# CHAP TERONE

## MACHINE ELEMENTSI

## BASIC CONCEPTS OF MACHINEELEMENTS

**Machine Design** is the creation of new and better machines and improving the existing ones.

**Classifications of Machine Design**-The machine design may be classified as follows:-

1. **Adaptive design-**In most cases, the designer's work is concerned with adaptation of existing designs. This type of design needs no special knowledge or skill and can be attempted by designers of ordinary technical training. The designer only makes minor alternation or modification in the existing designs of the product.
2. **Development design-**This type of design needs considerable scientific training and design ability in order to modify the existing designs into a new idea by adopting a new material or different method of manufacture. In this case, though the designer starts from the existing design, but the final product may differ quite markedly from the original product.
3. **New design-**This type of design needs lot of research, technical ability and creative thinking. Only those designers who have personal qualities of a sufficiently high order can take up the work of a new design.

### The design depending upon the methods used, may be classified as follows

a) **Rational design-**This type of design depends upon mathematical formulae of principle of mechanics.
b) **Empirical design-**This type of design depends upon empirical formulae based on the practice and past experience.
c) **Industrial design-**This type of design depends upon the production aspects to manufacture any machine component in the industry.
d) **Optimum design-**It is the best design for the given objective function under the specified constraints. It may be achieved by minimising the undesirable effects.
e) **System design-**It is the design of any complex mechanical system like a motor car.
f) **Element design-**It is the design of any element of the mechanical system like piston, crankshaft, connecting rod, etc.
g) **Computer aided design**-This type of design depends upon the use of computer systems to assist in the creation, modification, analysis and optimization of a design.

### General Considerations in Machine Design

The following are the general considerations in designing a machine component

1. **Type of load and stresses caused by the load-**The load, on a machine component, may act in several ways due to which the internal stresses are set up.
2. **Motion of the parts or kinematics of the machine-**The successful operation of any machine depends largely upon the simplest arrangement of the parts which will give the motion required. The motion of the parts may be :
   - Rectilinear motion which includes unidirectional and reciprocating motions.

- Curvilinear motion which includes rotary, oscillatory and simple harmonic.
- Constant velocity.
- Constant or variable acceleration.

3. **Selection of materials**-It is essential that a designer should have a thorough knowledge of the properties of materials and their behavior under working conditions. Some of the important characteristics of materials are: strength, durability, flexibility, weight, resistance to heat and corrosion, ability to cast, welded or hardened, machinability, electrical conductivity, etc.
4. **Form and size of the parts**-The form and size are based on judgments. The smallest practicable cross-section may be used, but it may be checked that the stresses induced in the designed cross-section are reasonably safe.
5. **Frictional resistance and lubrication**-There is always a loss of power due to frictional resistance and it should be noted that the friction of starting is higher than that of running friction. It is, therefore, essential that a careful attention must be given to the matter of lubrication of all surfaces which move in contact with others, whether in rotating, sliding, or rolling bearings.
6. **Convenient and economical features**-In designing, the operating features of the machine should be carefully studied. The starting, controlling and stopping levers should be located on the basis of convenient handling. The adjustment for wear must be provided employing the various take-up devices and arranging them so that the alignment of parts is preserved. If parts are to be changed for different products or replaced on account of wear or breakage, easy access should be provided and the necessity of removing other parts to accomplish this should be avoided if possible. The economical operation of a machine which is to be used for production or for the processing of material should be studied, in order to learn whether it has the maximum capacity consistent with the production of good work.
7. **Use of standard parts**-The use of standard parts is closely related to cost, because the cost of standard or stock parts is only a fraction of the cost of similar parts made to order. The standard or stock parts should be used whenever possible; parts for which patterns are already in existence such as gears, pulleys and bearings and parts which may be selected from regular shop stock such as screws, nuts and pins. Bolts and studs should be as few as possible to avoid the delay caused by changing drills, reamers and taps and also to decrease the number of wrenches required.
8. **Safety of operation**-Some machines are dangerous to operate, especially those which are speeded up to insure production at a maximum rate. Therefore, any moving part of a machine which is within the zone of a worker is considered an accident hazard and may be the cause of an injury. It is, therefore, necessary that a designer should always provide safety devices for the safety of the operator. The safety appliances should in no way interfere with operation of the machine.
9. **Workshop facilities**-A design engineer should be familiar with the limitations of his employer's workshop, in order to avoid the necessity of having work done in some

other workshop. It is sometimes necessary to plan and supervise the workshop operations and to draft methods for casting, handling and machining special parts

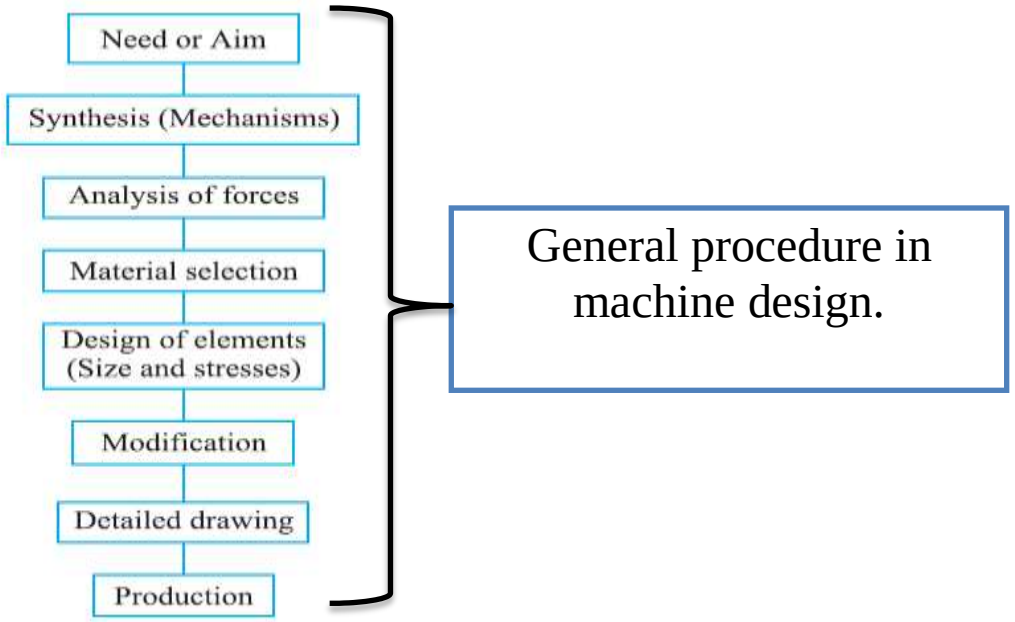
10. **Number of machines to be manufactured-**The number of articles or machines to be manufactured affects the design in a number of ways. The engineering and shop costs which are called fixed charges or overhead expenses are distributed over the number of articles to be manufactured. If only a few articles are to be made, extra expenses are not justified unless the machine is large or of some special design. An order calling for small number of the product will not permit any undue expense in the workshop processes, so that the designer should restrict his specification to standard parts as much as possible.
11. **Cost of construction-**The cost of construction of an article is the most important consideration involved in design. In some cases, it is quite possible that the high cost of an article may immediately bar it from further considerations. If an article has been invented and tests of handmade samples have shown that it has commercial value, it is then possible to justify the expenditure of a considerable sum of money in the design and development of automatic machines to produce the article, especially if it can be sold in large numbers. The aim of design engineer under all conditions should be to reduce the manufacturing cost to the minimum.
12. **Assembling-**Every machine or structure must be assembled as a unit before it can function. Large units must often be assembled in the shop, tested and then taken to be transported to their place of service. The final location of any machine is important and the design engineer must anticipate the exact location and the local facilities for erection.

## General Procedure in Machine Design

The general procedure to solve a design problem is as follows:

1. **Recognition of need**-First of all, make a complete statement of the problem, indicating the need, aim or purpose for which the machine is to be designed.
2. **Synthesis (Mechanisms)-** Select the possible mechanism or group of mechanisms which will give the desired motion.
3. **Analysis of forces-** Find the forces acting on each member of the machine and the energy transmitted by each member.
4. **Material selection**-Select the material best suited for each member of the machine.
5. **Design of elements (Size and Stresses)-** Find the size of each member of the machine by considering the force acting on the member and the permissible stresses for the material used. It should be kept in mind that each member should not deflect or deform than the permissible limit.
6. **Modification**-Modify the size of the member to agree with the past experience and judgment to facilitate manufacture. The modification may also be necessary by consideration of manufacturing to reduce overall cost.
7. **Detailed drawing**- Draw the detailed drawing of each component and the assembly of the machine with complete specification for the manufacturing processes suggested.

8. **Production**-The component, as per the drawing, is manufactured in the workshop.
   The flow chart for the general procedure in machine design is shown in Fig




# Engineering Materials and their Properties

## Classification of Engineering Materials

Engineering materials are mainly classified as:

**1. Metals and their alloys**, such as iron, steel, copper, aluminum, etc.

**2. Non-metals**, such as glass, rubber, plastic, etc.

The metals may be further classified as: (a) Ferrous metals, and (b) Non-ferrous metals.

**Ferrous metals** are those which have the iron as their main constituent, such as cast iron, wrought iron and steel.

N**on-ferrous** metals are those which have a metal other than iron as their main constituent, such as copper, aluminium, brass, tin, zinc, etc.

## Ferrous Metals

Ferrous metals are those which have iron as their main constituent. The ferrous metals commonly used in engineering practice are cast iron, wrought iron, steels and alloy steels. The principal raw material for all ferrous metals is pig iron which is obtained by smelting iron ore with coke and limestone, in the blast furnace.

## Cast Iron

The cast iron is obtained by re-melting pig iron with coke and limestone in a furnace known as cupola. It is primarily an alloy of iron and carbon. The carbon content in cast iron varies from 1.7 per cent to 4.5 per cent. It also contains small amounts of silicon, manganese, phosphorous and sulphur. Since the cast iron is a brittle material, therefore, it cannot be used in those parts of machines which are subjected to shocks. The properties of cast iron which make it a valuable material for engineering purposes are its low cost, good casting characteristics, high compressive strength, wear resistance and excellent machinability.

# Types of Cast Iron

The various types of cast iron in use are discussed as follows:

1. **Grey cast iron**-It is an ordinary commercial iron having the following compositions: Carbon = 3 to 3.5%; Silicon = 1 to 2.75%; Manganese = 0.40 to 1.0%; Phosphorous = 0.15 to 1%; Sulphur = 0.02 to 0.15%; and the remaining is iron. The grey colour is due to the fact that the carbon is present in the form of free graphite. It has a low tensile strength, high compressive strength and no ductility. It can be easily machined. A very good property of grey cast iron is that the free graphite in its structure acts as a lubricant. Due to this reason, it is very suitable for those parts where sliding action is desired. The grey iron castings are widely used for machine tool bodies, automotive cylinder blocks, heads, housings, fly-wheels, pipes and pipe fittings and agricultural implements.
2. **White cast iron.** The white cast iron shows a white fracture and has the following approximate compositions: Carbon=1.75 to 2.3%; Silicon=0.85 to 1.2%; Manganese= less than 0.4%; Phosphorus=less than 0.2%; Sulphur=less than 0.12% and the remaining is iron. The white colour is due to fact that it has no graphite and whole of the carbon is in the form of carbide (known as cementite) which is the hardest constituent of iron. The white cast iron has a high tensile strength and a low compressive strength. Since it is hard, therefore, it cannot be machined with ordinary cutting tools but requires grinding as shaping process. The white cast iron may be produced by casting against metal chills or by regulating analysis. The chills are used when a hard, wear resisting surface is desired for such products as for car wheels, rolls for crushing grains and jaw crusher plates.
3. **Chilled cast iron**. It is a white cast iron produced by quick cooling of molten iron. The quick cooling is generally called chilling and the cast iron so produced is called chilled cast iron. All castings are chilled at their outer skin by contact of the molten iron with the cool sand in the mould. But on most castings, this hardness penetrates to a very small depth (less than 1 mm). Sometimes, a casting is chilled intentionally and sometimes chilled becomes accidently to a considerable depth. The intentional chilling is carried out by putting inserts of iron or steel (chills) into the mould. When the molten metal comes into contact with the chill, its heat is readily conducted away and the hard surface is formed. Chills are used on any faces of a casting which are required to be hard to withstand wear and friction.
4. **Mottled cast iron**. It is a product in between grey and white cast iron in composition, color and general properties. It is obtained in castings where certain wearing surfaces have been chilled.
5. **Malleable cast iron.** The malleable iron is a cast iron-carbon alloy which solidifies in the as-cast condition in a graphite free structure, i.e. total carbon content is present in its combined form as cementite (Fe3C). It is ductile and may be bent without breaking or fracturing the section. The tensile strength of the malleable cast iron is usually higher than that of grey cast iron and has excellent machining qualities. It is used for machine parts for which the steel forgings would be too expensive and in which the metal should have a fair degree of accuracy, e.g. hubs of wagon wheels, small fittings for railway rolling stock, brake supports, parts of agricultural machinery, pipe fittings, door hinges, locks etc. In order to obtain a malleable iron casting, it is first cast into moulds of white cast iron. Then by a suitable heat treatment (i.e. annealing), the combined carbon of the white cast iron is separated into nodules of graphite.

## Alloy Cast Iron

The cast irons as discussed in above contain small percentages of other constituents like silicon, manganese, sulphur and phosphorus. These cast irons may be called as plain cast irons. The alloy cast iron is produced by adding alloying elements like nickel, chromium, molybdenum, copper and manganese in sufficient quantities. These alloying elements give more strength and result in improvement of properties. The alloy cast iron has special properties like increased strength, high wear resistance, corrosion resistance or heat resistance. The alloy cast irons are extensively used for gears, automobile parts like cylinders, pistons, piston rings, crank cases, crankshafts, camshafts, sprockets, wheels, pulleys, brake drums and shoes, parts of crushing and grinding machinery etc.

## Wrought Iron

It is the purest iron which contains at least 99.5% iron but may contain upto 99.9% iron. The typical composition of a wrought iron is Carbon = 0.020%, Silicon = 0.120%, Sulphur = 0.018%, Phosphorus = 0.020%, Slag = 0.070%, and the remaining is iron. The wrought iron is produced from pig iron by remelting it in the pudding furnace of reverberators type. The molten metal free from impurities is removed from the furnace as a pasty mass of iron and slag. The balls of this pasty mass, each about 45 to 65 kg are formed. These balls are then mechanically worked both to squeeze out the slag and to form it into some commercial shape. The wrought iron is a tough, malleable and ductile material. It cannot stand sudden and excessive shocks. Its ultimate tensile strength is 250 MPa to 500 MPa and the ultimate compressive strength is 300 MPa. It can be easily forged or welded. It is used for chains, crane hooks, railway couplings, water and steam pipes.

## Steel

It is an alloy of iron and carbon, with carbon content up to a maximum of 1.5%. The carbon occurs in the form of iron carbide, because of its ability to increase the hardness and strength of the steel. Other elements e.g. silicon, sulphur, phosphorus and manganese are also present to greater or lesser amount to impart certain desired properties to it. Most of the steel produced now-a-days is plain carbon steel or simply carbon steel. A carbon steel is defined as a steel which has its properties mainly due to its carbon content and does not contain more than 0.5% of silicon and 1.5% of manganese. The plain carbon steels varying from 0.06% carbon to 1.5% carbon are divided into the following types depending upon the carbon content.

- Dead mild steel — up to 0.15% carbon
- Low carbon or mild steel — 0.15% to 0.45% carbon
- Medium carbon steel — 0.45% to 0.8% carbon
- High carbon steel — 0.8% to 1.5% carbon

## Non-ferrous Metals

We have already discussed that the non-ferrous metals are those which contain a metal other than iron as their chief constituent. The non-ferrous metals are usually employed in industry due to the following characteristics:

- Ease of fabrication (casting, rolling, forging, welding and machining),
- Resistance to corrosion,
- Electrical and thermal conductivity, and
- Weight.

The various non-ferrous metals used in engineering practice are aluminium, copper, lead, tin, zinc, nickel, etc. and their alloys.

## Aluminium

It is white metal produced by electrical processes from its oxide (alumina), which is prepared from a clayey mineral called bauxite. It is a light metal having specific gravity 2.7 and melting point 658°C. The tensile strength of the metal varies from 90 MPa to 150 MPa. In its pure state, the metal would be weak and soft for most purposes, but when mixed with small amounts of other alloys, it becomes hard and rigid. So, it may be blanked, formed, drawn, turned, cast, forged and die cast. Its good electrical conductivity is an important property and is widely used for overhead cables. The high resistance to corrosion and its non-toxicity makes it a useful metal for cooking utensils under ordinary condition and thin foils are used for wrapping food items. It is extensively used in aircraft and an automobile component where saving of weight is an advantage.

## Copper

It is one of the most widely used non-ferrous metals in industry. It is a soft, malleable and ductile material with a reddish-brown appearance. Its specific gravity is 8.9 and melting point is 1083°C. The tensile strength varies from 150 MPa to 400 MPa under different conditions. It is a good conductor of electricity. It is largely used in making electric cables and wires for electric machinery and appliances, in electrotyping and electroplating, in making coins and household utensils. It may be cast, forged, rolled and drawn into wires. It is non-corrosive under ordinary conditions and resists weather very effectively. Copper in the form of tubes is used widely in mechanical engineering. It is also used for making ammunitions. It is used for making useful alloys with tin, zinc, nickel and aluminium.

## Gun Metal

It is an alloy of copper, tin and zinc. It usually contains 88% copper, 10% tin and 2% zinc. This metal is also known as Admiralty gun metal. The zinc is added to clean the metal and to increase its fluidity. It is not suitable for being worked in the cold state but may be forged when at about 600°C. The metal is very strong and resistant to corrosion by water and atmosphere. Originally, it was made for casting guns. It is extensively used for casting boiler fittings, bushes, bearings, glands, etc.

## Lead

It is a bluish grey metal having specific gravity 11.36 and melting point 326°C. It is so soft that it can be cut with a knife. It has no tenacity. It is extensively used for making solders, as a lining for acid tanks, cisterns, water pipes, and as coating for electrical cables. The lead base alloys are employed where a cheap and corrosion resistant material is required. An alloy containing 83% lead, 15% antimony, 1.5% tin and 0.5% copper is used for large bearings subjected to light service.

## Tin

It is brightly shining white metal. It is soft, malleable and ductile. It can be rolled into very thin sheets. It is used for making important alloys, fine solder, as a protective coating for iron and steel sheets and for making tin foil used as moisture proof packing. A tin base alloy

containing 88% tin, 8% antimony and 4% copper is called babbit metal. It is a soft material with a low coefficient of friction and has little strength. It is the most common bearing metal used with cast iron boxes where the bearings are subjected to high pressure and load.

## Selection of Materials for Engineering Purposes

The selection of a proper material, for engineering purposes, is one of the most difficult problems for the designer. The best material is one which serves the desired objective at the minimum cost. The 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, and
3. The cost of the materials.

The important properties which determine the utility of the material are physical, chemical and mechanical properties.

## Physical Properties of Metals

The physical properties of the metals include luster, colour, size and shape, density, electric and thermal conductivity, and melting point. The following table shows the important physical properties of some pure metals.

Table: Physical properties of metals.

| *Metal* | *Density* *(kg/m³)* | *Melting point* *(°C)* | *Thermal conductivity* *(W/m°C)* | *Coefficient of linear expansion at 20°C (μm/m/°C)* |
|---|---|---|---|---|
| Aluminium | 2700 | 660 | 220 | 23.0 |
| Brass | 8450 | 950 | 130 | 16.7 |
| Bronze | 8730 | 1040 | 67 | 17.3 |
| Cast iron | 7250 | 1300 | 54.5 | 9.0 |
| Copper | 8900 | 1083 | 393.5 | 16.7 |
| Lead | 11 400 | 327 | 33.5 | 29.1 |
| Monel metal | 8600 | 1350 | 25.2 | 14.0 |
| Nickel | 8900 | 1453 | 63.2 | 12.8 |
| Silver | 10 500 | 960 | 420 | 18.9 |
| Steel | 7850 | 1510 | 50.2 | 11.1 |
| Tin | 7400 | 232 | 67 | 21.4 |
| Tungsten | 19 300 | 3410 | 201 | 4.5 |
| Zinc | 7200 | 419 | 113 | 33.0 |
| Cobalt | 8850 | 1490 | 69.2 | 12.4 |
| Molybdenum | 10 200 | 2650 | 13 | 4.8 |
| Vanadium | 6000 | 1750 | — | 7.75 |

## Mechanical Properties of Metals

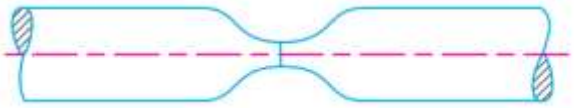
The mechanical properties of the metals are those which are associated with the ability of the material to resist mechanical forces and load. These mechanical properties of the metal include strength, stiffness, elasticity, plasticity, ductility, brittleness, malleability, toughness, resilience, creep and hardness. We shall now discuss these properties as follows:

1. **Strength**-It is the ability of a material to resist the externally applied forces without breaking or yielding. The internal resistance offered by a part to an externally applied force is called stress.
2. **Stiffness**-It is the ability of a material to resist deformation under stress. The modulus of elasticity is the measure of stiffness.
3. **Elasticity**-It is the property of a material to regain its original shape after deformation when the external forces are removed. This property is desirable for materials used in tools and machines. It may be noted that steel is more elastic than rubber.
4. **Plasticity**-It is property of a material which retains the deformation produced under load permanently. This property of the material is necessary for forgings, in stamping images on coins and in ornamental work.
5. **Ductility**-It is the property of a material enabling it to be drawn into wire with the application of a tensile force. A ductile material must be both strong and plastic. The ductility is usually measured by the terms, percentage elongation and percentage reduction in area. The ductile material commonly used in engineering practice (in order of diminishing ductility) are mild steel, copper, aluminium, nickel, zinc, tin and lead.
6. **Brittleness**-It is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. Brittle materials when subjected to tensile loads, snap off without giving any sensible elongation. Cast iron is a brittle material.
7. **Malleability**-It is a special case of ductility which permits materials to be rolled or hammered into thin sheets. A malleable material should be plastic but it is not essential to be so strong. The malleable materials commonly used in engineering practice (in order of diminishing malleability) are lead, soft steel, wrought iron, copper and aluminium.
8. **Toughness**-It is the property of a material to resist fracture due to high impact loads like hammer blows. The toughness of the material decreases when it is heated. It is measured by the amount of energy that a unit volume of the material has absorbed after being stressed up to the point of fracture. This property is desirable in parts subjected to shock and impact loads.
9. **Machinability**-It is the property of a material which refers to a relative case with which a material can be cut. The machinability of a material can be measured in a number of ways such as comparing the tool life for cutting different materials or thrust required to remove the material at some given rate or the energy required to remove a unit volume of the material. It may be noted that brass can be easily machined than steel.
10. **Resilience**-It is the property of a material to absorb energy and to resist shock and impact loads. It is measured by the amount of energy absorbed per unit volume within elastic limit. This property is essential for spring materials.
11. **Creep**-When a part is subjected to a constant stress at high temperature for a long period of time, it will undergo a slow and permanent deformation called **creep.** This property is considered in designing internal combustion engines, boilers and turbines.
12. **Fatigue**-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**. The failure is caused by means of a progressive crack formation which are usually fine and of microscopic size. This property is considered in designing shafts, connecting rods, springs, gears, etc.

13. **Hardness**-It is a very important property of the metals and has a wide variety of meanings. It embraces many different properties such as resistance to wear, scratching, deformation and machinability etc. It also means the ability of a metal to cut another metal. The hardness is usually expressed in numbers which are dependent on the method of making the test.
    The hardness of a metal may be determined by the following tests:
    a. Brinell hardness test,
    b. Rockwell hardness test,
    c. Vickers hardness (also called Diamond Pyramid) test, and
    d. Shore sclera scope.

# Stress-strain Diagram

1. **Proportional limit-**We see from the diagram that from point O to A is a straight line, which represents that the stress is proportional to strain. Beyond point A, the curve slightly deviates from the straight line. It is thus obvious, that Hooke's law holds good up to point A and it is known as proportional limit. It is defined as that stress at which the stress-strain curve begins to deviate from the straight line.
2. **Elastic limit-**It may be noted that even if the load is increased beyond point A up to the point B, the material will regain its shape and size when the load is removed. This means that the material has elastic properties up to the point B. This point is known as elastic limit. It is defined as the stress developed in the material without any permanent set. Note: Since the above two limits are very close to each other, therefore, for all practical purposes these are taken to be equal.
3. **Yield point-**If the material is stressed beyond point B, the plastic stage will reach i.e. on the removal of the load, and the material will not be able to recover its original size and shape. A little consideration will show that beyond point B, the strain increases at a faster rate with any increase in the stress until the point C is reached. At this point, the material yields before the load and there is an appreciable strain without any increase in stress. In case of mild steel, it will be seen that a small load drops to D, immediately after yielding commences. Hence there are two yield points C and D. The points C and D are called the upper and lower yield points respectively. The stress corresponding to yield point is known as yield point stress.



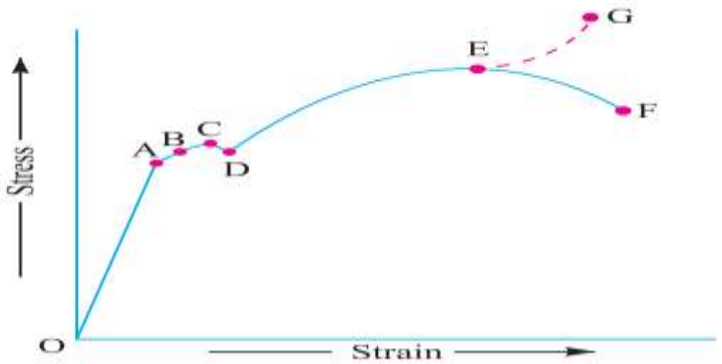



**Fig shows Stress-strain diagram for mild steel.**

4. **Ultimate stress**. At D, the specimen regains some strength and higher values of stresses are required for higher strains, than those between A and D. The stress (or load) goes on increasing till the point E is reached. The gradual increase in the strain (or length) of the specimen is followed with the uniform reduction of its cross-sectional area. The work done during stretching the specimen is transformed largely into heat and the specimen becomes hot. At E, the stress, which attains its maximum value, is known as ultimate stress. It is defined as the largest stress obtained by dividing the largest value of the load reached in a test to the original cross-sectional area of the test piece.
5. **Breaking stress.** After the specimen has reached the ultimate stress, a neck is formed, which decreases the cross-sectional area of the specimen, as shown in Fig. A little consideration will show that the stress (or load) necessary to break away the specimen, is less than the maximum stress. The stress is, therefore, reduced until the specimen breaks away at point F. The stress corresponding to point F is known as breaking stress.

## Working Stress

When designing machine parts, it is desirable to keep the stress lower than the maximum or ultimate stress at which failure of the material takes place. This stress is known as the ***working stress*** or ***design stress*.** It is also known as **safe** or **allowable stress**.

## Factor of Safety

It is defined as the ratio of the maximum stress to the working stress. Mathematically

$$\text{Factor of safety} = \frac{\text{Maximum stress}}{\text{Working or design stress}}$$

In case of ductile materials, the factor of safety is based upon the yield point stress. In such cases

$$\text{Factor of safety} = \frac{\text{Yield point stress}}{\text{Working or design stress}}$$

In case of brittle materials, the factor of safety for brittle materials is based on ultimate stress. In such case

$$\text{Factor of safety} = \frac{\text{Ultimate stress}}{\text{Working or design stress}}$$

## Selection of Factor of Safety

The selection of a proper factor of safety to be used in designing any machine component depends upon a number of considerations, such as the material, mode of manufacture, type of stress, general service conditions and shape of the parts. Before selecting a proper factor of safety, a design engineer should consider the following points:

- The reliability of the properties of the material and change of these properties during service,
- The reliability of test results and accuracy of application of these results to actual machine parts,
- The reliability of applied load,
- The certainty as to exact mode of failure,
- The extent of simplifying assumptions,

- The extent of localised stresses,
- The extent of initial stresses set up during manufacture,
- The extent of loss of life if failure occurs and
- The extent of loss of property if failure occurs.

The values of factor of safety based on ultimate strength for different materials and type of load are given in the following table:

| *Material* | *Steady load* | *Live load* | *Shock load* |
|---|---|---|---|
| Cast iron | 5 to 6 | 8 to 12 | 16 to 20 |
| Wrought iron | 4 | 7 | 10 to 15 |
| Steel | 4 | 8 | 12 to 16 |
| Soft materials and alloys | 6 | 9 | 15 |
| Leather | 9 | 12 | 15 |
| Timber | 7 | 10 to 15 | 20 |