5 ME4-04: Design of Machine Elements-I

Unit-I

CO1 :- To Select the engineering materials as per manufacturing and design consideration

Content :- Materials : Mechanical Properties and IS Coding of various materials, Selection of Material from properties and economic aspects.

Manufacturing Considerations in Design :- Standardization, Interchangeability, limits, fits tolerances and surface roughness, BIS codes, Design Consideration for cast, forged and Machined parts. Design for assembly.

Unit - 1.

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ii) Manufacturing Considerations in Design :- Standardization, Interchangeability, limits, fits and tolerances and surface roughness, BIS codes, Design Consideration for Casting, forging and machined parts, Design for assembly.

Introduction :-

Machine :- It is an object which convert one form of energy into other form and perform useful work.

Design :- It is a analysis of object and its drawing under the applied forces, stresses and other factors, to find whether the object is reliable or not.

Design of Machine elements can be defined as the analysis of each members of machine under given/required condition of force and stresses, before its Manufacturing.

Machine Design :- is the creation of new and better machines and improving the existing ones. A new or better machine is one which is more economical in the overall cost of production and operation.

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Basic Requirements of Machine Elements :-

A machine consists of various machine elements. Each part of a machine, which has motion with respect to some other part is called a machine element. The broad objective of designing a machine element is to ensure that it preserves its operating capacity during the stipulated service life with minimum manufacturing and operating costs. In order to achieve this objective, the machine element should satisfy following basic requirements :-

(i) Strength (ii) Rigidity (iii) Wear Resistance (iv) Minimum dimensions and Wei
(v) Manufacturability (vi) Safety (vii) Conformance to standards
(viii) Reliability (ix) Maintainability (x) Minimum life Cycle Cost.

Basic Procedure of Design of Machine Element :-

→ Specify Functions of Element

↓

Determine Forces Acting on Element

↓

Select Suitable Material for element

↓

Determine Failure Mode of Element

↓

Determine Geometric Dimensions of Element

↓

Modify Dimensions for Assembly and Manufacture and check Design at Critical Cross-sections

↓

Prepare Working Drawing of Element

↓

Production.

Engineering Materials :-

- **Metals**
  - **Ferrous** — eg:- Steels, Stainless Steels, Tool & die steels, Cast Irons
  - **Non-ferrous** — Aluminium, Copper, Titanium, Tungsten
- **Plastics**
  - **Thermoplastics** — Acrylics, ABS, Nylons, PVC
  - **Thermosets** — Epoxies, Phenolics, Polyimides
  - **Elastomers** — Rubbers, Silicones, Polyurethane
- **Ceramics & other** — Oxides, Nitrides, Carbides, Glasses
- **Composites** — Reinforced plastics, Metal-matrix, Ceramic-matrix, Laminates.

Mechanical Properties of Engineering Materials :-

Materials are characterised by their properties. They may be hard, ductile or heavy and conversely they may be soft, brittle or light.

The mechanical properties of materials are the properties which describe the behaviour of the material under the action of External forces. They usually relate to elastic and plastic behaviour of the materials. The mechanical properties are of significant importance in selection of material for structural machine component. The various mechanical properties are :-

1. **Strength** :- Strength is defined as the ability of the material to resist, without rupture, to external forces causing various types of stresses.

2. **Elasticity** :- It is the property of a material to regain its original shape after deformation when the external forces are removed.

3. **Plasticity** :- It is the property of a material which retains the deformation produced under load permanently.

4. **Ductility** :- It is the property of a material enabling it to be drawn into wire with the application of a tensile force.

5. **Brittleness** :- It is the property of breaking of a material with little permanent distortion.

7. <u>Toughness</u> :- It is the property of a material to resist fracture due to high impact loads like hammer blows.

<u>OR</u>

Toughness is defined as the ability of the material to absorb the energy before fracture has taken place.

8. <u>Resilience</u> :- Resilience is defined as the ability of the material to absorb energy when deformed elastically and to release this energy when unloaded.

9. <u>Stiffness or Rigidity</u> :- It is defined as the ability of the material to ~~absorb energy when deformed eto~~ resist deformation under the action of external load.

10. <u>Hardness</u> :- Hardness is defined as the resistance of the mater[ial] to penetration or permanent deformation.

11. <u>Creep</u> :- When a member is subjected to a constant load over a long period of time it undergoes a slow permanent deformation and this is termed as "creep".

This is dependent on temperature. Usually at elevated temperature creep is high.

12. <u>Fatigue</u> :- When a material is subjected to repeated stresses, it fails at stresses below the yield point stresses. Such type of failure of a material is known as fatigue.

<u>Factors to be considered in Machine Design</u> :-

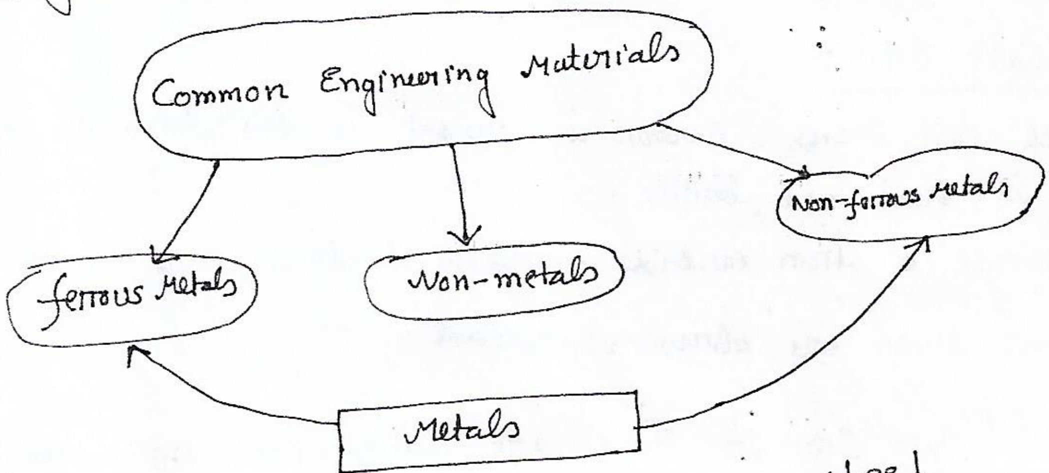
- ↳ What device or Mechanism to be used?
- ↳ Material
- ↳ Forces on the elements
- ↳ Size, shape and space requirements.
- ↳ Weight of the product.
- ↳ The Method of manufacturing the components and their assembly.
- ↳ How will it operate.
- ↳ Reliability and safety aspects.
- ↳ Inspectibility

Selection of Materials for Engineering Purposes :-

Following factors should be considered while selecting the material :-

1. Availability of the Materials
2. Suitability of the materials for the working conditions in service. {Properties}
3. The cost of the material

Common Engineering materials :-



Important ferrous Metals :- Cast Iron, wrought iron, steel

⇒ Cast Iron :-

→ Cast Iron is obtained by re-melting pig iron with coke and limestone in a furnace known as cupola furnace.

→ Alloy of Iron, carbon and silicon.
→ Hard and Brittle
→ Carbon content within 1.7 % to 3 % (or 4 %).
→ Carbon presence : free carbon / iron carbide Fe_3C

Properties of C.I which make it a valuable material for engineering purposes :-
(a) low cost
(b) good casting characteristics
(c) high compressive strength
(d) wear resistance
(e) Excellent machinability.

The types of Cast Iron :-

↳ Grey cast iron
↳ white cast Iron
↳ malleable cast Iron
↳ spheroidal or nodular cast Iron
↳ austenitic cast Iron
↳ abrasion resistant cast Iron

I) Grey Cast Iron :-

↳ Carbon here is mainly in the form of free graphite due to which it is grey in colour.

↳ This type of Cast Iron is inexpensive and has high compressive strength.

↳ According to Indian standard specifications, the ~~the~~ grey cast Iron is designated by the alphabets 'FG' followed by a figure indicating the minimum tensile strength in MPa or N/mm^2.

↳ eg:- FG150

↳ The grey iron castings are widely used for machine tool bodies, automotive cylinder bloc heads, housing, fly-wheels, pipes and pipe fittings and agricultural implements.

2. White Cast Iron :-

↳ In these cast Irons, carbon is present in the form of iron carbide (Fe_3C) which is hard and brittle.

↳ The presence of iron carbide increases hardness and makes it difficult to machine

↳ These cast Irons are abrasion resistant.

3. Malleable Cast Iron :- There are white cast irons rendered malleable by annealing. These are tougher than grey cast iron and they can be twisted or bent without fracture.

↳ Excellent machining properties, inexpensive.

↳ used for making parts where forging is expensive. {eg:- Hubs for wagon wheels, brake supports}

↳ According to Indian standard specifications, the malleable cast iron may be of three types :- (i) Whiteheart Malleable cast Iron (ii) Blackheart malleable C.I (iii) Pearlitic malleable cast Iron, according to the chemical composition, temperature and time cycle of annealing process.

- Whiteheart malleable cast Iron :- WM350, WM400
- Blackheart malleable cast Iron :- BM300 ; BM320
- Pearlitic malleable cast Iron :- PM450 ; PM500.

4. Spheroidal or nodular graphite Cast Iron :- In these cast irons graphite is present in the form of spheres or nodules.

↳ High tensile strength

↳ Good elongation properties.

Austenitic cast Iron :- Depending on the form of graphite present these cast iron is classified broadly under two headings :-

i. Austenitic flake graphite iron

ii. Spheroidal / nodular graphite Iron.

→ used for making automobile parts :- Cylinders, pistons, piston rings, brake drums, etc.

Abrasion resistant cast Iron :- These are alloy cast Iron and the alloying elements render abrasion resistance.

Typical designation :- ABR33 Ni4 Cr2

↳ Indicates a tensile strength in MPa with 4% Ni and 2% Chromium.

Wrought Iron :- This is the very pure iron where the iron content is of the order of 99.5%. It is produced by remelting pig iron and small amount of silicon, sulphur or phosphorus may be present.

↳ It is tough, malleable, and ductile and can easily be forged or welded.

↳ It cannot however take sudden shock.

↳ Chains, crane hooks, railway couplings and such other components may be made of this iron.

Steel :- This is by far the most important engineering material and there is an enormous variety of steel to meet the wide variety of engineering requirements.

Steel is basically an alloy of iron and carbon in which the carbon content is generally less than 1.7% and carbon is present in the form of iron carbide which imparts hardness and strength.

Two main categories of steel are :-

ⓐ Plain carbon steel

ⓑ Alloy steel

Plain carbon steel :- The properties of plain carbon steel depend mainly on the carbon percentage. Other alloying elements are not usually present in more than

Plain carbon steel ~~depend mainly on the~~ are designated as C01, C14, C45 where the number indicates the carbon percentage.

Categorization of plain carbon steels :-

1. Dead mild steel → upto 0.15 % carbon
2. Low carbon or mild steel → 0.15 to 0.45 % carbon
3. Medium Carbon steel → 0.45 to 0.8 % C
4. High Carbon steel → 0.8 to 1.5 % C

In general higher carbon percentage indicates higher strength.

Alloy steel :- These are steels in which elements other than carbon are added in sufficient quantities to impart desired properties, such as wear resistance, corrosion resistance, electric or magnetic properties.

Chief alloying elements :-

- Nickel → Strength and toughness
- Chromium → hardness and strength
- Tungsten → hardness at elevated temperature
- Vanadium → tensile strength
- Manganese → high strength in hot rolled / heat treated condition.
- Silicon → high elastic limit
- Cobalt → hardness
- Molybdenum → extra tensile strength.

Steel Designated on the basis of Mechanical Properties :-

These steels are carbon and low alloy steels where the main criterion in the selection and inspection of steel is the tensile strength or yield stress. According to the Indian standard, these steels are designated by a small 'Fe' or 'FeE' depending on whether the steel has been specified on the basis of minimum tensile strength or yield strength, followed by the figure indicating the minimum tensile strength or yield stress in N/mm^2 or MPa

for example :-

Fe 290 ⇒ means a steel having minimum tensile strength of 290 MPa.

Fe E 280 ⇒ means a steel having yield strength of 280 MPa.

Steel Designated on the Basis of Chemical Composition :- According to Indian standard, the carbon steels are designated in the following order :-

ⓐ Figure indicating 100 times the average percentage of carbon content.

b.) Letter 'C' and

c) Figure indicating 10 times the average percentage of manganese content.

For example :- 20C8 → means a carbon steel containing 0.15 to .25 per cent (.2 percent on an average) carbon and .60 to .90 percent (0.75 percent rounded off to 0.8 per cent on an average) manganese.

Indian standard Designation of low and medium alloy steels :-

① Figure indicating 100 times the average percentage carbon.

② Chemical symbol for alloying elements each followed by the figure for its average percentage content multiplied by a factor as given below :-

Element	Multiplying factor
Cr, Co, Ni, Mn, Si and W	4
Al, Be, V, Pb, Cu, Nb, Ti, Ta, Zr, and Mo	10
P, S and N	100

Example :- Steel containing .4 % carbon, 1% chromium and .25% molybdenum

↳ 40 Cr4 Mo2

Other types of steels :-

#a. Stainless steel :- It is defined as that steel which when correctly heat treated and finished, resists oxidation and corrosive attack from most corrosive media. Different types of stainless steels are :-

a. Martensitic steel

b. Ferritic stainless steel

c. Austenitic stainless steel

b. Heat Resisting steels :- The steels which can resist creep and oxidation at high temperatures and retain sufficient strength are called heat resisting steels. Different types of HRS are :-

1. Low alloy steels
2. Values steels
3. Plain chromium steel
4. Austenitic chromium ~~steel~~ nickel steels.

Indian Standard Designation of high alloy steels {Stainless steel and HRS}

According to Indian standard; the high alloy steels are designated in the following order :-

1. Letter X
2. Figure indicating 100 times the percentage of carbon content.
3. Chemical symbol for alloying elements each followed by a figure for its average percentage content rounded off to the nearest integer.
4. Chemical symbol to indicate specially added element to allow the desired properties

eg :- X10Cr18Ni9 means alloy steel with average carbon 0.10 %, chromium 18 and Nickel 9%.

c. High speed Tool steels :- These steels are used for cutting metals at a much higher cutting speed than ordinary carbon tool steels.

Different types of high speed steels are :-

1. 18-4-1 high speed steel :- This steel on an average contains 18 % tungsten, 4% chromium and 1% vanadium. It is considered to be one of the best of all purpose tool steels. It is widely used for drills, lathe, planer and shaper tools, milling cutters, reamers, punches, etc.

2. Molybdenum high speed steel :- particularly used for drilling and tapping operations

3. Super high speed steel :- principally used for heavy cutting operations which impose high pressure and temperatures on the tool.

Indian Standard Designation of High Speed Tool steel :-

The high speed tool steels are designated in the following order :-

1. Letter 'XT'
2. Figure indicating 100 times the percentage of carbon content.
3. Chemical symbol for alloying elements each followed by the figure for its average percentage content rounded off to the nearest integer, and
4. Chemical symbol to indicate specially added element to attain the desired properties.

example :- XT 75 W18 Cr4 V1 means a tool steel with average carbon content of .75 percent, tungsten 18%, chromium 4% and vandium 1%.

Non-ferrous Metals :- Metals containing elements other than iron as their chief constituents are usually referred to as non-ferrous metals.
The non-ferrous metals are usually employed in industry due to the following characteristics :-

a. Ease of fabrication (Casting, rolling, forging, welding and machining),
b. Resistance to corrosion
c. Electrical and thermal conductivity
d. Weight

Various non-ferrous metals used in engineering practice are :-

1. Aluminium :→ This is the white metal produced from Alumina. In its pure state it is weak and soft but addition of small amounts of Cu, Mn, Si and Magnesium makes it hard and strong. It is also corrosion resistant, low weight, and non-toxic.

Aluminium alloys :-

a. Duralumin :- This is an alloy of 4% Cu, 0.5% Mn, 0.5% Mg and rest is aluminium. It is widely used in automobile and aircraft components.

b. Y alloy :- This is an alloy of 4% Cu, 1.5% Mn, 2% Ni, .6% each of Silicon, Magnesium, Iron and remainder is Aluminium. Y alloy has better strength (than duralumin) at high temperature, therefore it is much ... ft engines for cylinder heads and pistons.

c. Magnalium :- This is an aluminium alloy with 2 to 10 % magnesium. It also contains 1·75 % Cu. Due to its light weight and good strength it is used for aircraft and automobile components.

2. Copper :- Copper is one of the most widely used non-ferrous metals in industry. It is soft, malleable and ductile and is a good conductor of heat and electricity.

Copper alloys :-

(a) Copper-zinc alloys (Brass)
(b) Copper-tin alloys (Bronze)

3. Gun metal :- It is an alloy of copper, tin and zinc. It usually contains 88% Cu, 10 % tin and 2 % Zn. This is suitable for working in cold state. It was originally made for casting guns but now used for casting boiler fittings, bushes, bearings, glands, etc.

Non-metals :- Non-metallic materials are used in engineering practice due to their low density, low cost, flexibility, resistant to heat and electricity.

1. Plastics :- These are synthetic materials which can be moulded into desired shapes under pressure with or without application of heat. These are now extensively used in various industrial applications for their corrosion resistance, dimensional stability and relatively low cost. There are two main types of plastics :-

a. Thermosetting plastics :- Thermosetting plastics are formed under heat and pressure. It initially softens and with increasing heat and pressure, polymerization takes place. This results in hardening of the material. These plastics cannot be deformed or remoulded again under heat and pressure.

Examples :- phenol-formaldehyde (Bakelite)
phenol-furfural (Durite)
Epoxy resins
Phenolic resins

b. Thermoplastics :- They do not become hard with the application of heat and pressure and no chemical change takes place. They remain soft at

Examples of thermoplastics :- cellulose nitrate (Celluloid)
polythene
Polyvinyl acetate
Polyvinyl chloride (PVC)

2. Rubber :- It has high bulk modulus and is used for drive elements, sealing, vibration isolation and similar applications.

3. Leather :- This is widely used in engineering for its flexibility and wear resistance.

1. Ferrodo :- It is a trade name given to asbestos lined with lead oxide. It is generally used as a friction lining for clutches and brakes.

Standardization in Design :- For easy identification of materials, further improvement of machine elements and easy replacement of worn-out parts and for quick and easy manufacturing, the parameters of machine elements are standardized.

In design, the aim is to use as many standard components as possible for a given mechanism. Standardization is defined as obligatory norms or standards to which various characteristics of a product should conform. The characteristics include materials, dimensions and quality of the product, method of testing and method of marking, packing and storing of the product. Standardization becomes a global activity to cover all economical, technical and material aspects of Engineering products. The work of standardization is accomplished by national or international organizations.

The following standards are used in Mechanical Engineering design:-

1. Standards for materials, their chemical compositions, mechanical properties and heat treatments.
2. Shapes and dimensions of commonly used machine elements such as bolts, screws, and nuts, rivets, belts, etc.
3. Standards for fits, tolerances and surface finish of components.
4. Standards for testing of products such as pressure vessels, boilers, etc.

There are three types of standards used in the design :-

↳ International standards organization (I.S.O)
↳ national standards, such as I.S (Bureau of Indian Standards)
↳ Company standards for use in a particular company or a group of sister concerns like air crafts and ship building industries manufacture their products with their own standard without adopting the general standard parts. This type of individual plant standardization is known as Normalization.

<u>Preferred Numbers</u> :- In engineering design many times the designer has to specify the size of the product. The 'size' of the product is a general term which includes different parameters like power transmitting capacity, load carrying capacity, speed, dimensions of the components and weight of the components. These parameters are expressed numerically eg: 5 K 10 KN, 1000 rpm. Often the product is manufactured in different sizes or : de for instance, a company may be manufacturing different models of electric motors ranging from 0.5 KW to 50 KW to cater to the need of different customers Preferred numbers are used to specify the 'sizes' of the products in these cases. Preferred numbers were first introduced by Charles Renard. These are nothing but a series of numbers in a geometric progression specially selected to be used for standardization in preference to any other random numbers.

They are written as integral powers of 10. The first four are called basic series (denoted as R5, R10, R20, and R40) which increase in steps of 58%, 26%, 12%, 6% respectively and other are called derived series. Each series has its own series factor.

The series factors are as follows :-

R5 series $\sqrt[5]{10} = 1.58$
R10 series $\sqrt[10]{10} = 1.26$
R20 series $\sqrt[20]{10} = 1.12$
R40 series $\sqrt[40]{10} = 1.06$

The resultant numbers are rounded as per international standards

<u>USES</u> :- Preferred numbers are an important tool, which minimize unnecessary variation in sizes. They assist the designer in avoiding selection of sizes in an arbitrary manner. The complete range is covered by minimum number of sizes which is advantageous to producer and

Interchangeability :- The term interchangeability is normally employed for the mass production of identical items within the prescribed limit of sizes. To maintain the sizes of the part within a close degree of accuracy, a lot of time is required, but even then there will be small variations. If the variations are within certain limits, all parts of equivalent size will be equally fit for operating in machines and mechanisms. Therefore certain variations are recognised and allowed in the sizes of the mating parts to give the required fitting. This facilitates to select at random from a large number of parts for an assembly and results in a considerable saving in the cost of production.

In order to control the size of finished part, with due allowance for error, for interchangeable parts is called limit system.

Important Terms used in limit System :-

Nominal size :- It is the size of a part specified in the drawing as a matter of convenience.

2. Basic size :- It is the size of a part to which all limits of variation (i.e tolerances) are applied to arrive at final dimensioning of the mating parts. The nomial or basic size of a part is often the same.

3. Actual size :- It is the actual measured dimension of the part.

4. limit of sizes :- There are two extreme permissible sizes for a dimension of the part. The largest permissible size for a dimension of the part is called upper or high or maximum limit, whereas the smallest size of the part is known as lower or minimum limit.

5. Allowance :- It is the difference between the basic dimensions of the mating parts. The allowance may be positive or negative. 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.

6. Tolerance :- It is the difference between the upper limit and lower limit of a dimension. In other words, it is the maximum permissible variation in a dimension.

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

8. 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.

9. Upper deviation :- It is the algebraic difference between the maximum size and the basic size.

10. Lower deviation :- It is the algebraic difference between the minimum size and the basic size.

11. Actual deviation :- It is the algebraic difference between an actual size and the corresponding basic size.

12. Mean deviation :- It is the arithmetical mean between the upper and lower deviations.

13. Fundamental deviation :- It is one of the two deviations which is conventionally chosen to define the position of the tolerance zone in relation to zero line.

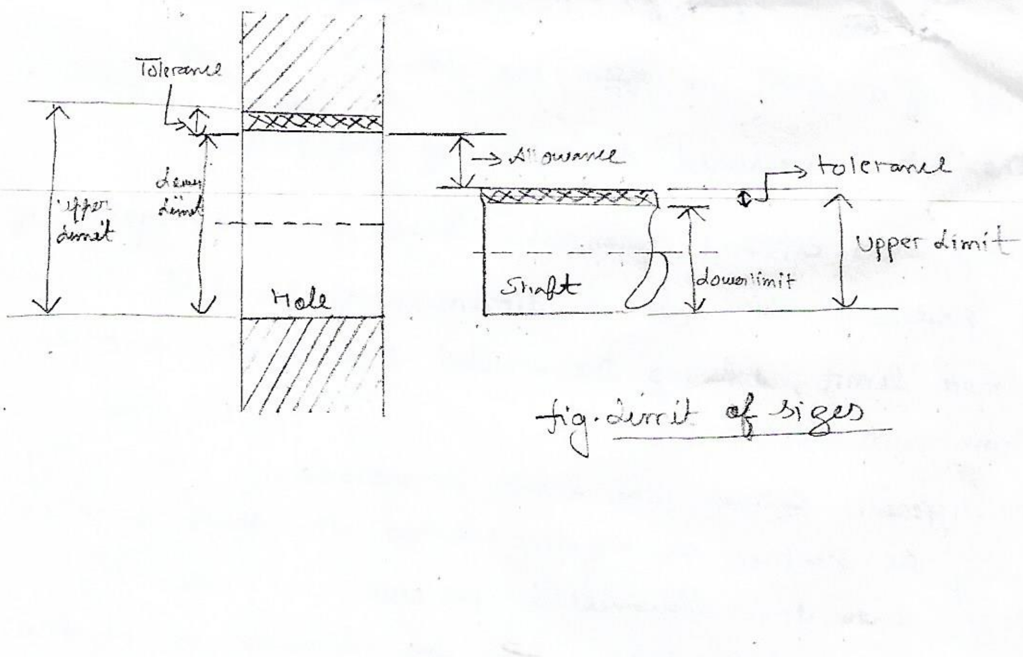
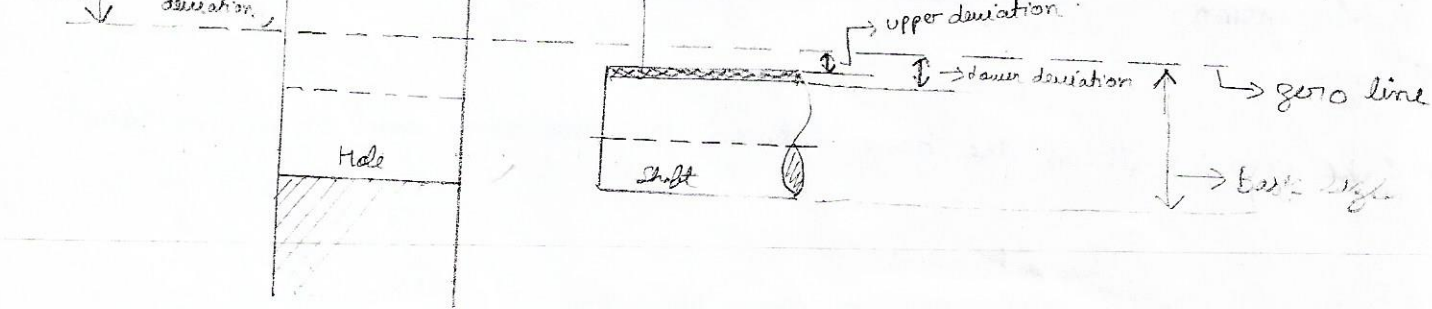


fig. limit of sizes



Fit :- The degree of tightness or looseness between the two mating parts is known as a fit of the parts. The nature of fit is characterised by the presence and size of clearance and interference.

The clearance is the amount by which the actual size of the shaft is less than the actual size of the mating hole in an assembly. The difference must be positive.

The interference is the amount by which the actual size of a shaft is larger than the actual finished size of the mating hole in an assembly. The difference must be negative.

Types of fits :-

1. Clearance fit :- In this type of fit, the size limits for mating parts are so selected that clearance between them always occur. In a clearance fit, the tolerance zone of the hole is entirely above the tolerance zone of the shaft.

In a clearance fit, the difference between the minimum size of the hole and the maximum size of the shaft is known as minimum clearance whereas the difference between the maximum size of the hole and minimum size of the shaft is called maximum clearance.

The clearance fits may be slide fit, easy sliding fit, running fit, slack running fit, and loose running fit.

2. Interference fit :- In this type of fit, the size limits for the mating parts are so selected that interference between them always occur. In an interference fit, the tolerance zone of the hole is entirely below the tolerance zone of the shaft.

The difference between the maximum size of the hole and the minimum size of the shaft is known as minimum interference, whereas the difference between the minimum size of the hole and the maximum size of the shaft is called maximum interference.

The interference fits may be shrink fit, heavy fit and light drive fit.

3. Transition fit :- In this type of fit, the size limits for the mating parts are so selected that either a clearance or interference may occur depending upon the actual size of the mating parts. In a transition fit, the tolerance zones [illegible] overlap.

Basis of limit System :-

1. Hole basis system :- When the hole is kept as a constant member (i.e when the lower deviation of the hole is zero) and different fits are obtained by varying the shaft size, then the limit system is said to be on a hole basis.

2. Shaft basis system :- When the shaft is kept as a constant member (i.e when the upper deviation of the shaft is zero) and different fits are obtained by varying the hole size, then the limit system is said to be on a shaft basis.

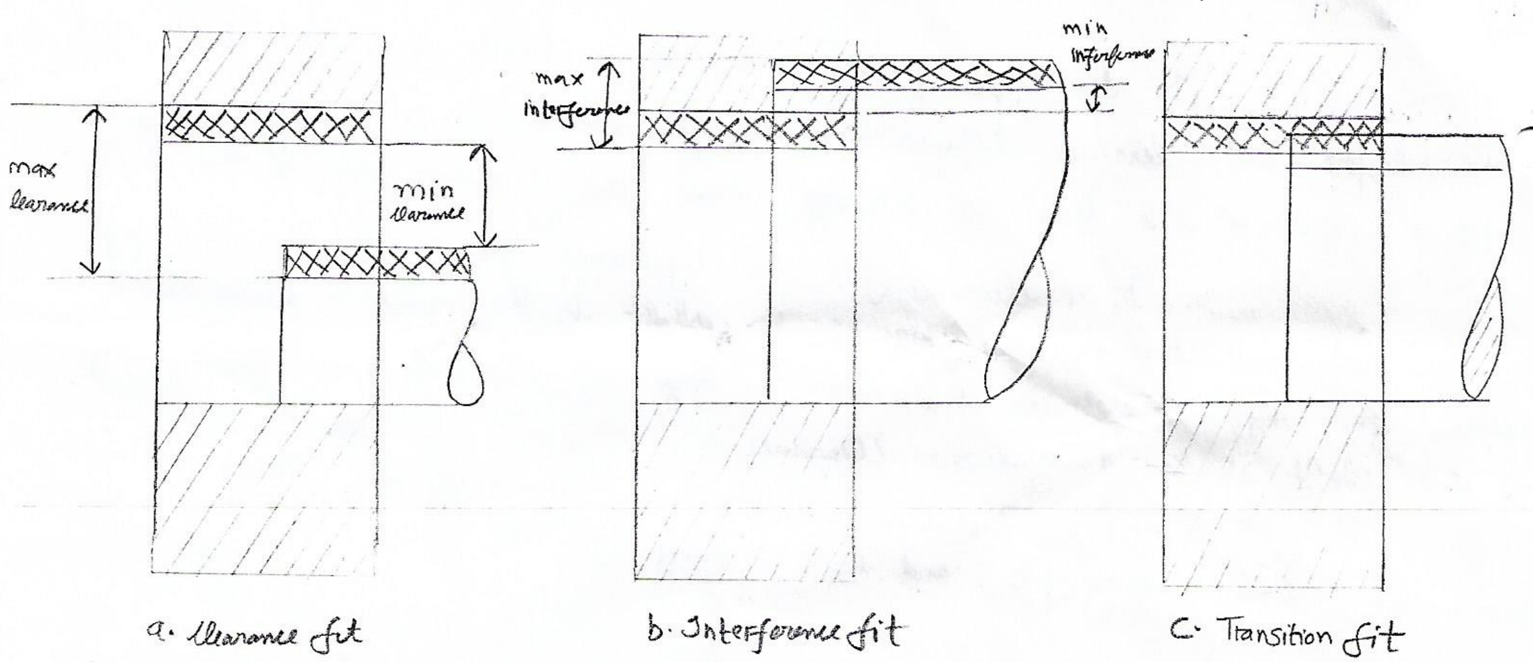


fig. types of fits

Indian Standard System of limits and fits :- According to Indian Standard, the system of limits and fits Comprises of 18 grades of fundamental tolerances (designated as IT 01, IT0 and IT1 to IT 16 } and 25 types of fundamental deviations indicated by letter symbols for both holes and shafts (Capital letter A to ZC for holes and small letters a to zc for shafts) in diameter steps ranging from 1 to 500 mm.

The values of standard tolerances for different grades :-

For IT 01, $i\,(\text{micron}) = 0.3 + .008D$

For IT 0, $i\,(\text{micron}) = 0.5 + .012D$

For IT 1, $i\,(\text{micron}) = 0.8 + 0.020D$

{ i = Standard tolerance unit.

For IT 5 to IT16, $i\,(\text{micron}) = 0.45\sqrt[3]{D} + 0.001D$, where D is the size of or geometric mean diameter in mm.

For hole, H stands for a dimension whose lower deviation refers to the basic size. The hole H for which the lower deviation is zero is called a basic hole. Similarly, for shafts, h stands for a dimension whose upper deviation refers to the basic size. The shaft h for which the upper deviation is zero is called a basic shaft.

A fit is designated by its basic size followed by symbols representing the limits of each of its two components, the hole being quoted first. For example, 100 H6/g5 means basic size is 100 mm and tolerance grade for the hole is 6 and for the shaft is 5.

Design considerations for Castings :-

The general principles for the casting design are as follows :-

1. Keep the stressed areas of the part in Compression.
2. Round all External Corners.
3. Wherever possible, the Section thickness throughout should be held as Uniform as compatible with overall Design Consideration.
4. Avoid very thin Sections.
5. Avoid Concentration of Metal at the junctions.

Design Considerations of Forgings:-

① While designing a forging the profile is selected in such a way that fibres lines are parallel to tensile forces and perpendicular to shear forces. It is only in case of forged parts that the fibre lines are arranged in a favourable way to withstand stresses due to external load.

② Forged component should be provided adequate draft to facilitate easy removal of parts from die impressions.

③ The forging should be provided with adequate fillet and corner radii to avoid cracks on surfaces and to overcome difficulties in filling the material.

④ Thin sections and ribs should be avoided in forged components, since thin sections cools at a faster rate and requires excessive force for plastic deformation. It reduces life of die.

Design Considerations of Machined Parts :-

① Avoid Machining
② Specify liberal tolerances
③ Avoid sharp Corners
④ use stock Dimensions
⑤ Design Rigid Parts
⑥ Avoid Shoulders and Undercuts.
⑦ Avoid Hard Materials.

Calculation of fundamental deviation for shafts.

$ei = es - IT$ or $es = ei + IT$

for shafts a to h, the upper deviations (es) are considered whereas for shafts j to zc, the lower deviations (ei) is to be considered.

Q1. The dimensions of the mating parts, according to basic hole system, are given as follows :-

Hole : 25.00 mm Shaft : 24.97 mm
25.02 mm 24.95 mm

Find the hole tolerance, shaft tolerance and allowance.

Solution:- Given:- lower limit of hole = 25 mm ; Upper limit of hole = 25.02 mm
Upper limit of shaft = 24.97 mm ; lower limit of shaft = 24.95 mm.

(a) hole tolerance = upper limit of hole − lower limit of hole
= 25.02 − 25 = .02 mm Ans.

(b) Shaft tolerance = upper limit of shaft − lower limit of shaft
= 24.97 − 24.95 = .02 mm Ans.

(c) allowance = lower limit of hole − upper limit of shaft
= 25.00 − 24.97 = .03 mm Ans.

Q2 Calculate the tolerances, fundamental deviations and limits of sizes for the shaft designated as 40 H8/f7.

Solution:- The shaft designation 40 H8/f7 means that the basic size is 40 mm and the tolerance grade for the hole is 8 (i.e IT 8) and for the shaft is 7 (i.e IT7).

Tolerances:- Since 40 mm lies in the diameter steps of 30 to 50 mm, therefore the geometric mean diameter, $D = \sqrt{30 \times 50} = 38.73$ mm

standard tolerance unit, $i = 0.45\sqrt[3]{D} + .001 D$
$= .45 \sqrt[3]{38.73} + 0.001 \times 38.73$
$= 1.55973$ or 1.56 microns.

From table:- the standard tolerance for the hole of grade 8 (IT 8)

↳ 25 i

$= 25 \times .00156 = 0.039$ mm Ans.

and the standard tolerance for the shaft of grade 7 (IT 7).

↳ 16 i

$= 16 \times .00156 = 0.025$ mm Ans.

Fundamental deviation :-

We know that fundamental deviation (lower deviation) for hole (H),

$EI = 0$

From table:- we find that fundamental deviation (upper deviation) for shaft f,

$es = -5.5 (D)^{0.41}$

$= -24.63$ or -25 microns.

$= -25 \times 0.001 = -0.025$ mm Ans

∴ fundamental deviation (lower deviation) for shaft f,

$ei = es - IT = -0.025 - 0.025 =$ ~~-0.50 mm~~ **-0.050** Ans.

The -ve sign indicates that fundamental deviation lies below the zero line.

Limits of sizes:-

Lower limit for hole = Basic size = 40 mm

Upper limit for hole = Lower limit for hole + Tolerance for hole

$= 40 + 0.039 = 40.039$ mm

Upper limit for shaft = Lower limit for hole or basic size - F.D (U.D).

(∵ shaft f lies below the zero line)

$= 40 - 0.025 = 39.975$ mm

Lower limit for shaft = Upper limit for shaft - tolerance for shaft.

$= 39.975 - 0.025 = 39.95$ mm Ans.

Q3(a) – A hole is dimensioned as $25^{+0.33}_{+0.0}$ and the shaft is dimensioned as $25^{-0.040}_{-0.061}$. Determine the hole tolerance, shaft tolerance and allowance of the fit. What type of fit shall be established.

Solution:– upper limit of hole $= 25 + 0.33$
$= 25.33$ mm

lower limit of hole $= 25 + 0.0 = 25$ mm

hole tolerance $= 25.33 - 25 = .33$ mm

upper limit of shaft $= 25 - 0.040$
$= 24.96$ mm

lower limit of shaft $= 25 - .061 = 24.939$ mm.

shaft tolerance $= 24.96 - 24.939$ mm.
$= 0.021$ mm.

hole tolerance > shaft tolerance ∴ It is a clearance fit.

Q3(b) A hole is dimensioned as $25^{\pm 0.03}$ mm and the shaft is dimensioned as $25^{\pm 0.02}$ mm. What type of fit will be established? Determine hole tolerance, shaft tolerance and allowance of the fit?