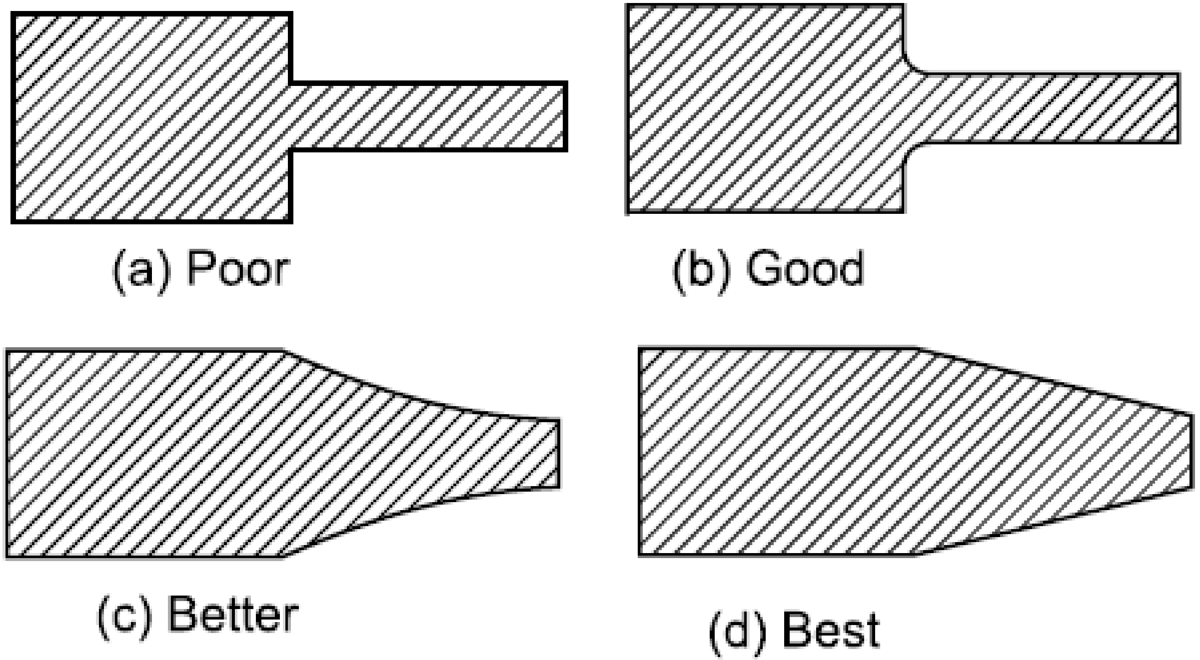
Design considerations of Castings

(b) Round all external corners. It has two advantages: (i) it increases endurance limit and (ii) reduces formation of brittle chilled edges



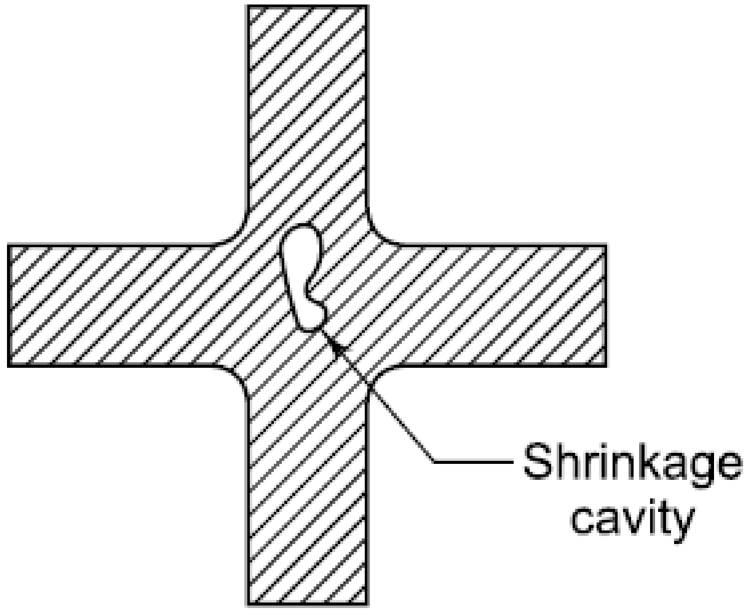
Design considerations of Castings

(c) Whenever possible, the section thickness throughout should be held as uniform as compatible with overall design considerations.



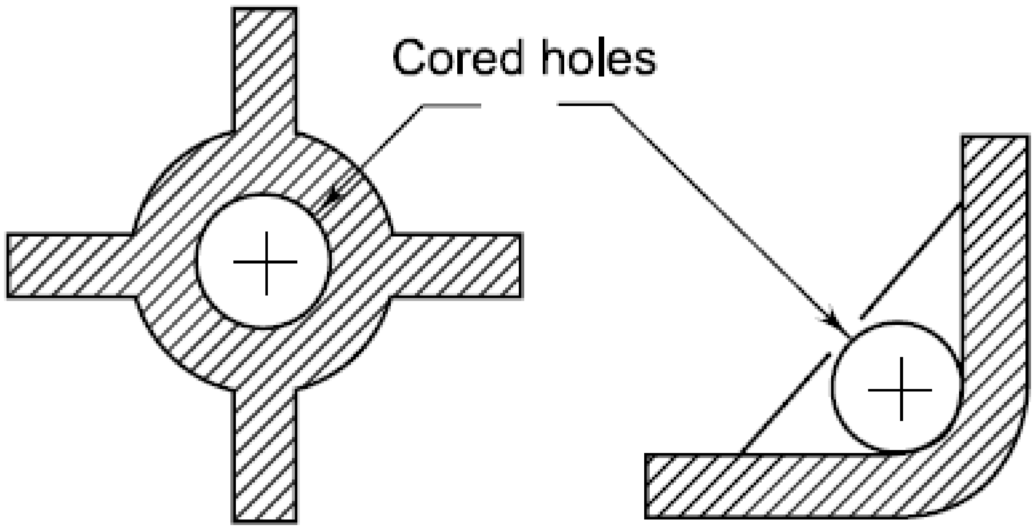
Design considerations of Castings

(d) 'Avoid concentration of metal at the junction' as the same is likely to result in shrinkage cavity or a blow hole.



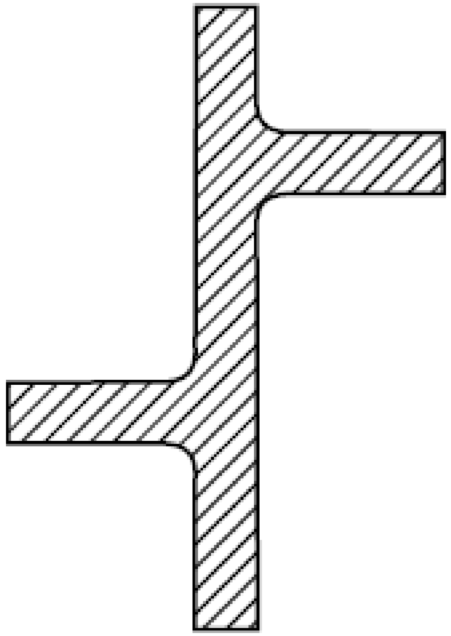
Design considerations of Castings

To avoid concentration of metal at the junction, one way is to provide cored openings in webs and ribs.



Design considerations of Castings

Alternatively, staggering can also be considered for ribs and webs.



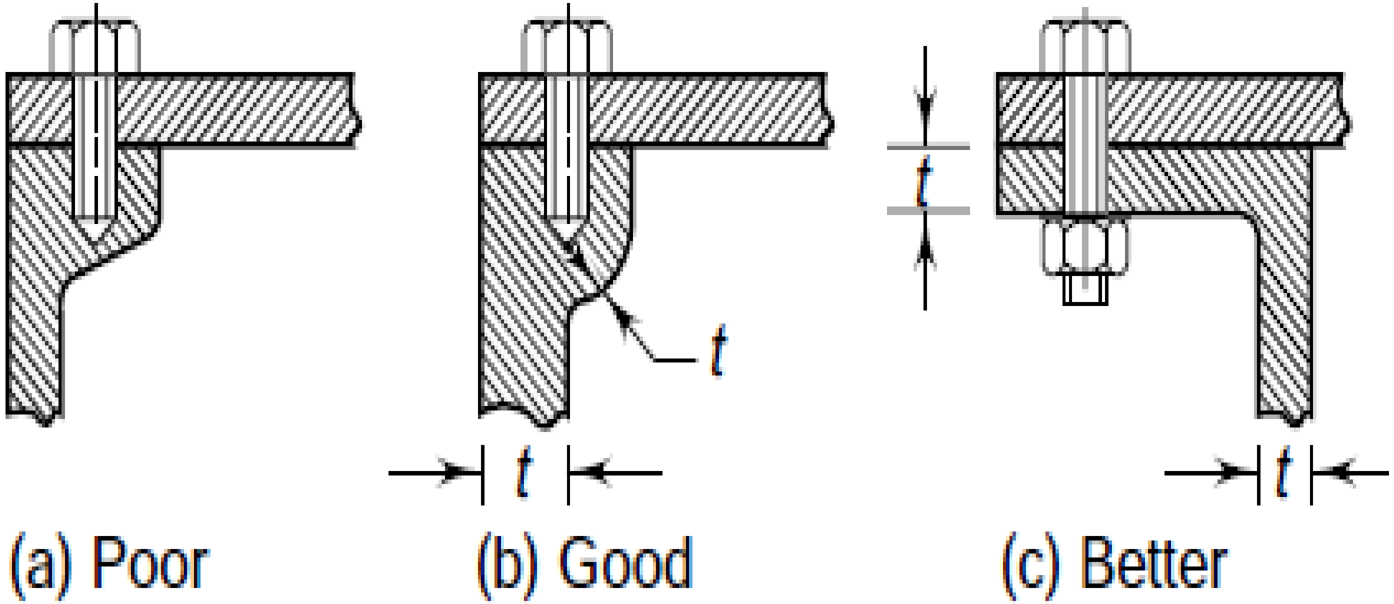
Staggered ribs

Design considerations of Castings

(e) Avoid very thin sections. In case from design point of view, the calculated thickness is small, same should be increased so as the same can be properly casted. In general, minimum thickness for grey cast iron components is about 7 mm for parts up to 500 mm long.

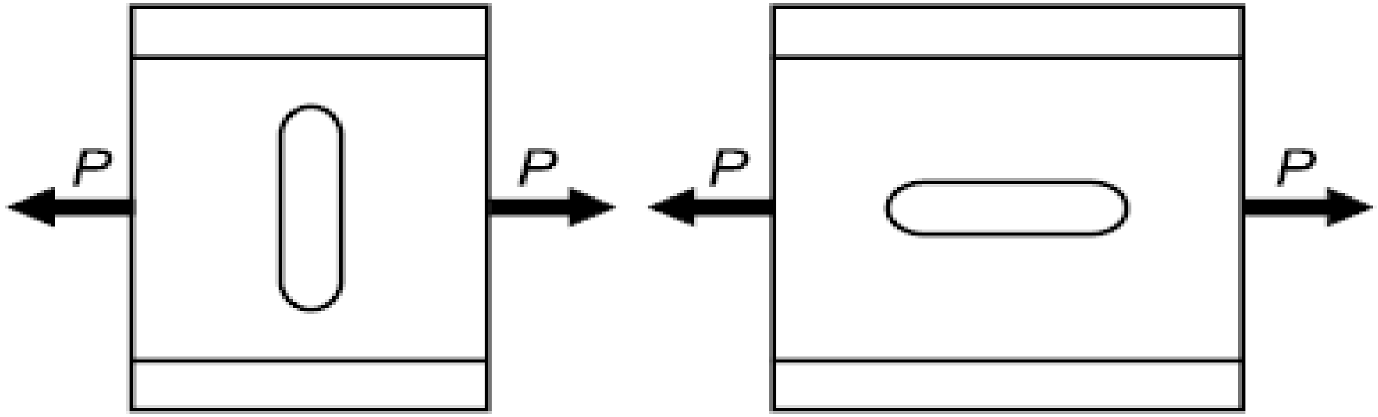
(f) Shot blast the parts, wherever possible. It significantly increases endurance limit particularly in case of thin sections.

Design considerations of Castings



Uniform wall thickness

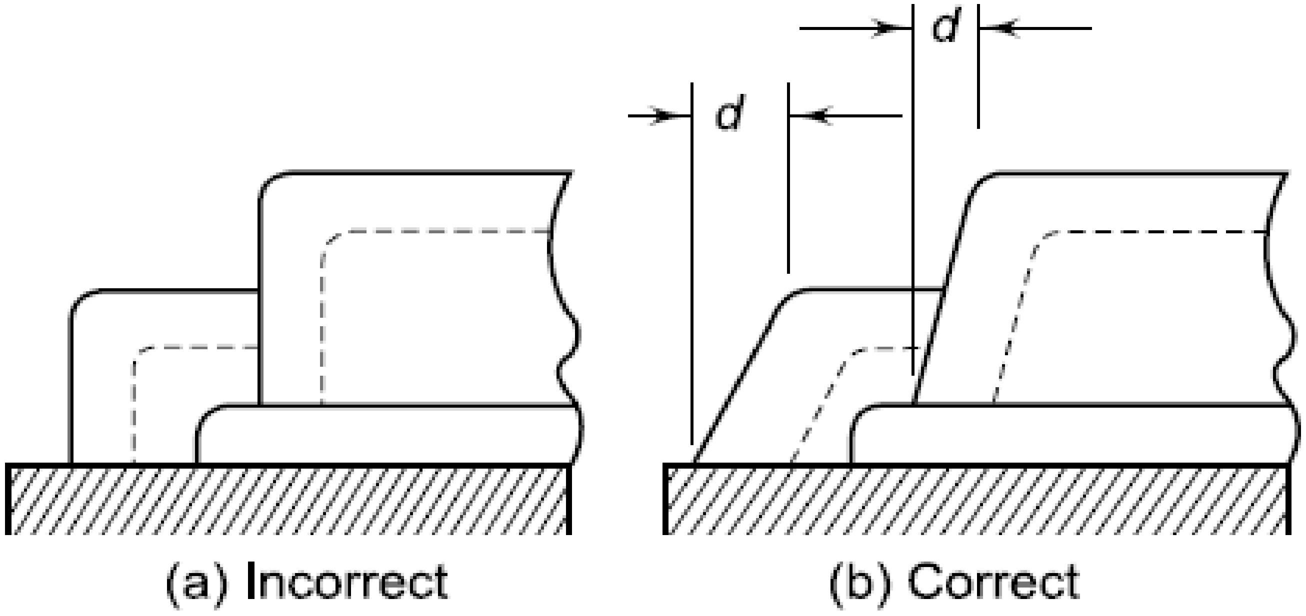
Design considerations of Castings



(a) Poor (b) Good

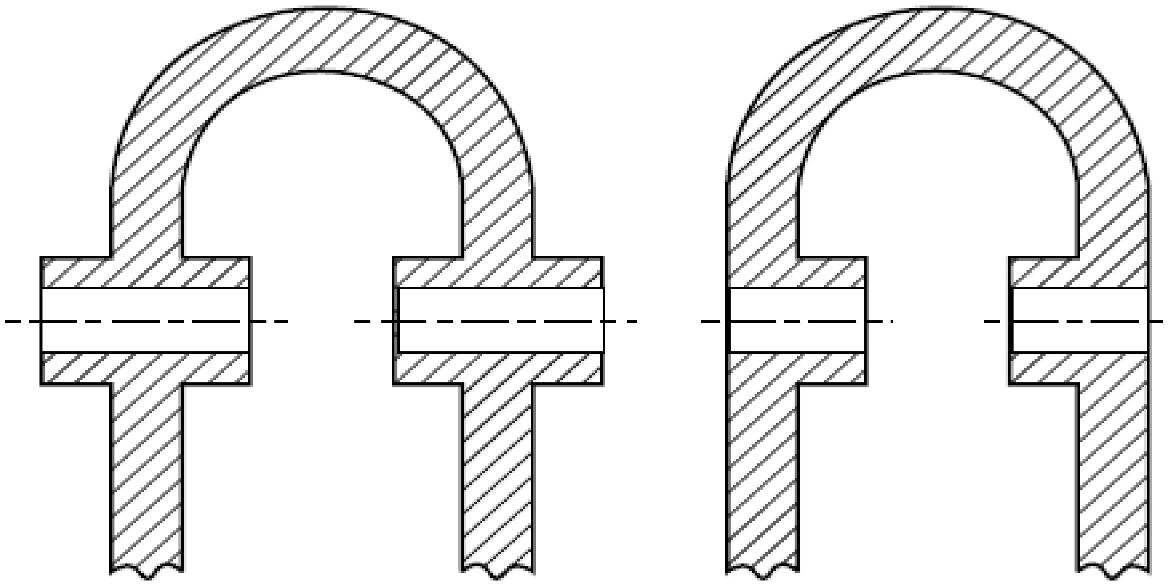
Holes in the direction of forces

Design considerations of Castings



Provision of draft

Design considerations of Castings



(a) Incorrect (b) Correct

Outside bosses should be omitted

Design considerations of Castings - Summary

(a) Always keep stressed areas of the part in compression

(b) Round all external corners

(c) Whenever possible, the section thickness throughout should be held as uniform as possible

(d) 'Avoid concentration of metal at the junction' as the same is likely to result in shrinkage cavity or a blow hole.

(e) Avoid very thin sections. In case from design point of view, the calculated thickness is small, same should be increased so as the same can be properly casted.

(f) Shot blast the parts, wherever possible. It significantly increases endurance limit particularly in case of thin sections.

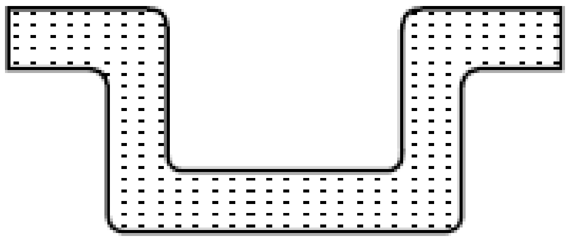
Design considerations of Forgings

Forged components are used in following circumstances:

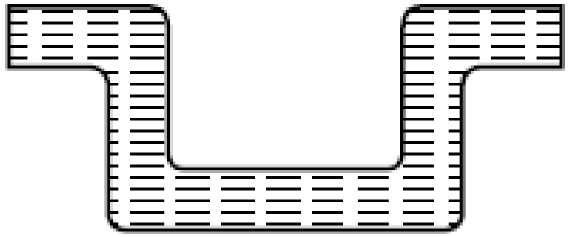
- Moving components should be light weight to reduce inertia forces (connecting rod)
- Components subjected to excessive stresses (IC Engine components)
- Small components that must be supported by other structures (hand tools)
- Components that must be free from internal cracks (valve bodies)
- Components whose failure may cause injury or expensive damage

Design considerations of Forgings

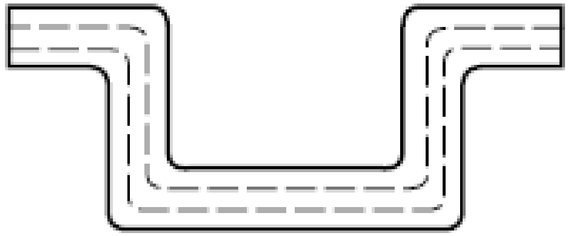
(a) While designing a forging, advantage should be taken of direction of fiber lines. While designing a forging, the profile is selected in such a way that fiber lines are parallel to tensile forces and perpendicular to shear forces.



(a) Cast Component



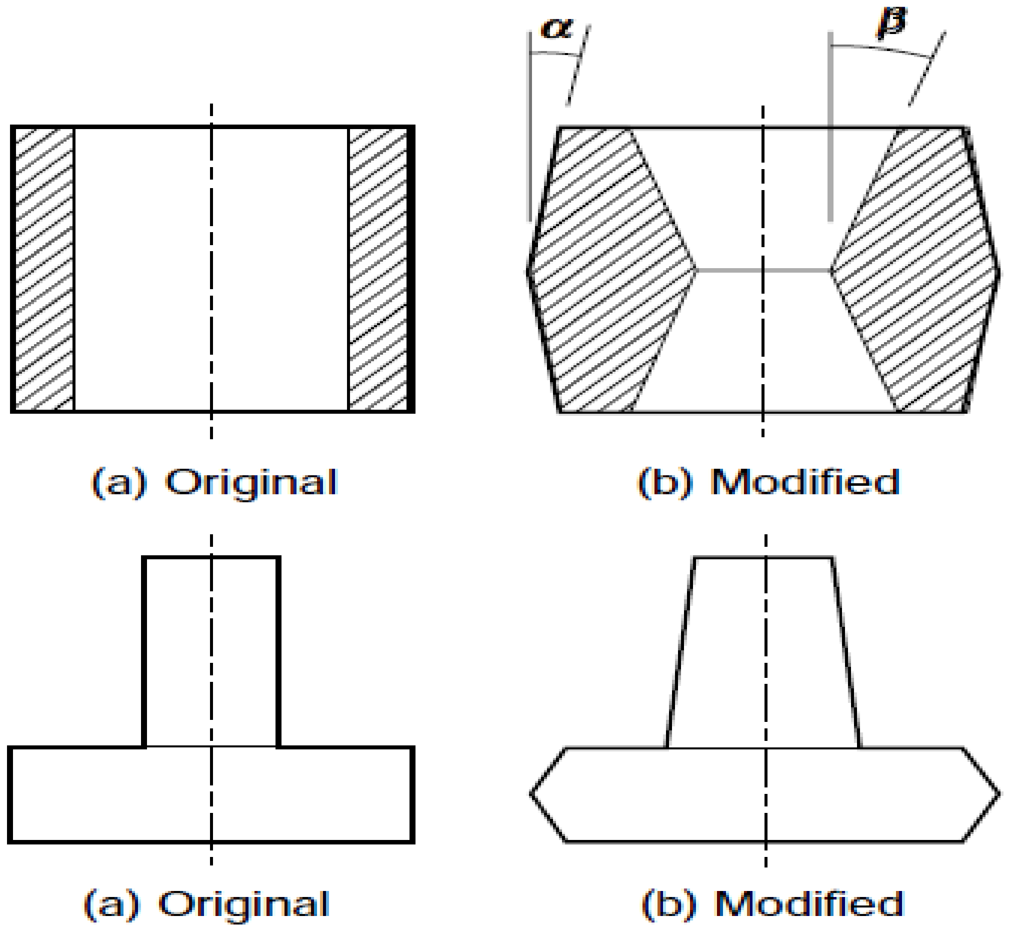
(b) Machined Component



(c) Forged Component

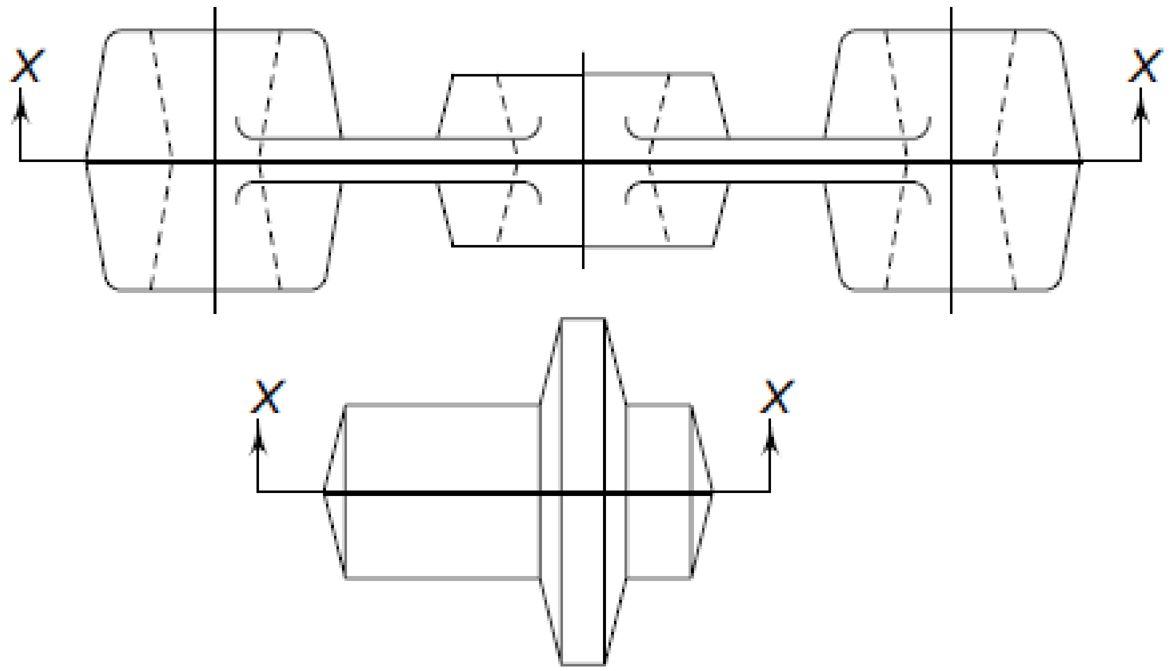
Design considerations of Forgings

(b) The forged component should be provided with an adequate draft for easy removal of part from the die impression



Design considerations of Forgings

(c) The parting line should be in one plane as far as possible and it must divide the forging into two equal parts.



Design considerations of Forgings

(d) The forgings should be provided with adequate fillet and corner radii, as sharp corners result in increasing difficulties in filling the material, excessive forging forces and poor die life.

(e) Thin sections and ribs should be avoided in forged components

Design considerations of Forgings - Summary

(a) While designing a forging, advantage should be taken of direction of fiber lines

(b) The forged component should be provided with an adequate draft for easy removal of part from the die impression

(c) The parting line should be in one plane as far as possible and it must divide the forging into two equal parts

(d) The forgings should be provided with adequate fillet and corner radii

(e) Thin sections and ribs should be avoided in forged components

Design considerations of Machined parts

Machined components are used in following circumstances:

- Components requiring precision and high dimensional accuracy
- Components requiring flatness, roundness, parallelism or circularity for their proper functioning
- Components of interchangeable assembly
- Components that requires relative motion with each other

Design considerations of Machined parts

(a) As far as possible, secondary machining operations should be avoided

(b) Specify liberal dimensional and geometrical tolerances. Closer the tolerance, higher the cost

(c) Designer should avoid shapes that requires sharp corners

(d) Stock dimensions should be promoted as far as possible

(e) Components with thin walls or webs should be avoided as the same induces significant cutting forces on the component

(f) Avoid shoulders and undercuts as the same requires separate tools

(g) Avoid hard materials as these are difficult to machine

Design for Manufacture and Assembly (DFMA)

Why DFMA?

- For simplifying design
- Decreasing assembly cost
- Improves product reliability
- Reduces operation time

Guidelines for DFMA

The guidelines of DFMA are as follows:

- *Reduce the parts count (results in lower cost)*
- *Use of modular designs (simplifies final assembly)*
- *Optimize part handling (part should retain same orientation throughout)*
- *Assemble in the open (Reduces chance of mfg. defects slipping past the inspector)*
- *Do not fight gravity (design so that products can be assembled from bottom to top)*
- *Design for part identity (symmetrical parts are easier to handle and orient)*
- *Limited use of fasteners (cost of fastening is 6 to 10 times than cost of fasteners)*
- *Design parts for simple assembly (misalignment of parts from different vendors creates problems)*
- *Reduce, simplify and optimize manufacturing processes*

Tolerances

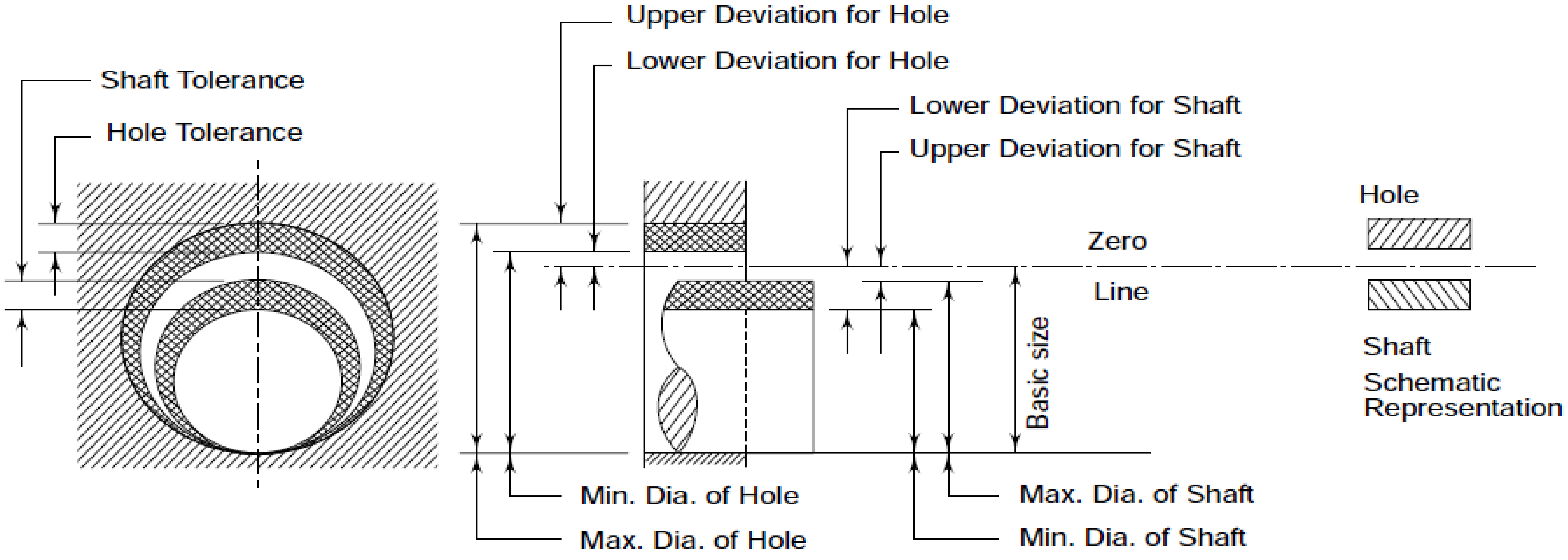
Why required?

- Due to inaccuracies of manufacturing methods, it is not possible to machine a component to a given dimension.
- The components are so manufactured that their dimensions lie between two limits
- The basic dimension is called normal or basic size while difference between two limits is called permissible tolerance

Tolerance is permissible variation in the dimensions of the component

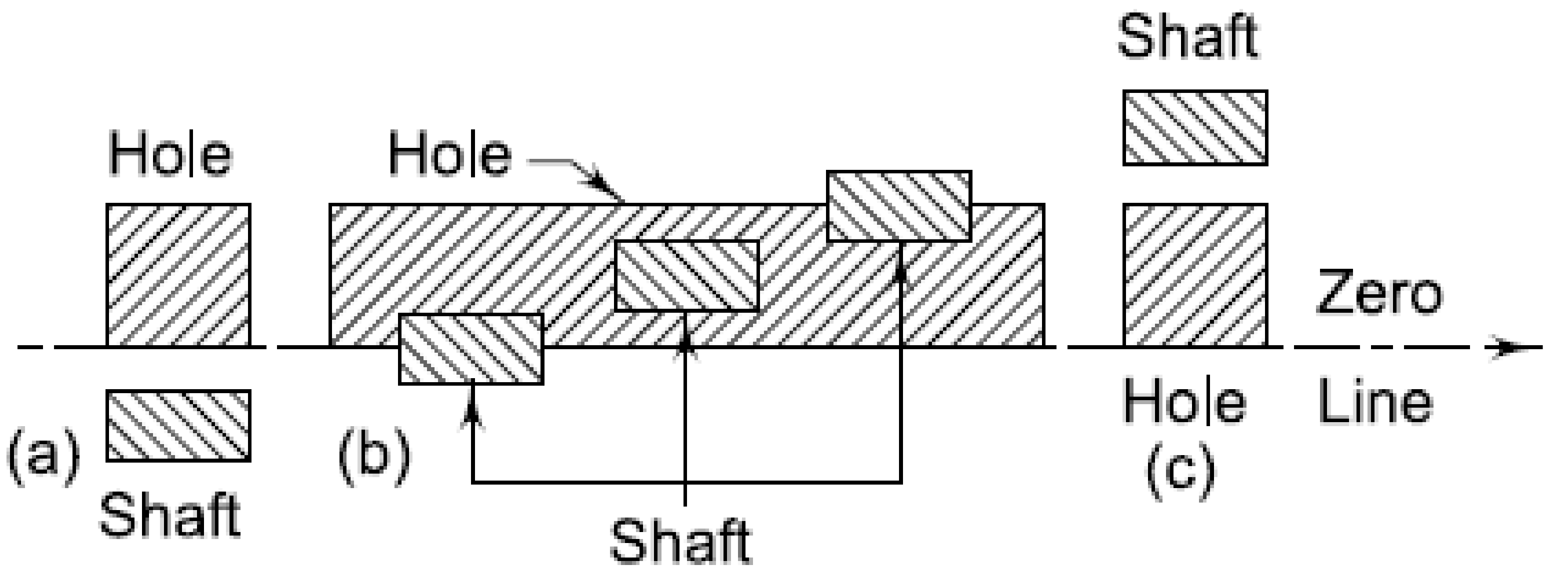
- Can be of two types: (i) unilateral and (ii) bilateral

Tolerances


Upper Deviation for Hole
Lower Deviation for Hole
Shaft Tolerance
Hole Tolerance
Lower Deviation for Shaft
Upper Deviation for Shaft
Hole
Zero
Line
Basic size
Shaft
Schematic Representation
Min. Dia. of Hole
Max. Dia. of Hole
Max. Dia. of Shaft
Min. Dia. of Shaft

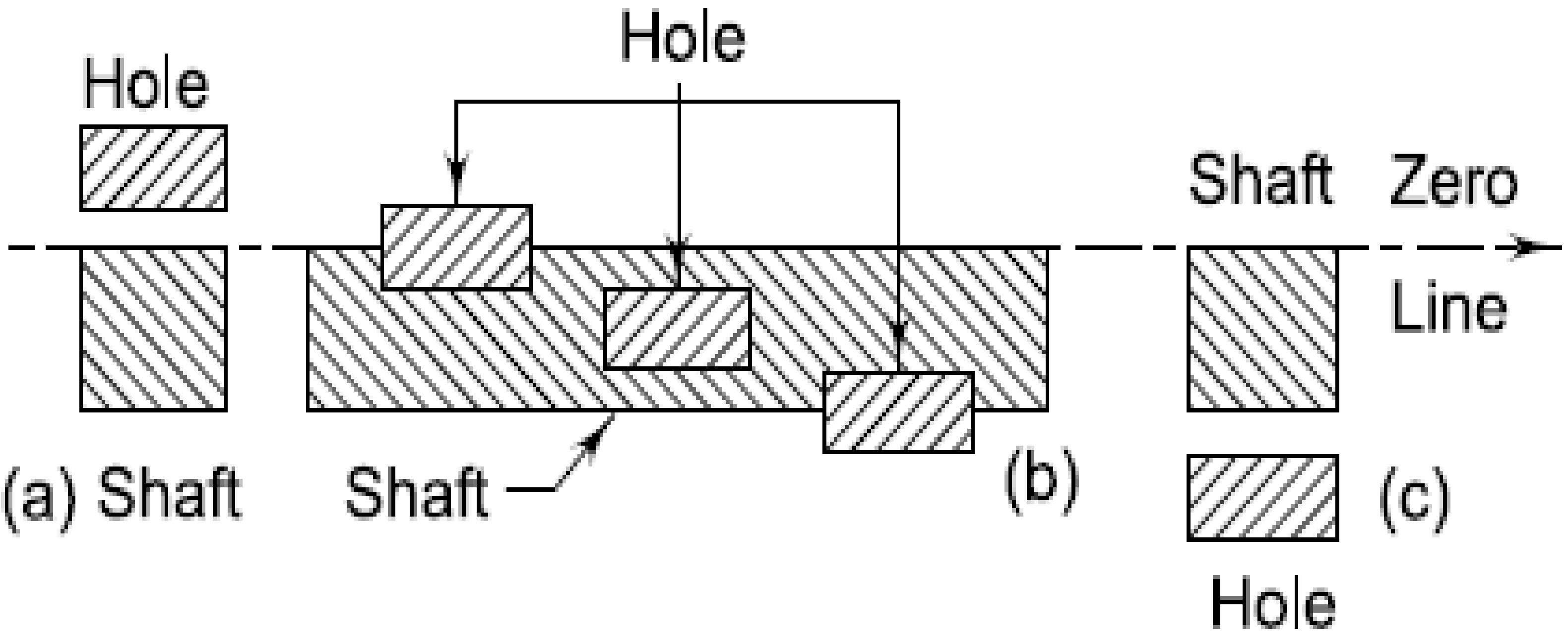
Fits

- When two parts are assembled, the relationship resulting from the difference between their sizes before assembly is called a fit.
- Hole basis system: fits are obtained by associating various shafts with a single hole whose lower deviation is zero.



Fits

- Shaft basis system: fits are obtained by associating various holes with a single shaft whose upper deviation is zero.



Allowance

- It is intentional difference between the maximum material limits of mating parts

- It is minimum clearance (positive allowance) in case of clearance fit and maximum interference (negative allowance) in case of interference fit.

ISO System of fits and tolerances

- Tolerance is specified by an alphabet capital or small followed by a number.
- For ex. 50 H8/g7 or 50 H8-g7 denotes tolerance for basic size of shaft and hole of 50 mm

ISO System of fits and tolerances

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

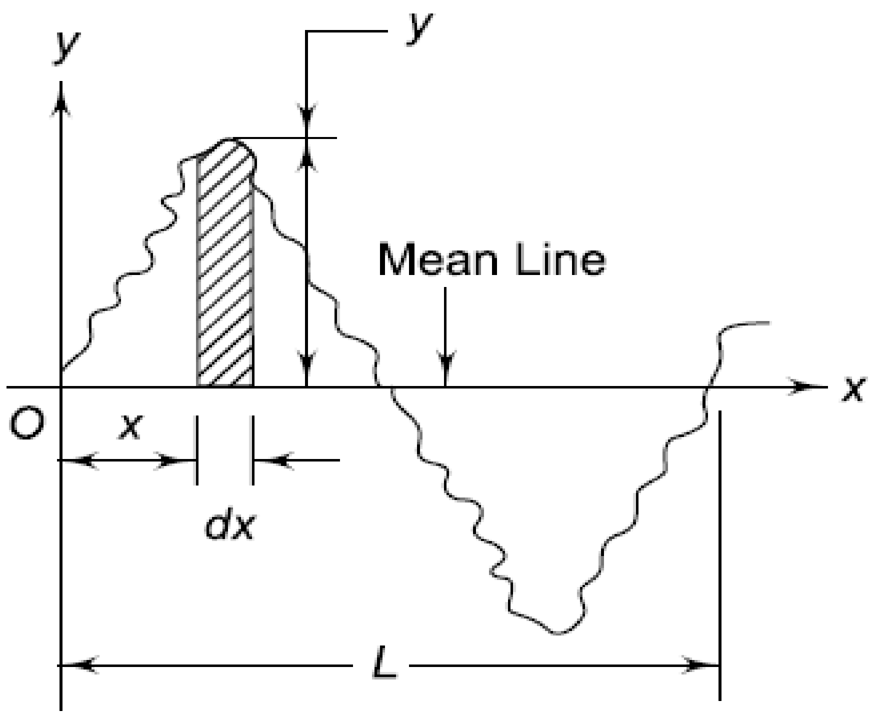
Surface Roughness

'Surface roughness' plays an important role in the performance of certain machine elements. Some of the examples are:

- Friction and wear increases with surface roughness (undesirable in bearings)
- Rough surface offers reduced contact area in interference fits
- Endurance strength significantly reduces with poor surface finish
- Corrosion resistance is adversely affected by poor surface finish

It is necessary for the designer to specify optimum surface finish from the consideration of functional requirement and cost of manufacturing

Surface Roughness -Measurement



Magnified surface profile

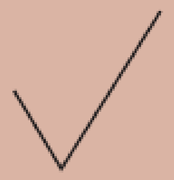
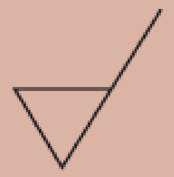
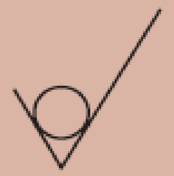
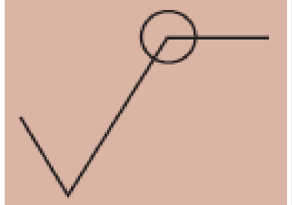
The centre line average (CLA) is given by:

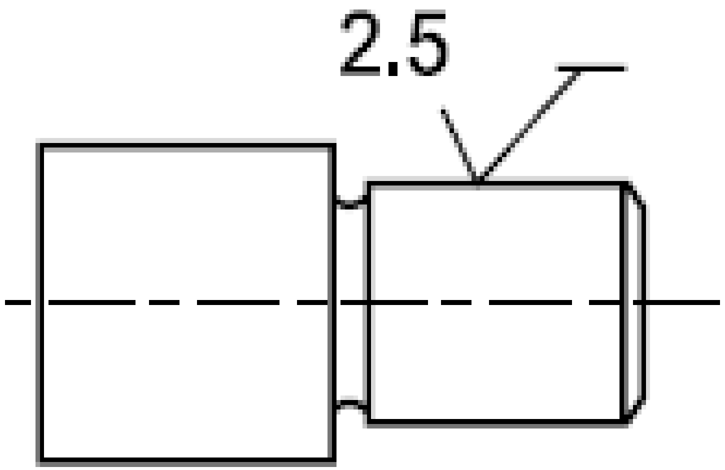
$$\text{cla} = \frac{1}{L}\int_0^L y\,dx$$

and the **rms** (root mean square) value as

$$\text{rms} = \left[\frac{1}{L}\int_0^L y^2\,dx\right]^{1/2}$$

Surface Roughness - Symbols

	Basic symbol
	Material removal by machining required
	Material removal not permitted
	The same finish for all surfaces



Surface Roughness – General values for common machining processes

Machining method	*Roughness (microns)*
turning–shaping–milling	12.5–1.0
boring	6.5–0.5
drilling	6.25–2.5
reaming	2.5–0.5
surface grinding	6.25–0.5
cylindrical grinding	2.5–0.25
honing–lapping	0.5–0.05
polishing–buffing	0.5–0.05

Thanks for Kind Attention