MECHANICAL ENGINEERING AND MACHINES IN MECHATRONICS

MECE 104

FUNDAMENTALS OF MECHATRONICS ENGINEERING

Force, friction and lubrication-force

The subject 'machines in mechatronics' is that branch of engineering and science which deals with the study of relative motion between the various parts of a machine as well as the forces acting on them. The knowledge of this subject is very essential for an engineer to design the various parts of mechatronic systems.

Force, friction and lubrication-force

Force is that physical quantity which causes or tends to cause a change in the state of rest or motion of a body. **The line of action of a force** is a line drawn through the point of application of the force and along the direction along which the force acts.

If a change in motion is prevented, force will cause a deformation or change in the shape of the body. In statics, it is often convenient to consider the effect of a force which acts on a rigid body. The **perfect rigid body** will not suffer deformation under the action of any force.

Force, friction and lubrication-force

A force is completely defined by its magnitude, point of application, and direction. A body is said to be in equilibrium under the action of a system of forces if all forces acting on it are in balance. In statics all forces come in pairs—an action and a reaction.

A body is in equilibrium under the action of two forces provided the forces are equal in magnitude and have the same line of action but act in opposite directions.

Force, friction and lubrication

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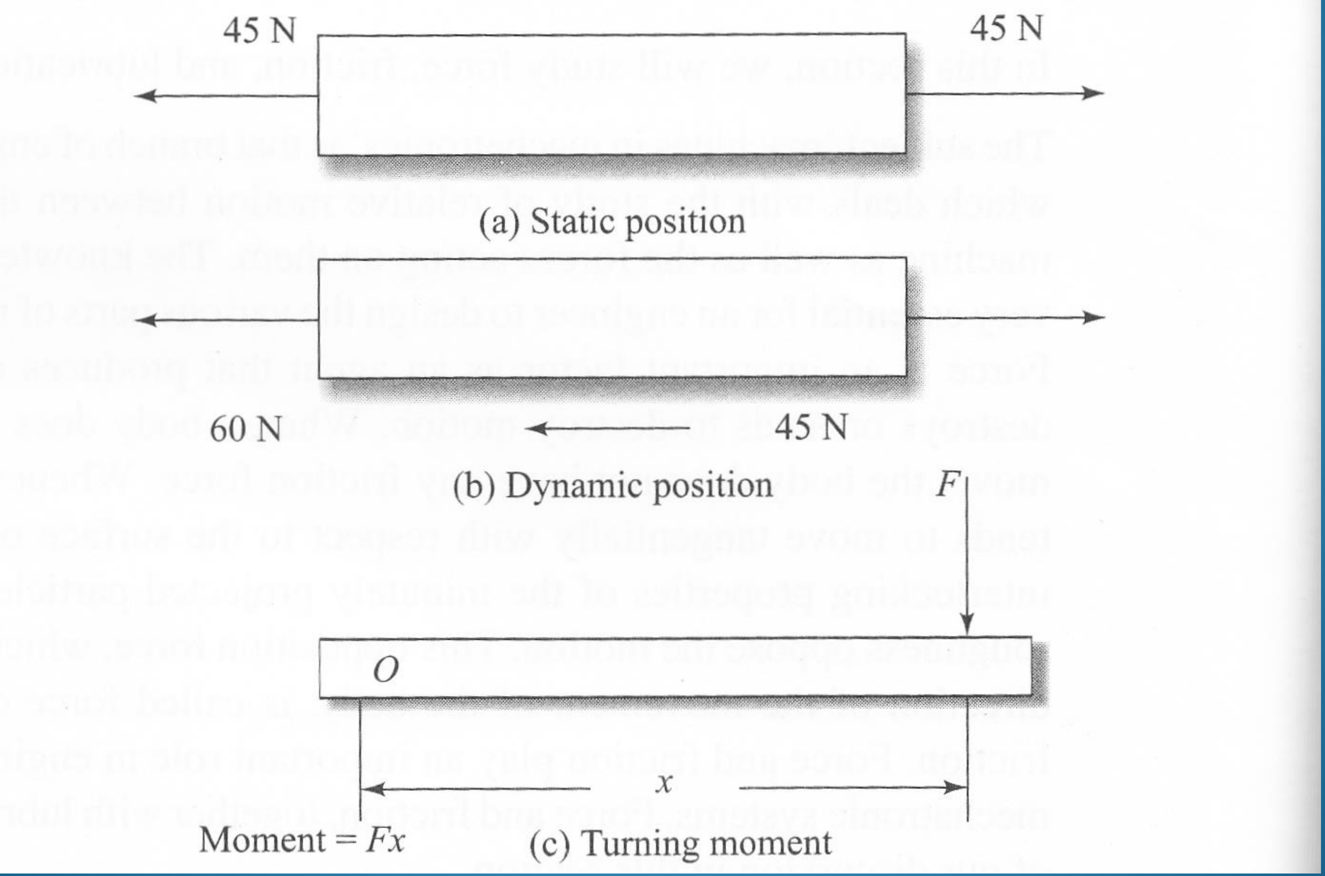


Force, friction and lubrication-force

The action of a force on a rigid body tends to move or rotate the body. The turning effect or tendency of a force to cause rotation about any point equals the product of the force and the perpendicular distance of the line of action of the force from at the point. This turning effect is called **moment of a force at the point**, and the distance is called **moment arm**.

Force, friction and lubrication-force

If a body is at rest under the action of a number of coplanar forces, the moments must be balanced; otherwise the unbalanced resultant moment will cause a rotation or linear motion of the body. Figure illustrates the static and dynamic positions of a body, and the turning moment.

Force, friction and lubrication-force

Dynamics deals with linear forces or moments acting on a body in motion, linear or rotational. In linear motion, the force acting on the body is equal to the mass of the body multiplied by acceleration. For rotational motion, it is called torque, which is equal to the mass moment of inertia multiplied by angular acceleration. In Figure two equal forces act in opposite direction and hence the body is in equilibrium.

Force, friction and lubrication-force

In this case, the body is strained. In Figure an additional 15 N force acts on one side and hence the body moves in the direction of the additional force. In this case, the body is subjected to strain as well as motion. When a body is in motion it is said to be dynamic.

A couple is formed by two equal, parallel forces which are not collinear and act in opposite directions. The moment of a couple is the product of one of the forces and the perpendicular distance between the lines of action of the forces.

Force, friction and lubrication-friction

Suppose a body of weight W rests on a surface. It then exerts a normal force in a direction opposite to that in which the weight is acting. To move the body, a force F tangential to the surface has to be overcome by applying an external force P. This force F is known as **friction**.

Force, friction and lubrication- friction

Figure illustrates the various forces acting on a body at rest. If the magnitude of the external force, P, is increased, the frictional force also increases until its magnitude reaches a certain maximum value F_M. If P is increased further, the force of friction cannot balance the external force any more and the body starts moving. The ratio of this maximum frictional force F_M to the normal reaction R is constant and depends only on the nature of the pair of surfaces in contact. The ratio of F_M to R is called coefficient of static friction, which is denoted by μ_s.

Force, friction and lubrication-friction

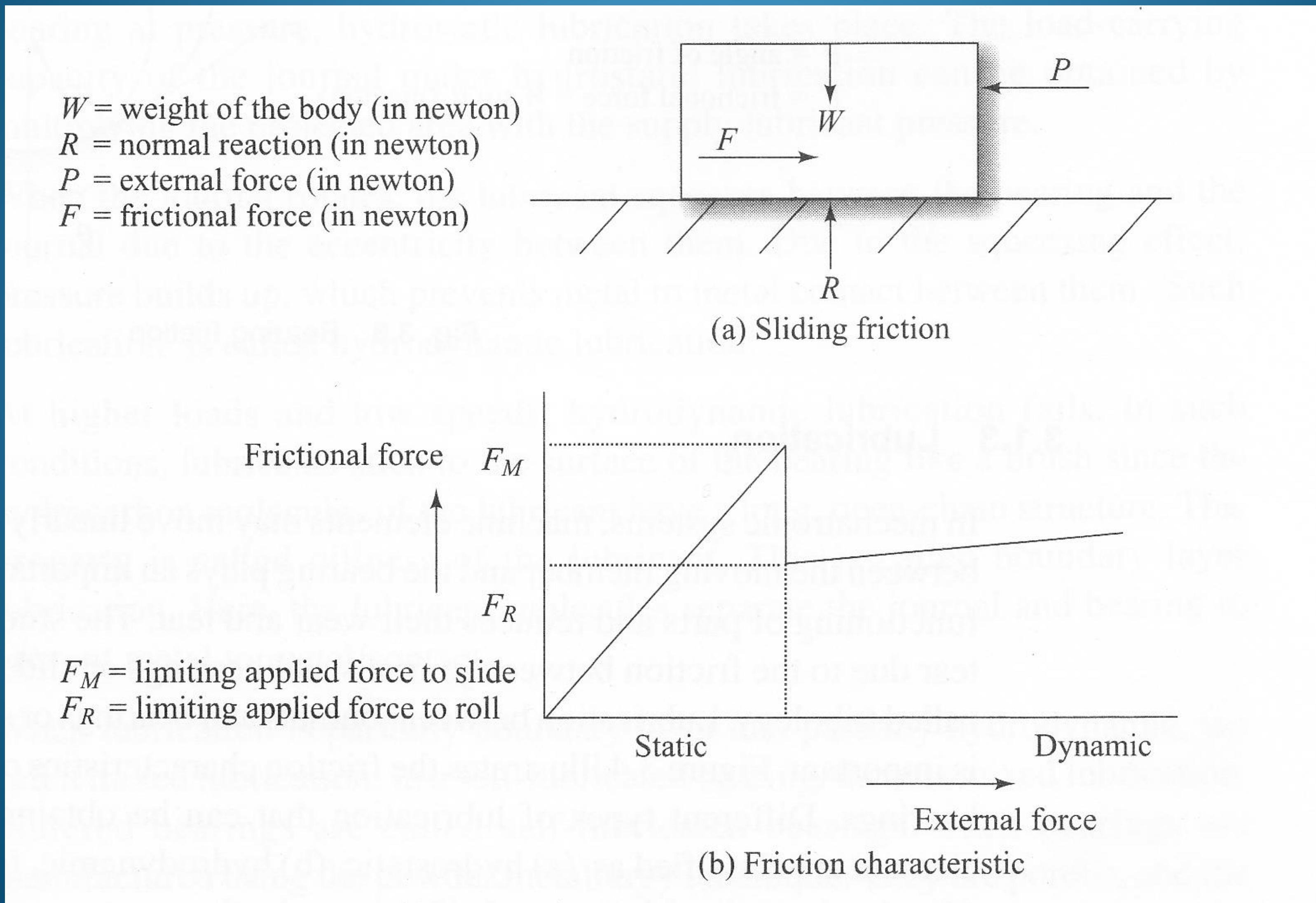
When sliding is just about to start, the pulling force $P = \mu_s R$.

As soon as the body starts moving, the magnitude of the frictional force drops from F_M to F_R.

This frictional force F_R is given by $\mu_R R$, where μ_R called the coefficient of sliding friction and is less than the coefficient of static friction.

Sliding friction depends on the nature and roughness of the surface, but is independent of the area of contact and the speed of the slide.

Force, friction and lubrication-friction



(a) Sliding friction

(b) Friction characteristic

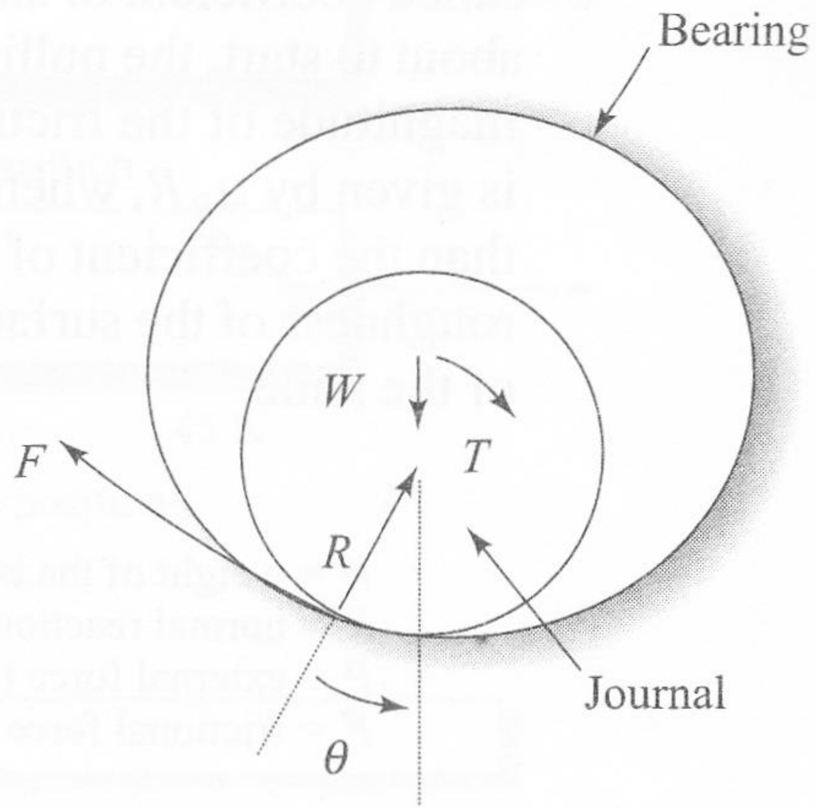
Force, friction and lubrication

For a wheel to roll on the ground without slipping, there must be a force of friction at the contact between the wheel and the track. There is a resistance to the rolling motion of the wheel due to deformation of the wheel and the track under the load. The resistance is called the **rolling resistance**. It acts opposite to the linear motion of the axle. The ratio of the maximum rolling resistance to the normal reaction between the wheel and the track is known as **the coefficient of rolling resistance**.

Force, friction and lubrication

W = weight acting on the journal
R = normal reaction (newton)
I = torque in (newton metre)

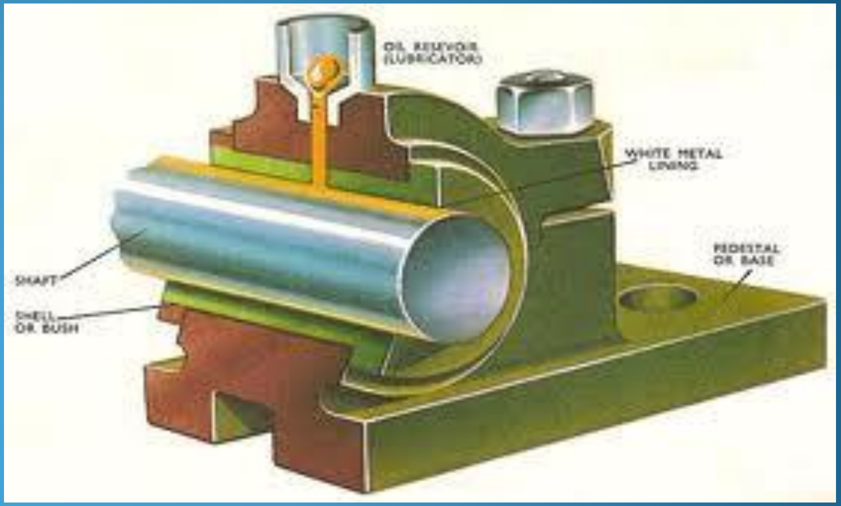
θ = angle of friction
F = frictional force = $W \sin\theta$ (newton)



Force, friction and lubrication

Journal bearings are used to provide lateral support to rotating shafts and axles. If they are fully lubricated, the frictional resistance depends upon the speed of rotation, the clearance between the axle and the bearing, and the viscosity of the lubricant. The coefficient of viscous friction due to fluid flow is less than the coefficient of rolling resistance. Hence, for skating, wheels are not used— the skate moves by sliding. Figure illustrates the bearing and journal assembly which produces a viscous friction.

Force, friction and lubrication



lubrication

In mechatronic systems, machine elements may move linearly or rotate. Friction between the moving member and the bearing plays an important role in a smooth functioning of parts and reduces their wear and tear. The study of the wear and tear due to the friction between journals and bearings or sliders and bearings is called **tribology**.

lubrication

Lubrication between journals and bearings or sliders and bearing is important. Figure illustrates the friction characteristics of linear and rotary bearings. Different types of lubrication that can be obtained in any moving element are classified as

(a) hydrostatic,

(b) hydrodynamic,

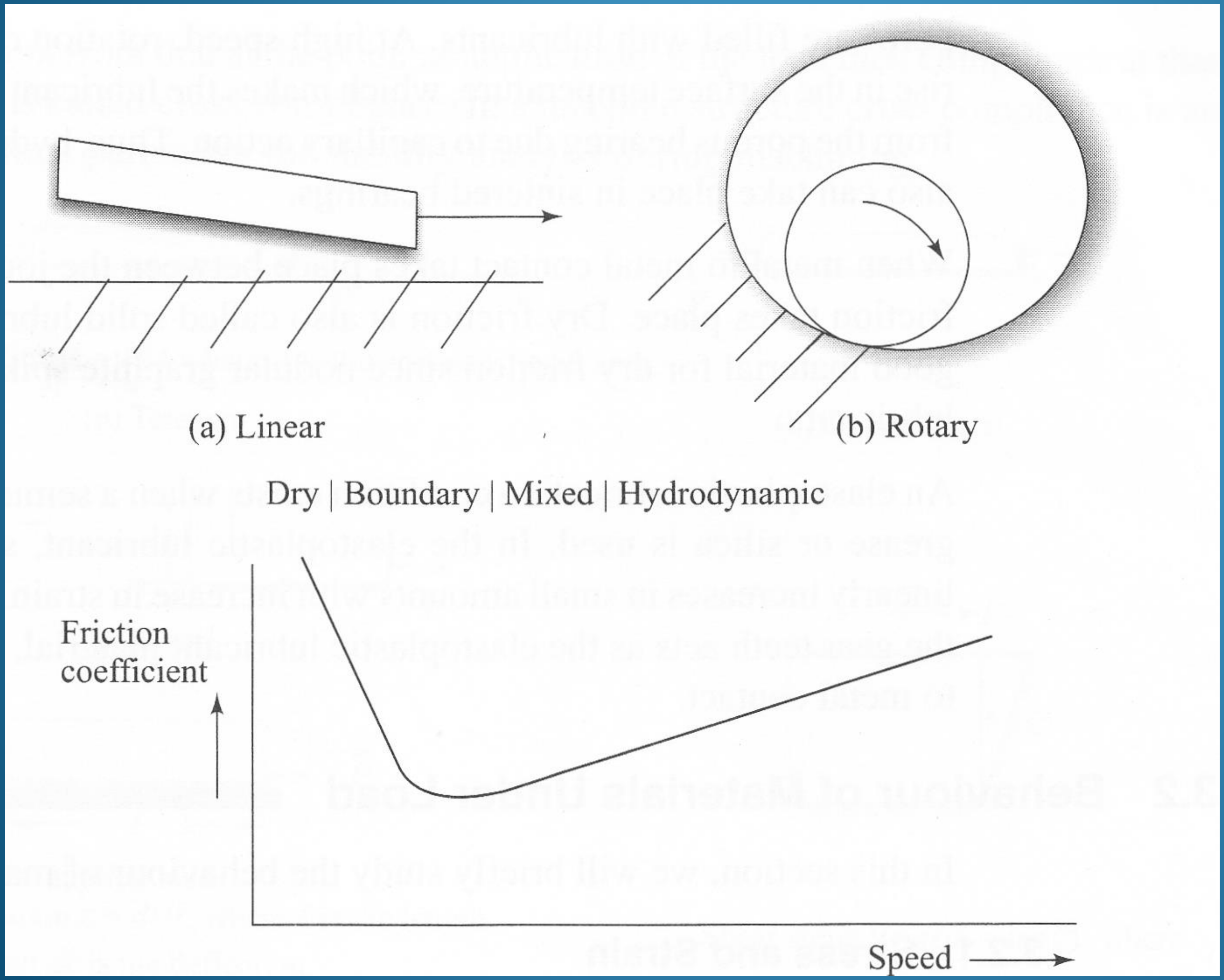
(c) boundary layer,

(d) mixed

(e) dry friction, and

(f) elastoplastic.

Force, friction and lubrication



lubrication

When a lubricant is supplied between a journal and a bearing or a slider and a bearing at pressure, **hydrostatic lubrication** takes place. The load-carrying capacity of the journal under hydrostatic lubrication can be obtained by multiplying the projected area with the supply lubricant pressure.

When the journal rotates, the lubricant squeezes between the bearing and the journal due to the eccentricity between them. Due to the squeezing effect, pressure builds up, which prevents metal to metal contact between them. Such lubrication is called **hydrodynamic lubrication**.

lubrication

At higher loads and low speeds, hydrodynamic lubrication fails. In such conditions, lubricants stick to the surface of the bearing like a brush since the hydrocarbon molecules of the lubricant have a long, open-chain structure. This property is called oiliness of the lubricant. This is called **boundary layer lubrication**. Here, the lubricant molecules separate the journal and bearing to prevent metal to metal contact.

When lubrication is partially boundary layer and partially hydrodynamic, we call it **mixed lubrication**. In a self-lubricated bearing, there is mixed lubrication.

lubrication

When metal to metal contact takes place between the journal and bearing, **dry friction** takes place. Dry friction is also called solid lubrication. Cast iron is a good material for dry friction since nodular graphite spikes act as a good solid lubricant.

An **elastoplastic lubrication** condition exists when a semisolid lubricant such as grease or silica is used. In the elastoplastic lubricant, stress in the lubricant linearly increases in small amounts with increase in strain. Grease used between the gear teeth acts as the elastoplastic lubricant material, which prevents metal to metal contact.

Behaviour of materials under load - Stress and Strain

When an external force acts on a body, an internal resistance is set up within the body to balance the external load. The resistance carried per unit area is called the stress.

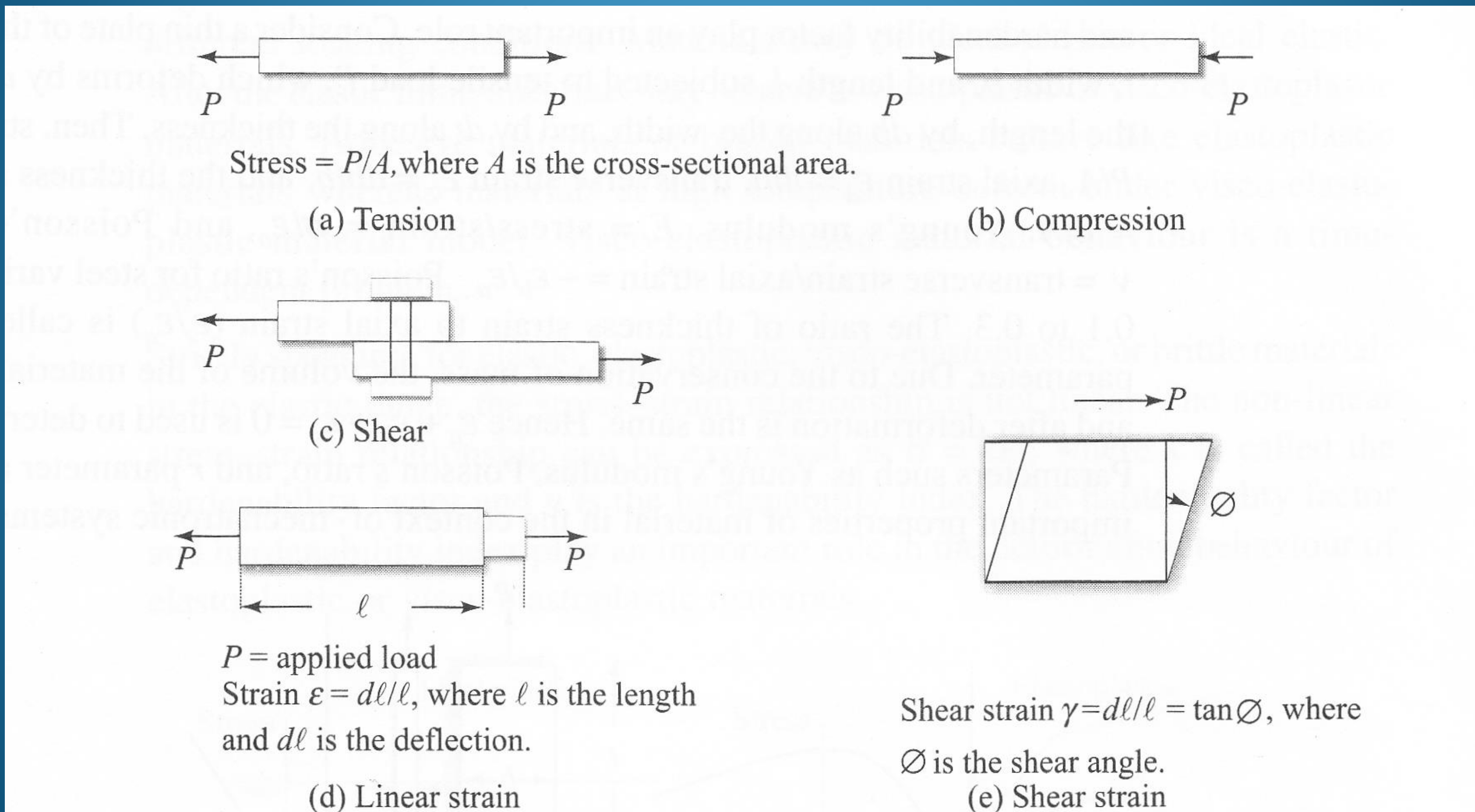
When the applied force tends to compress the material or crush it, the material is said to be in compression and the stress is referred to as **compressive stress**.

When the force tends to expand the material or tear it apart, the material is said to be in tension and the stress is referred to as **tensile stress**.

Behaviour of materials under load - Stress and Strain

When the force tends to cause the particles of the material to slide over one another, the material is said to be in **shear stress**. In the case of tensile force and compressive force, the area carrying the force is the area of the cross section in the plane perpendicular to the direction of the force. In the case of a shear force, the area carrying the force is the area to be sheared in the direction of the line of action of the force

Behaviour of materials under load - Stress and Strain



Behaviour of materials under load - Stress and Strain

Figure illustrates the different loading conditions on a rigid body. If a change of motion of the rigid body is prevented, the force applied will cause a deformation or change in the shape of the body. **Strain** is the change in dimension that takes place in the material due to an externally applied force. **Linear strain** is the ratio of change in length when a tensile or compressive force is applied.

Behaviour of materials under load - Stress and Strain

Shear strain is measured by the angular distortion caused by an external force. The load per unit deflection in a body is called **stiffness.** Deflection per unit load is called **compliance**. If deformation per unit load at a point on the body is different from that at the point of application of the load then compliance at that point is called cross compliance. In a machine structure cross compliance is an important parameter for stability analysis during machining.

Behaviour of materials under load - Stress and Strain Behaviour

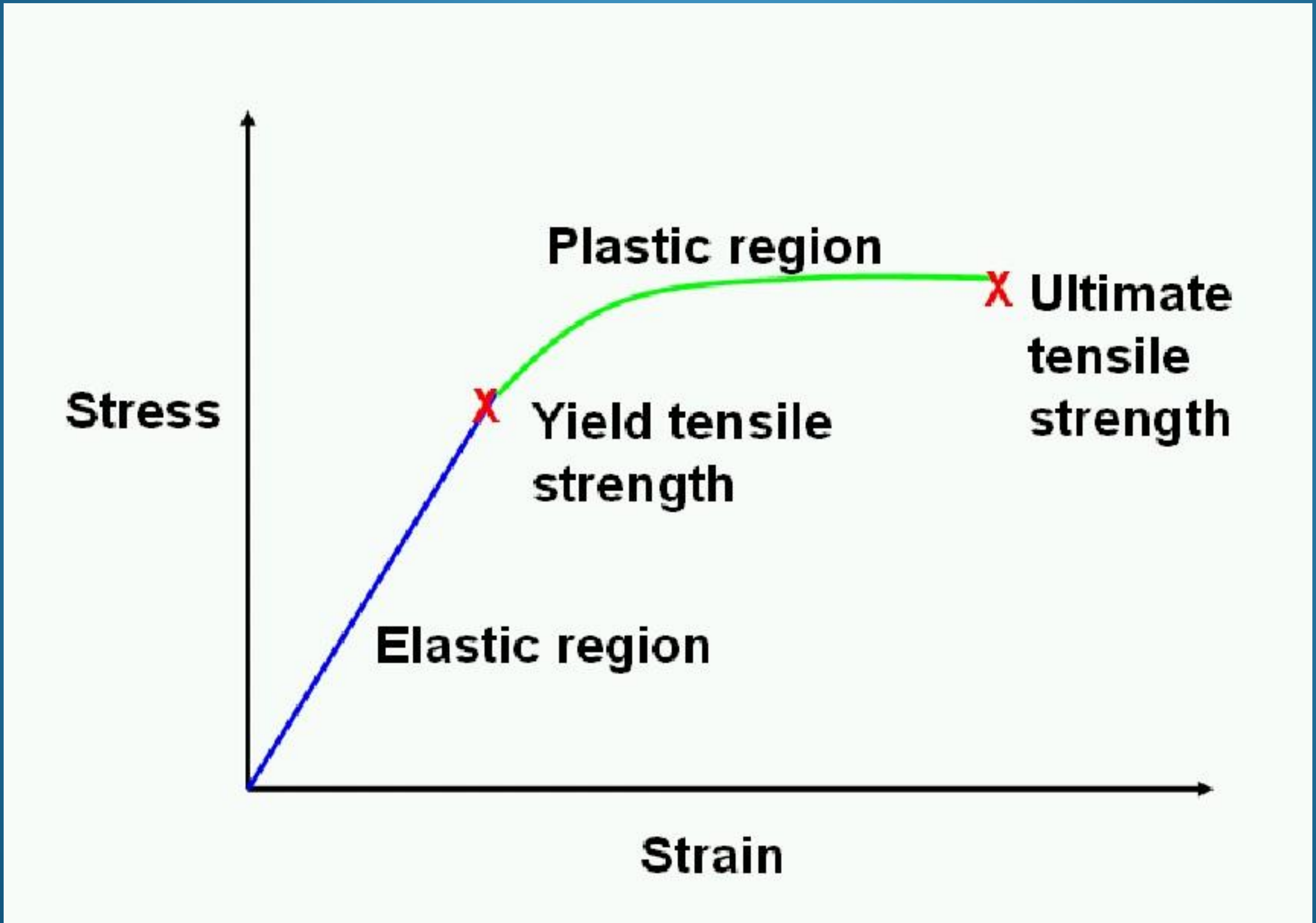
The strength of a material is expressed as the stress required to cause it to fracture. The maximum force required to break a material divided by the original cross-sectional area at the point of fracture is called the **ultimate tensile strength** of the material in tension.

All materials are elastic to a certain extent. In the elastic region, the material stretches if a tensile force is applied to it and returns to its original length on the removal of the force. There is a limit to this elastic property in every material, which is known as the **elastic limit**.

Behaviour of materials under load - Stress and Strain Behaviour

If the force exceeds the elastic limit, the body deforms. The stress corresponding to the elastic limit is called **yield stress**. The stress-strain curves for ductile and brittle materials are shown in Figure. When the material is loaded within the elastic limit, the stress is proportional to strain. The constant of proportionality is called the **modulus of elasticity** or Young's modulus. Similarly, when shear stress is divided by shear strain, the constant obtained is termed the **modulus of rigidity**.

Behaviour of materials under load - Stress and Strain Behaviour



Behaviour of materials under load

It is obvious that the stress allowed in any component of a machine must be less than the stress that would cause permanent deformation. A safe working stress is chosen with regard to the conditions under which the material is to work. The ratio of the yield stress to allowable stress is termed **the factor of safety**.

Consider a thin plate of thickness t, width b, and length l, subjected to tensile load P, which deforms by dl along the length, by db along the width, and by dt along the thickness. Then, stress $\sigma = P/A$, axial strain $\varepsilon_a = dl/l$, transverse strain $\varepsilon_b = db/b$, and the thickness strain $\varepsilon_t = dt/t$. Young's modulus, E = stress/strain, and Poisson's ratio, v= transverse strain/axial strain Poisson's ratio for steel varies from 0.1 to 0.3.

Behaviour of materials under load

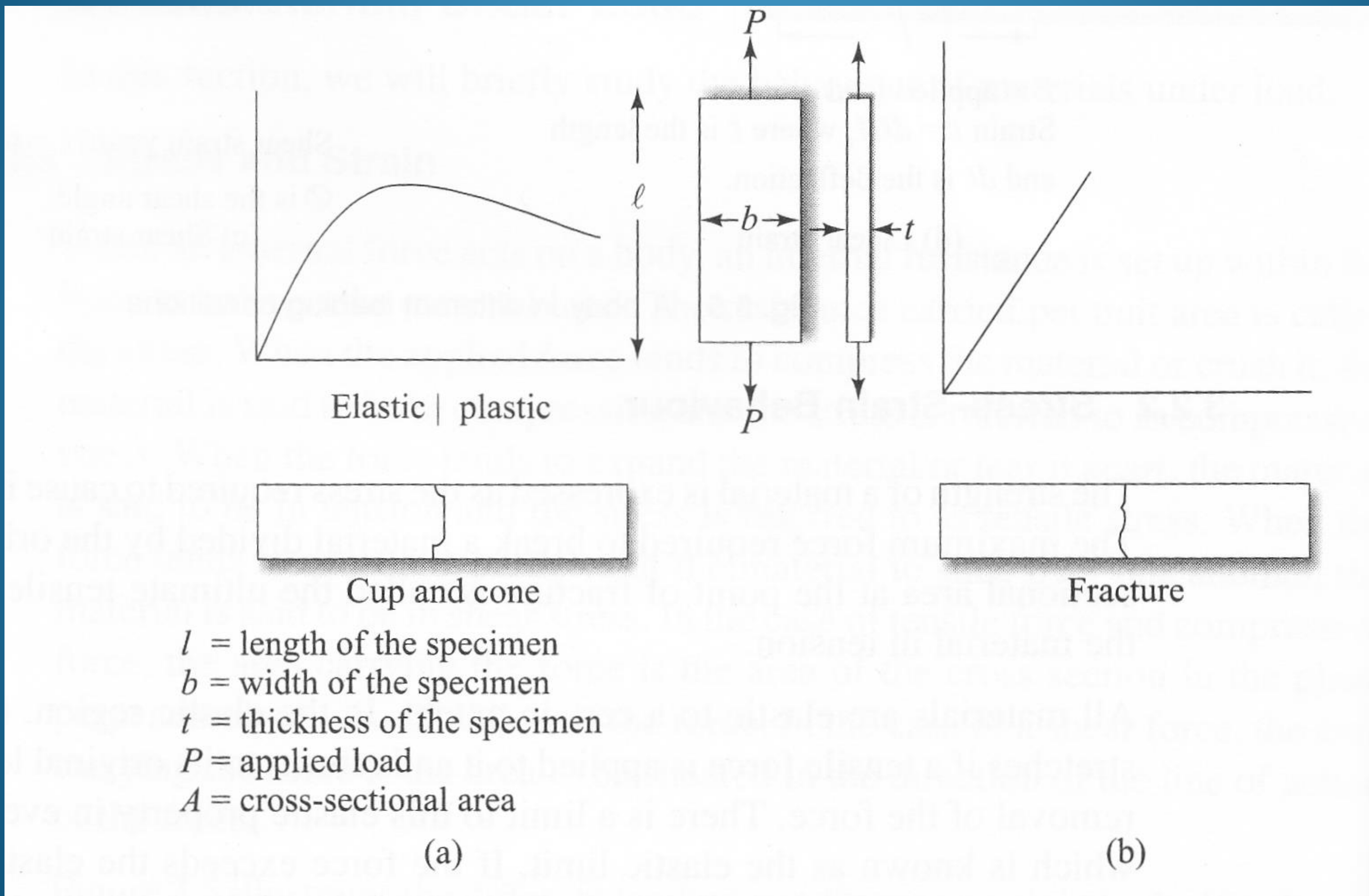


Fig. 3.6 Stress–strain curves (a) ductile material and (b) brittle material

Behaviour of materials under load

For isotropic materials, Young's modulus E and Poisson's ratio v are constants along the x, y, and z directions. Steel, alloys, and non-ferrous metals behave like isotropic materials. If Young's modulus and Poisson's ratio are different along the x, y, and z directions, then the material is said to be anisotropic. Resins, composites, metal matrix composites, and fibre reinforced plastic (FRP) are examples of anisotropic materials. Metals and alloys have unique physic properties. Tailored physical properties can be obtained in composite form by different orientations of fibres or reinforcement.

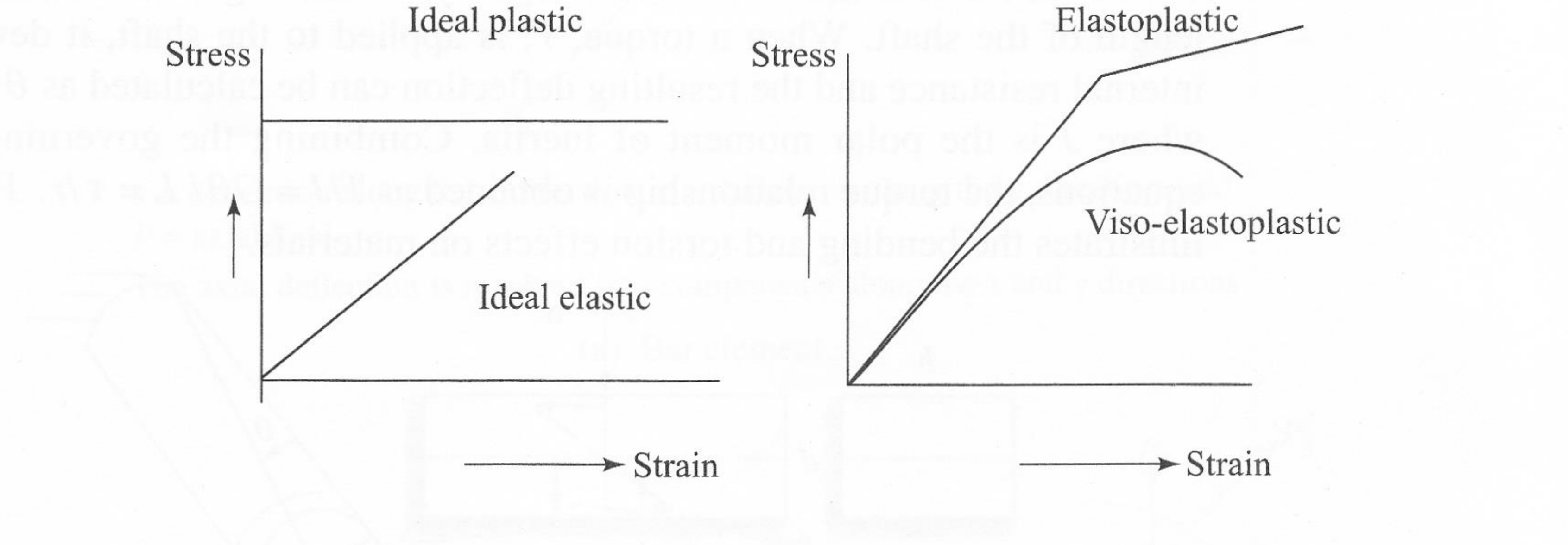
Behaviour of materials under load

Fibre Reinforced Plastic products; sheet and tube

Behaviour of materials under load

Figure illustrates the stress-strain relationship of different materials under different loading conditions. Materials may be ideal plastic or ideal elastic. After the elastic limit, materials may behave as elastoplastic or visco-elastoplastic materials. Adhesive materials or brazed materials behave like elastoplastic materials whereas materials at high temperature deform under visco-elastoplastic material model. Visco-elastoplastic material behaviour is a time-dependent problem.

Behaviour of materials under load



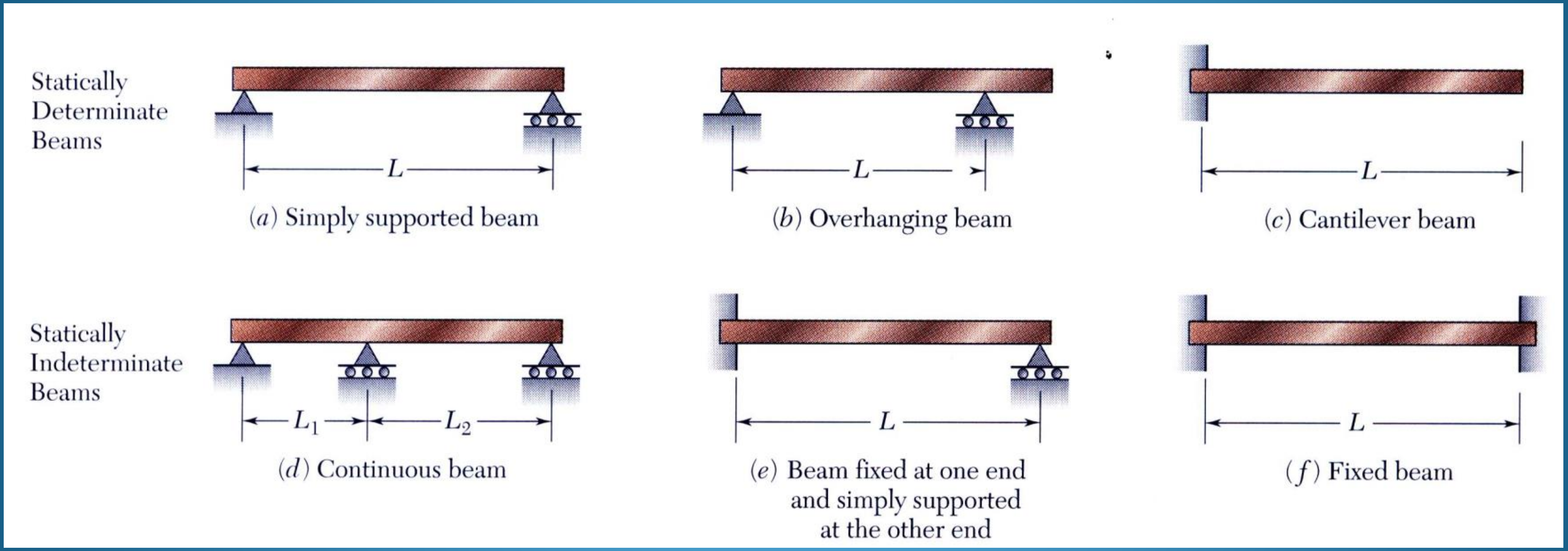
(a) Ideal elastic and ideal plastic (b) Elastoplastic and visco-elastoplastic meterials

Behaviour of materials under load

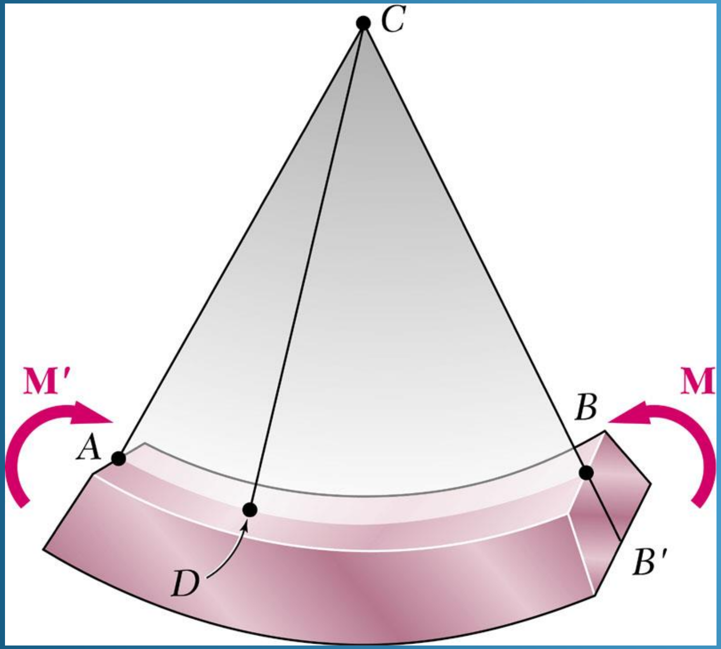
The term '**beam**' is used for a single rigid length of the material that can support a system of external forces at right angles to its axis. A beam may be loaded with a concentrated load or a distributed load, or both. A rigid, long material that can carry axial loads only is called a **strut**.

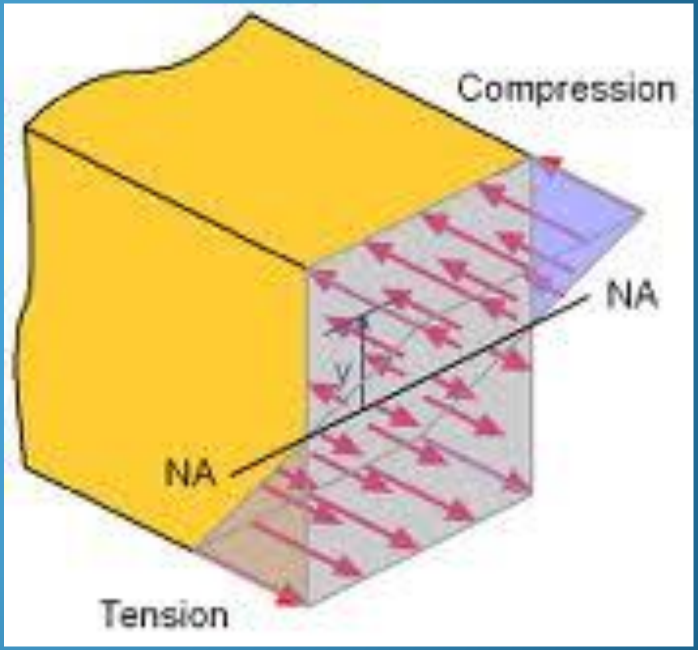
A beam which is fixed at one end, leaving the other end free, is called a **cantileve**r. A beam with its ends resting freely on a support is called a **simply supported beam**, and a beam with both ends fixed is called a **fixed beam**.

Behaviour of materials under load



Behaviour of materials under load





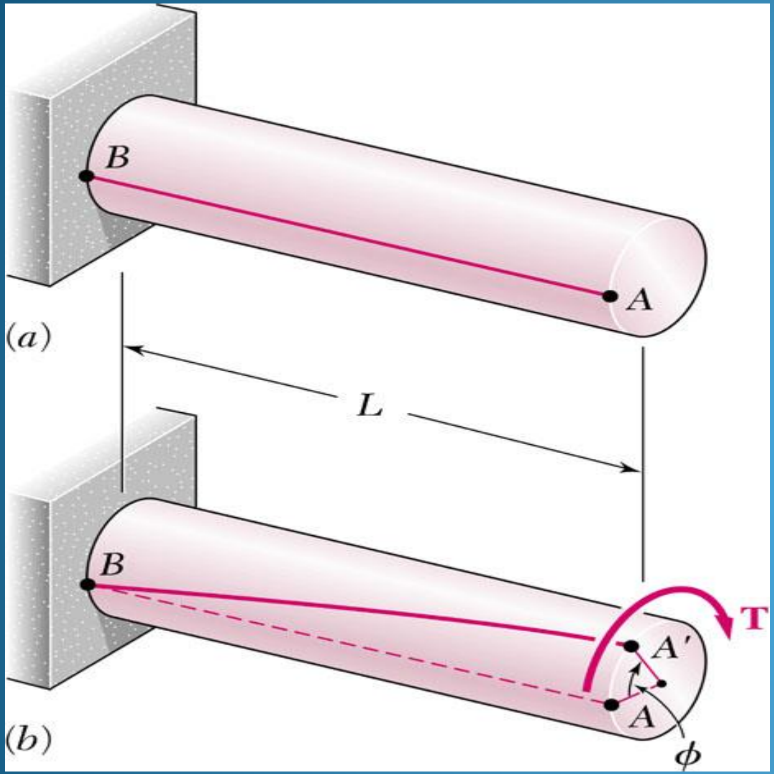
Behaviour of materials under load

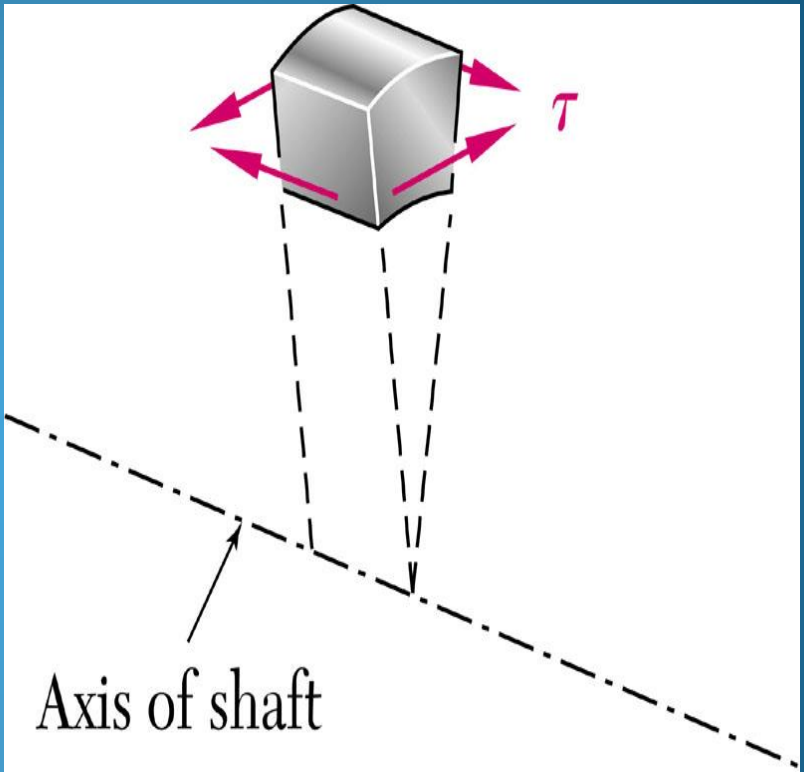
The loads on a beam tend to shear the beam and bend it as well. These effects on the beam are measured by measuring the shearing force and bending moment, respectively. The effect of a bending beam is to cause tensile and compressive stresses in it. Tensile stresses are set up in the lower half of the section and compressive stresses in the upper half. The axis with a stress value of zero is called the neutral axis. The stress at any distance y from the neutral axis is given by $\sigma_t = My/I$, where M is bending moment, I is the moment of inertia of the cross-sectional area.

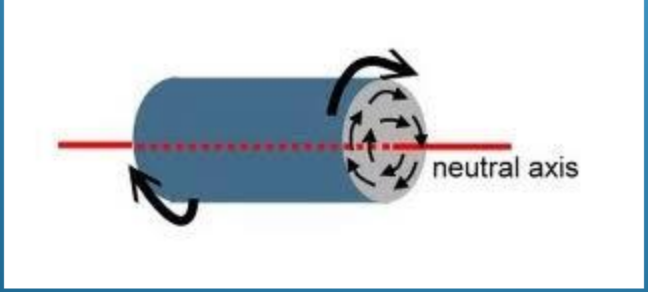
Behaviour of materials under load

The moment of a force applied to a shaft which tends to twist or turn it is termed as turning moment or torque. The shaft suffers a shear stress. The shear stress at any point in a cross section at a distance *r* from the axis of the shaft is given by $\tau = Tr/J$, where *T*, is torque applied to the shaft, *J* is the polar moment of inertia.

Behaviour of materials under load



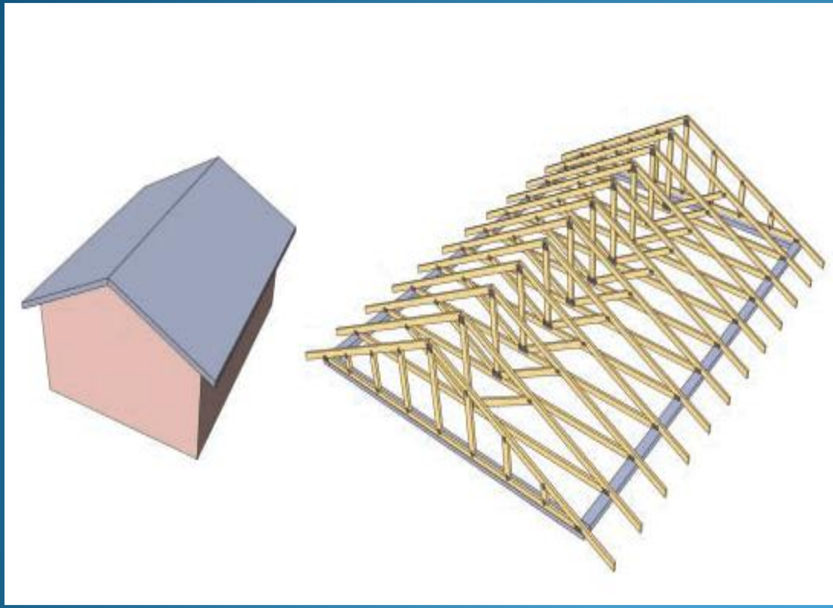


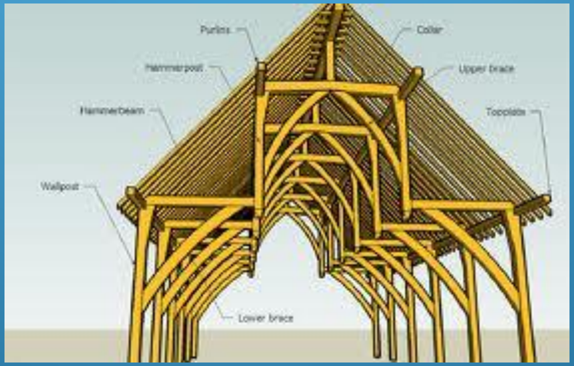


Behaviour of materials under load- Trusses and frames

Structures composed of bar elements and those composed of beam elements are classified as **trusses and frames**, respectively. Bars can only carry axial loads and deform axially, whereas beams can take transverse loads and bending moments about an axis perpendicular to the plane of the member. All the members of a truss are subjected to only axial loads and a truss cannot carry transverse shearing forces and bending moments.

Behaviour of materials under load





Behaviour of materials under load – Materials

The modern mechatronic systems are designed to operate at higher speeds and feeds. They should possess improved accuracy and higher rigidity, and should operate at reduced noise levels. This calls for optimizing the design of mechatronic system elements and selection of the right type of materials. Effective heat treatment and fabrication are of the utmost importance. The factors to be considered while selecting the materials are:

(a) functional requirement,

(b) ease of fabrication,

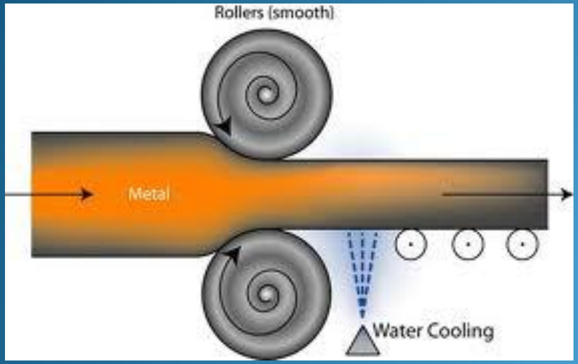
(c) machinability,

(d) cost, and (e) availability.

Behaviour of materials under load – Materials

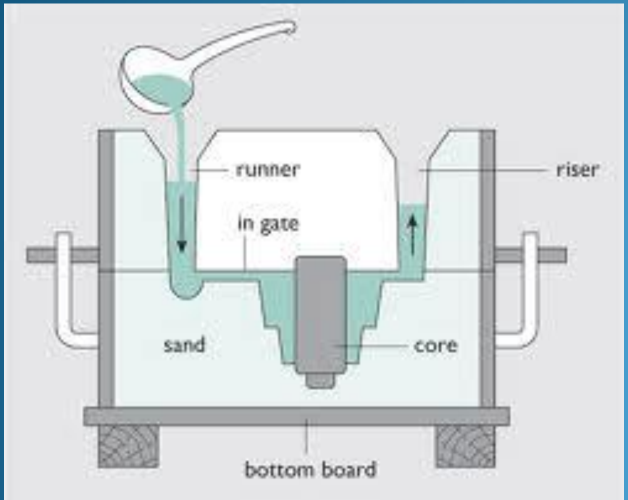
Materials used for mechatronic systems are classified as (a) **casting materials** such as grey cast iron, spheroidal graphite cast iron, malleable cast iron, steel casting, and casting of copper-based alloys and aluminium-based alloys, and (b) **rolled or forged materials** such as medium carbon-steel, alloy steel, highspeed steels, forged copper-based alloys and aluminium-based alloys. Various materials such as friction-reducing materials turcite, plastic, and rubber products and metallic resins and fibre composites are widely used in mechatronic systems in industries.

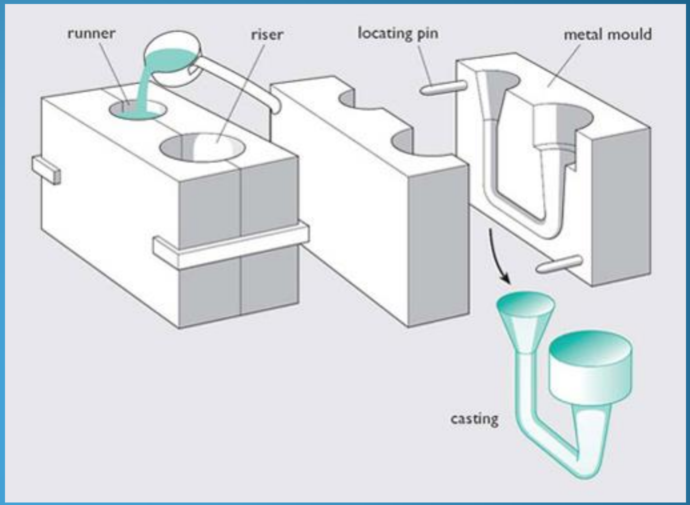
Behaviour of materials under load – Materials



Rolling is the most widely used deformation process. It consists of passing metal between two rollers, which exert compressive stresses, reducing the metal thickness. Where simple shapes are to be made in large quantity, rolling is the most economical process. Rolled products include sheets, structural shapes and rails as well as intermediate shapes for wire drawing or forging. Circular shapes, ‘I’ beams and railway tracks are manufactured using grooved rolls.

Behaviour of materials under load – Materials





The casting (or pouring) group of processes is one of the most convenient for making three-dimensional shapes, especially if repeated copies are required. However, you do have to be able to get your material into liquid form, and it has then to be ‘runny’ enough to be poured.

To get a liquid, you have to either melt the material; or dissolve it in a solvent which is subsequently evaporated off (the ‘solution route’); or pour liquid precursors into a mould where they react chemically to form a solid (the ‘reaction route’).

Behaviour of materials under load – Heat treatment

Heat treatment is a process of austenite transformation into slow or fast cooling products by a diffusion or diffusionless process.

Annealing refers to any heating, soaking, and cooling operation which is usually done to induce softening. Annealing may also be carried out to relieve internal stress induced by a cold or hot working process. **Normalizing** is a process of heating steel to 50°C above the upper critical temperature followed by cooling in still air. The primary purpose of normalizing is to refine the grain structure prior to hardening or to reduce segregation in casting or forging and to harden the steel slightly to improve machinability.

Behaviour of materials under load – Heat treatment

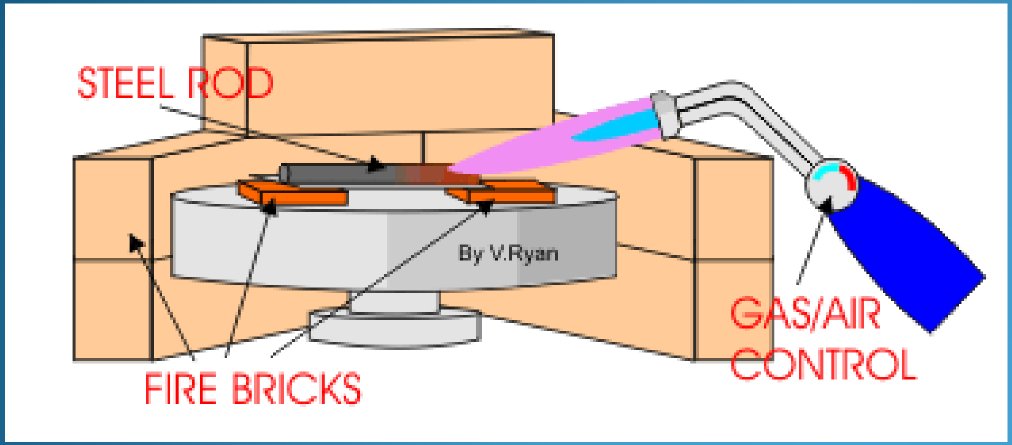
Annealing is necessary because the glass is a poor conductor of heat and cools unevenly when it emerges from the forming machine.

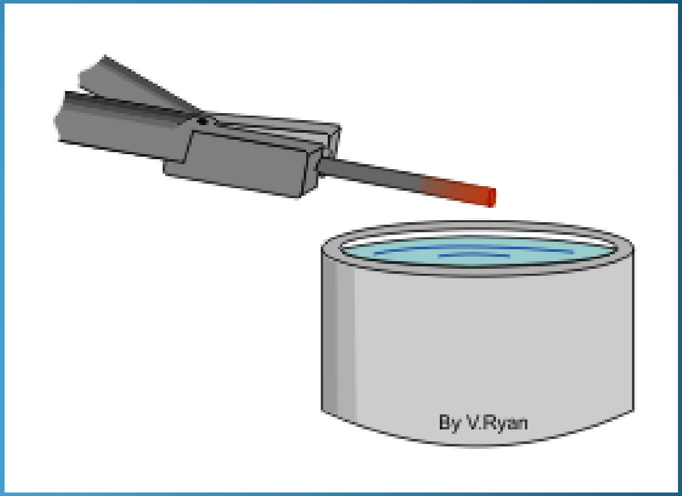
Behaviour of materials under load

<u>**Case hardening**</u> is a process of hardening ferrous alloys in which the surface layer or case is made substantially harder than the interior or core. The harder surface is resistant to wear and fatigue, and a toughened core resists impact and bending.

<u>**Flame hardening**</u> is a process of case hardening wherein the surface of the metal is heated very rapidly by using an oxy-acetylene flame (thereby creating a thermal gradient) and subsequently quenching in water or oil.

Behaviour of materials under load – Heat treatment





The steel is heated to red heat. It may only be necessary to harden one part of the steel and so heat can be concentrated in this area.

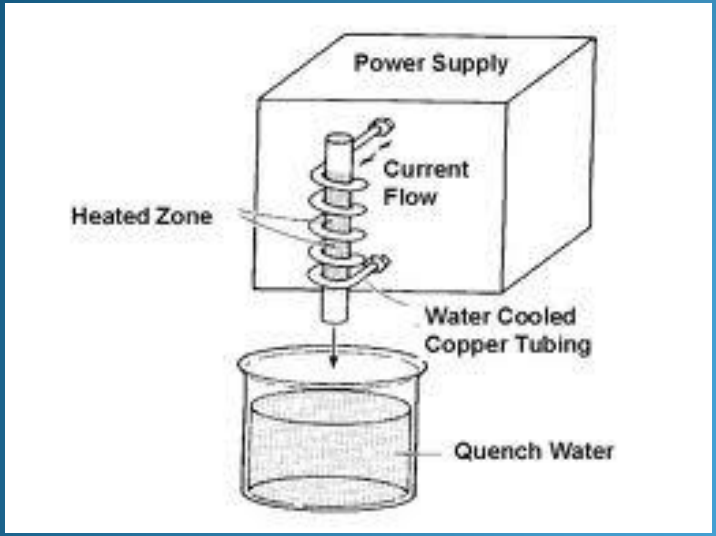
The steel is removed from the brazing hearth with blacksmiths tongs and plunged into case hardening compound and allowed to cool a little. The case hardening compound is high in carbon.

Behaviour of materials under load

Induction hardening involves the case hardening of a ferrous alloy by heating it above the transformation range by means of electrical induction and cooling as desired.

Liquid carbursing involves the case hardening of low-carbon and alloy steels by heating above the critical range in a molten cyanide salt, which induces both carbon and nitrogen into the case.

Behaviour of materials under load



In this process an electric current flow is induced in the workpiece to produce a heating action. Every electrical conductor carrying a current has a magnetic field surrounding the conductor. Since the core wire is a dead-end circuit, the induced current cannot flow anyplace, so the net effect is heating of the wire. The induced current in the core conductor alternates at frequencies from 60 cycles per second (60 Hz) to millions of Hertz. The resistance to current flow causes very rapid heating of the core material. Heating occurs from the outside inward. Induction hardening process includes water quench after the heating process. The big advantage of this system is its speed and ability to confine heating on small parts. The major disadvantage is the cost.

Behaviour of materials under load

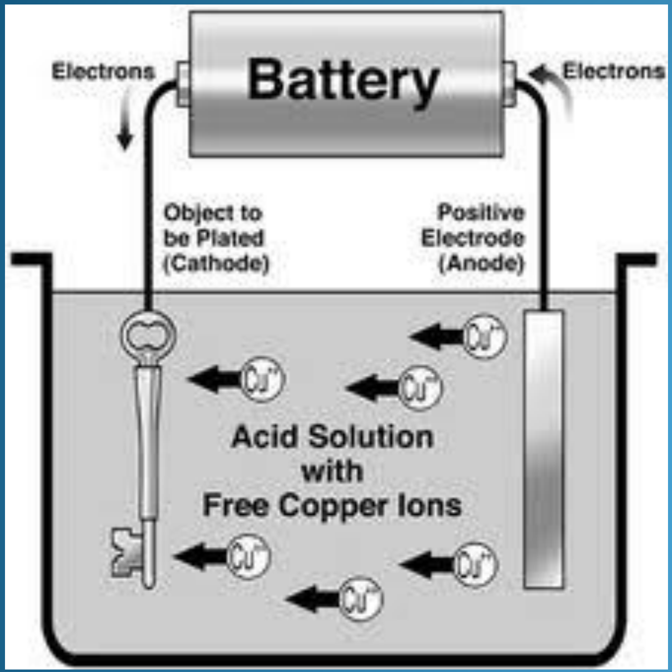
Electroplating or **electrodeposition** is a branch of electrometallurgy which deals with the art of depositing metals by means of electric current. The mechanism of electroplating is based on the theory of ionic dissociation and electrolysis. Copper can be electroplated on both ferrous and non-ferrous metals by using solutions of copper cyanide or acids.

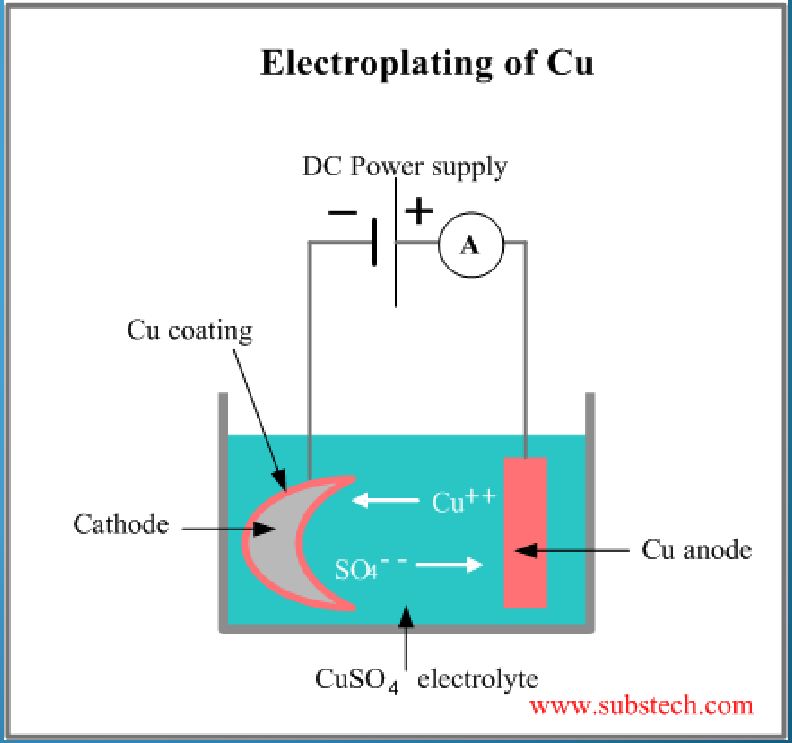
Commercial electroplating generally involves the use of copper cyanide, since more copper can be electroplated by this method.

Behaviour of materials under load

Most nickel plating salts are a mixture of nickel sulphate and nickel chloride, basic acid and stabilizers to control the quantity of nickel deposits. Chromium plating is done for decorative purposes, to improve corrosion resistance or to produce hard, abrasion-resistant surfaces. Tin, cadmium, silver, and gold plating are commonly used in mechatronic systems in industries.

Behaviour of materials under load





Behaviour of materials under load – Machine structure

The machine structure is the load carrying and supporting member of a machine tool. Motors that drive mechanisms and other functional assemblies of the machine are aligned to each other and rigidly fixed to the machine structure. Machine structures are subjected to static and dynamic forces.

It is therefore essential that they do not deform or vibrate beyond the permissible limit under the action of forces. The machine structure configuration is also influenced by considerations of manufacture, assembly, and operation.

Behaviour of materials under load – Machine structure

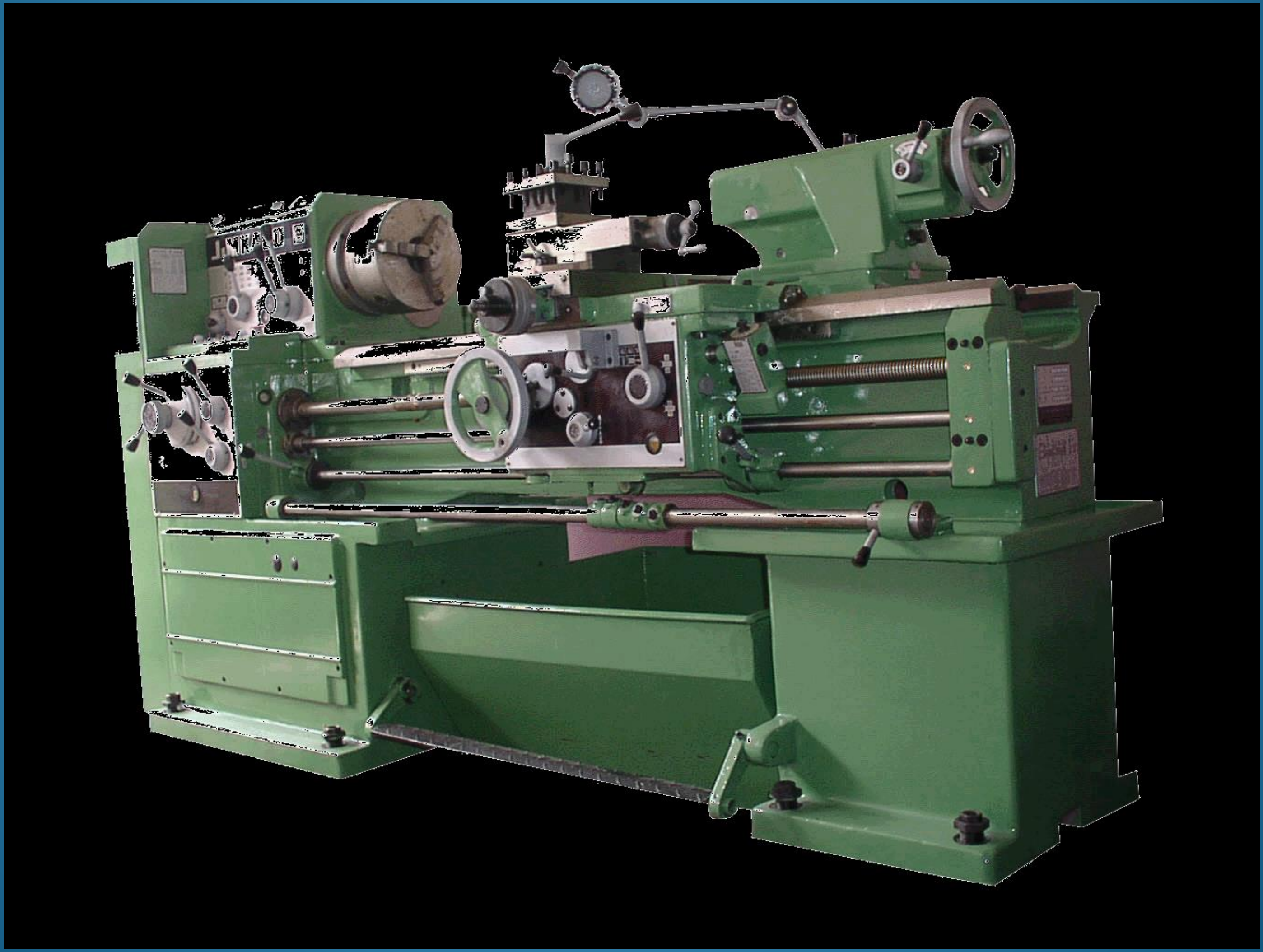
The basic design factor-involved in the design of a machine tool structure are static load, dynamic load, and thermal load. The static load of machine tools results from weights of slides and the workpiece, and from the force due to cutting. The structure should have adequate stiffness to keep the deformation of the structure within the permissible value.

Behaviour of materials under load – Machine structure

Dynamic loads are often used for the constantly changing forces acting on the structure while movement takes place. These forces may cause the whole machine system to vibrate. The origins of such vibration are

(a) unbalanced rotating parts,
(b) improper machine gears,
(c) bearing irregularities, and
(d) interrupted cuts while machining.

Behaviour of materials under load – Machine structure



Behaviour of materials under load – Machine structure

In a machine tool, there are a number of local heat sources which set up thermal gradients within the structure of the machine. Some of the heat sources are;

(a) the electric motor,

(b) friction in mechanical drives,

(c) friction in bearings,

(d) the machining process,

(e) the temperature of the surrounding objects.

The heat sources cause localized deformation, resulting in considerable inaccuracies in machine performance.

Behaviour of materials under load – Guideways

Guideways are used in machine tools to control the direction or line of action of the carriage or the table on which a tool or workpiece is held and to absorb all the static and dynamic forces.

The shapes and sizes of the workpieces produced depend on the geometric and kinematic accuracy of the guideways.

The geometric relationship of the slide and guideways with the machine base determines the geometric accuracy of the machine. Kinematic accuracy depends on the straightness, flatness, and parallelism error in the guideways.

Behaviour of materials under load – Guideways

Moreover, any kind of wear in the guideways reduces the accuracy of the guide motion. The points that must be considered while designing guideways are

(a) rigidity,

(b) dampening capability,

(c) geometric and kinematic accuracy,

(d) velocity of slide,

(e) friction characteristic,

(f) provision for adjustment of ply,

(g) position relative to work area, and

(h) protection against swarf and damage.

Behaviour of materials under load – Guideways

Guideways are generally of two types;

- Friction guideways
- Antifriction linear motion guideways.

Antifriction linear motion guideways are used in CNC machines and tools because they

(a) reduce the amount of wear,

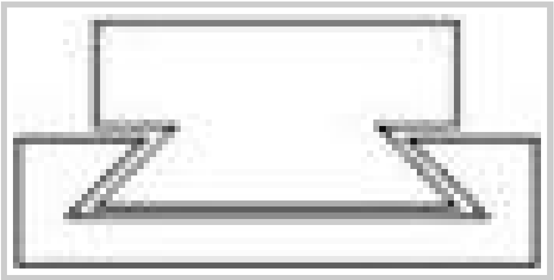
(b) improve smoothness of movement,

(c) reduce friction,

(d) reduce heat generation.

Behaviour of materials under load – Guideways

Dovetail guide ways; Cast-iron



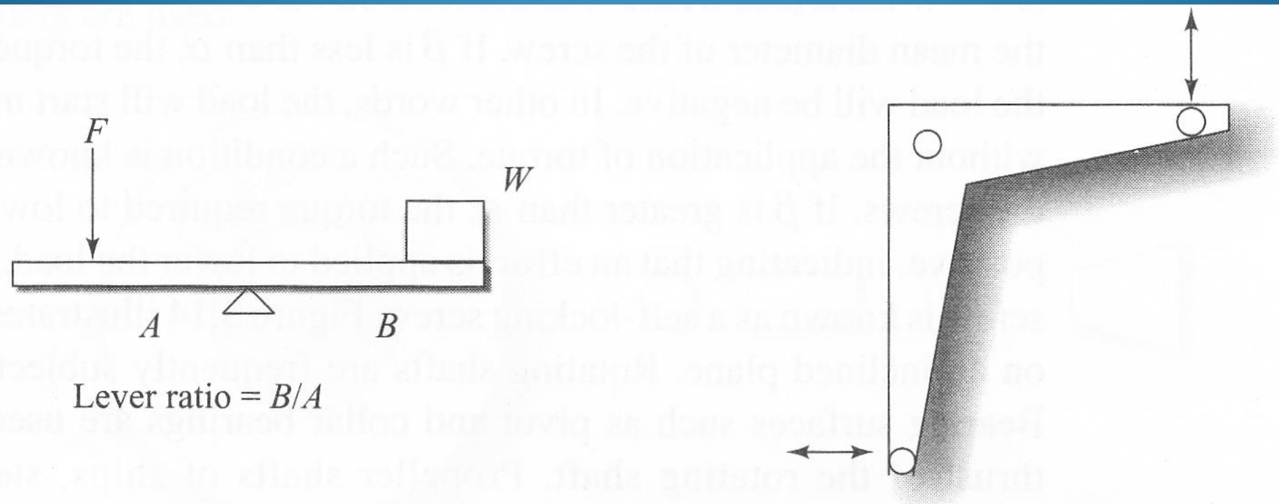
Dovetail

Behaviour of materials under load

Lever mechanisms are widely used in mechatronic systems. For even a small force, a lever should react without any friction or addition of any other force. Systems of levers are used to measure the weight of a body by balancing it against gravitational force as well as to balance the known weights by varying the lever ratio or by a counterweight.

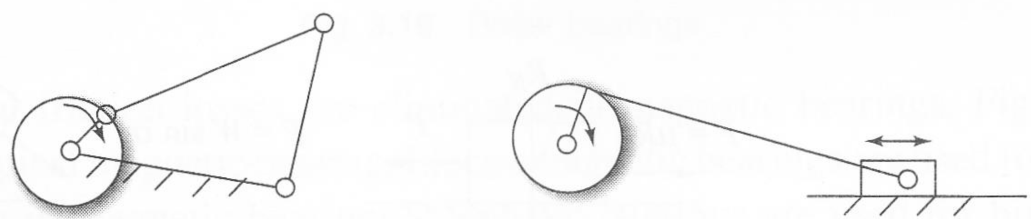
A bell column lever is used to transmit the displacement or force in mutually perpendicular directions.

Behaviour of materials under load



(a) Simple lever (b) Bell column lever

Fig. 3.12 Simple and bell column levers



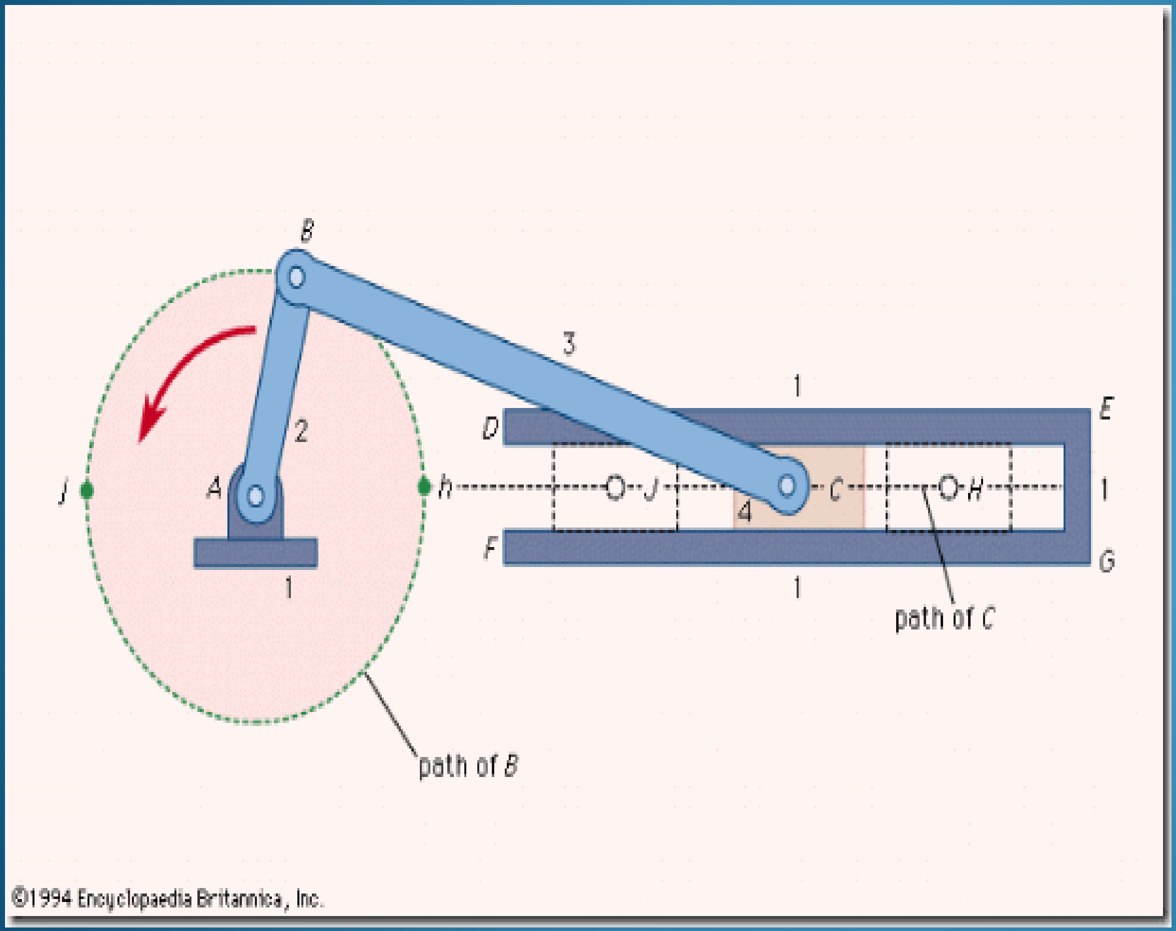
(a) Four-bar chain (b) Single-slider crank chain

Behaviour of materials under load

In the displacement type of lever mechanism, the addition of force through a spring improves the accuracy since the spring prevents backlash and play. Two levers of a machine, in contact with each other, are said to form a pair. A pair may be a sliding, turning, rolling, screw, or spherical pair.

When the kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion, they are said to form a **kinematic chain**. When any of the levers of the kinematic chain is fixed, the chain is known as a **mechanism**.

Behaviour of materials under load



Behaviour of materials under load

A mechanism with four levers is known as a **four-bar mechanism**. When a mechanism is required to transmit power or to do some particular type of work, it becomes a machine. Obtaining different mechanisms by fixing different links in a kinematic chain is known as inversion of mechanism.

Inversions of a four-bar chain mechanism are

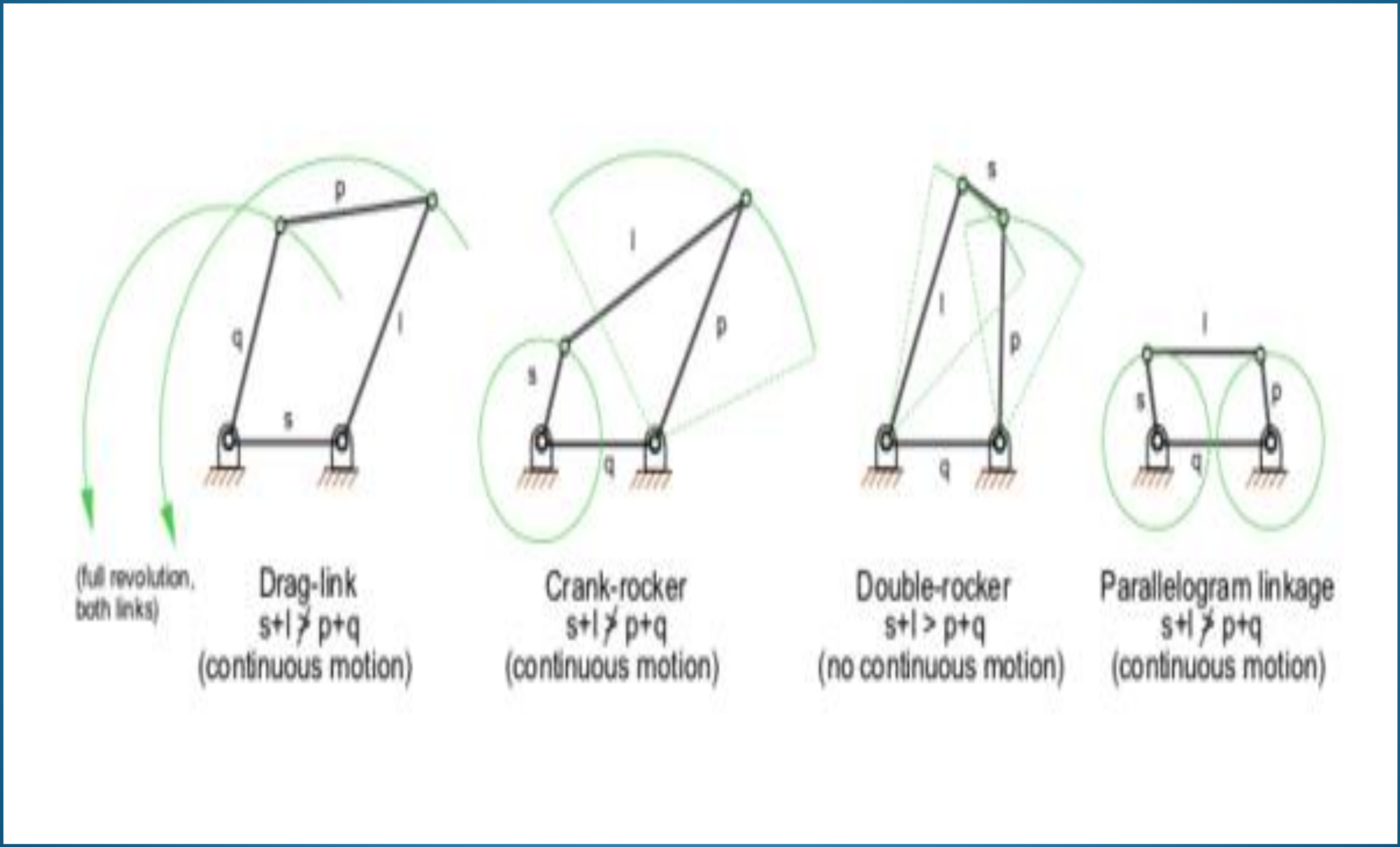
(a)crank-and-lever mechanism,

(b) double-crank mechanism, and

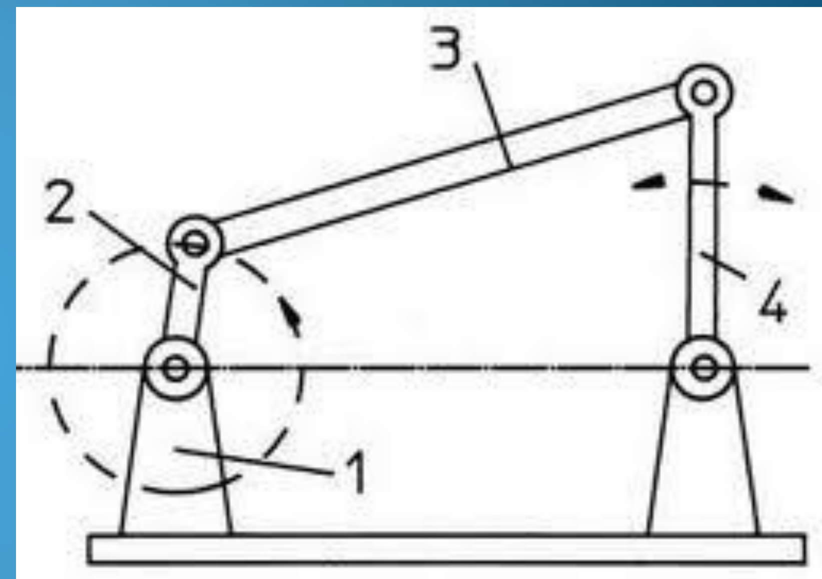
(c) double-lever mechanism.

Figure 3.12 illustrates the working of a simple lever and bell crank lever and Fig. 3.13 shows the four-bar mechanism and its inversion.

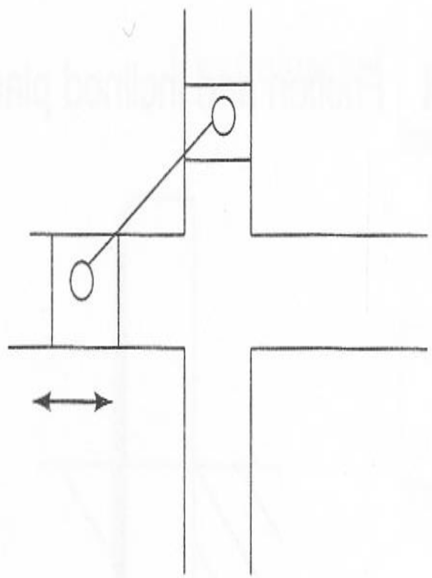
Behaviour of materials under load



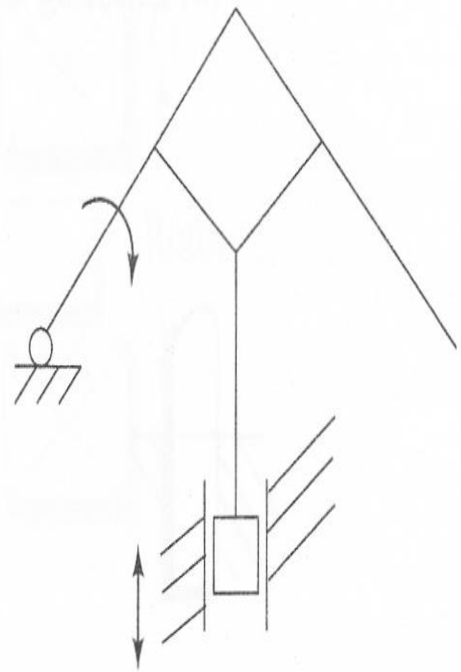
Behaviour of materials under load



Behaviour of materials under load – Guideways



(c) Double-slider crank chain



(d) Double-lever mechanism

Behaviour of materials under load-Bearings

Mechanisms working on friction include the plane power screw, pivot and collar beams, and friction clutches.

Rotating shafts are frequently subjected to axial thrust. Bearing surfaces such as pivot and collar bearings are used to take the axial thrust of the rotating shaft. Propeller shafts of ships, steam turbines, and instruments with moving spindles are examples of shafts which carry an axial thrust. Figure 3.15 shows the different pivot bearings and a single flat collar bearing.

Behaviour of materials under load

All the bearing parts are in transition fit since the bearing should allow a free rotation of the rolling element and the outer and inner rings should not get cold welded with the housing or body. Bearings have to deal with radial and thrust loads. For this purpose, different rolling elements such as balls, cylindrical rollers, and needle type or tapered rollers are used.

Behaviour of materials under load

A rolling element bearing is considered a very important mechanical component as it is used for almost all rotary applications. Such a bearing consists of two circular metal rings and a set of rolling elements. One of the rings is larger than the other. The smaller of the two is called the inner ring and the larger one the outer ring. The inner ring fits well within the perimeter of the outer ring. Figure 3.16 shows a typical roller bearing.

Behaviour of materials under load

Behaviour of materials under load

The principal application of the friction clutch is in the transmission of power of shafts and machines which must be started and stopped frequently. The force of friction is used to start the shaft from rest and gradually bring it up to the proper speed without excessive slippage of the friction surface. In an automobile, the friction clutch is used to connect the engine to the driven shaft.

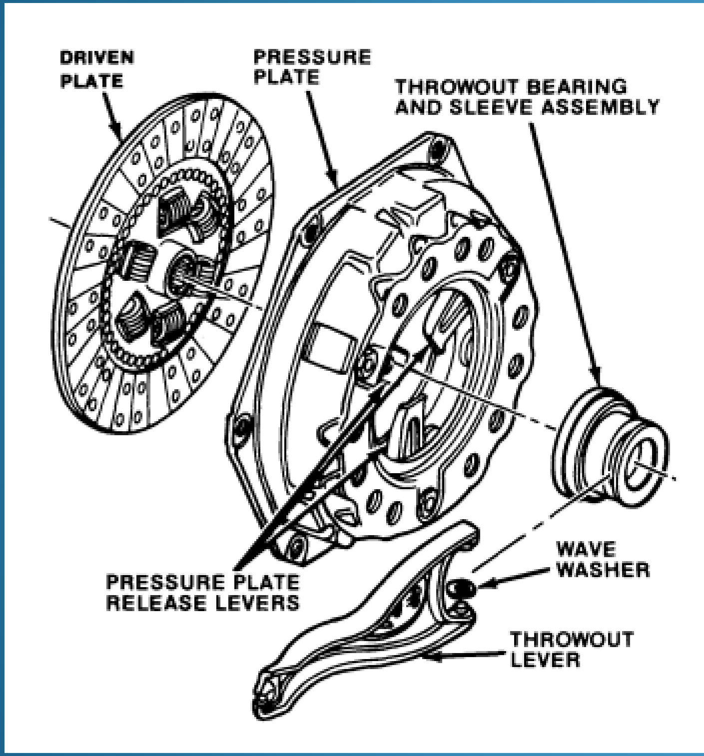
Behaviour of materials under load

Friction clutches of different types such as

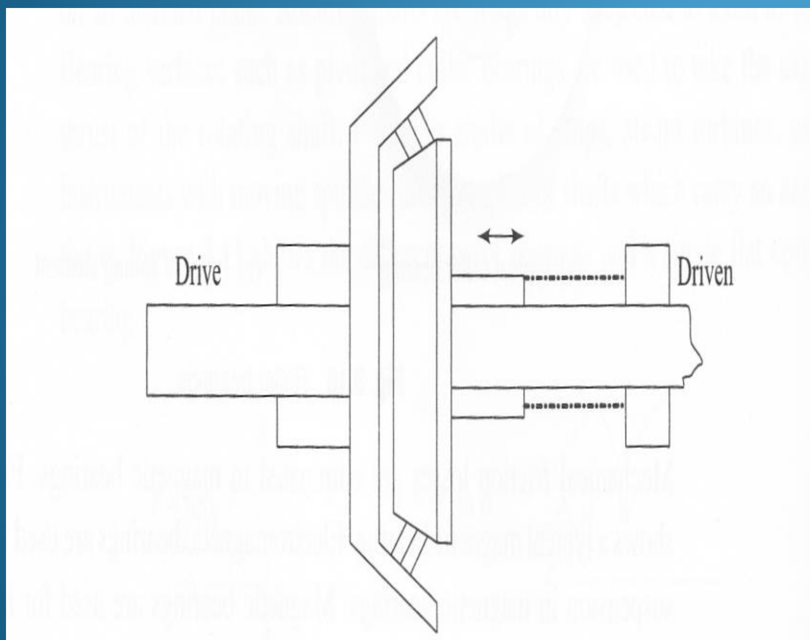
- disc or plate clutch (single disc or multiple disc clutch),
- cone clutch,
- centrifugal clutch

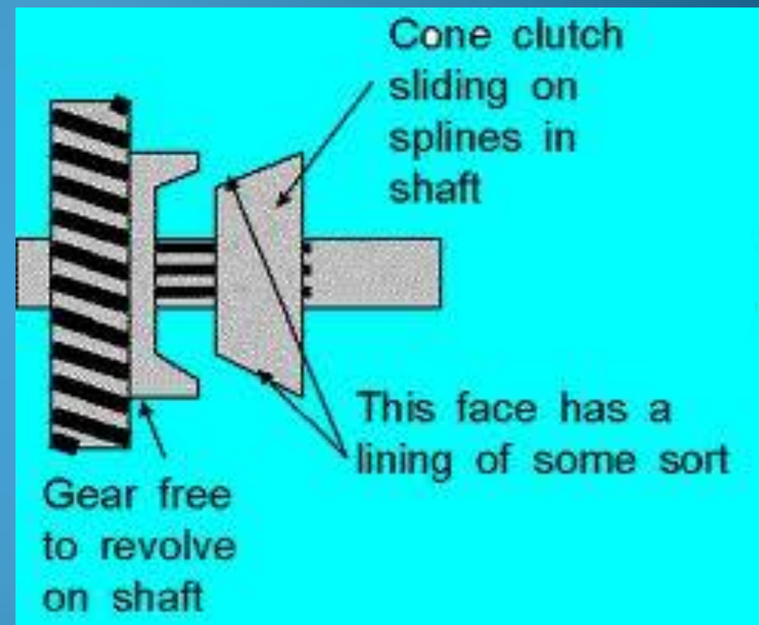
The cone clutch consists of a pair of friction surfaces only. The contact surfaces of the clutch may be metal to metal, but more often the driven member is lined with some material such as wood, leather, cork, or asbestos. Figure 3.18 shows a cone clutch.

Behaviour of materials under load



Behaviour of materials under load

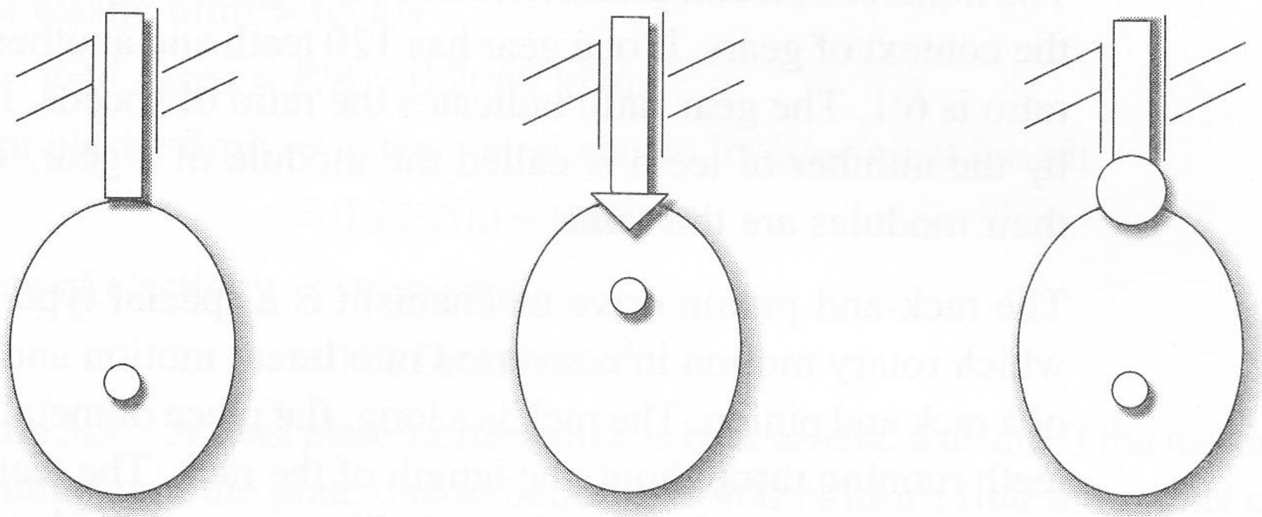




Behaviour of materials under load

A simple cam follower system is a wheel with an axle not in the centre. The follower rests on the edge of the cam. As the cam rotates, the follower moves up and down. The contour of the cam is broadly divided into three regions, rise, fall, and dwell. The rise portion of the cam makes it possible to raise the followers; during the fall portion, the follower returns to its original position or reference position. In the dwell portion of a typical cam, the followers do not move relative to the cam axis. Each portion can be described in terms of profile equations— the displacement, velocity, and acceleration profiles.

Behaviour of materials under load

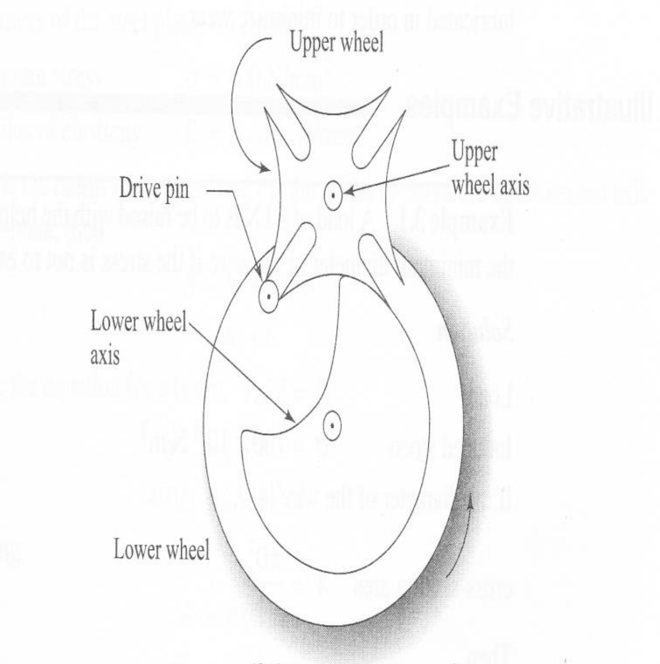


(e) Cam and follower

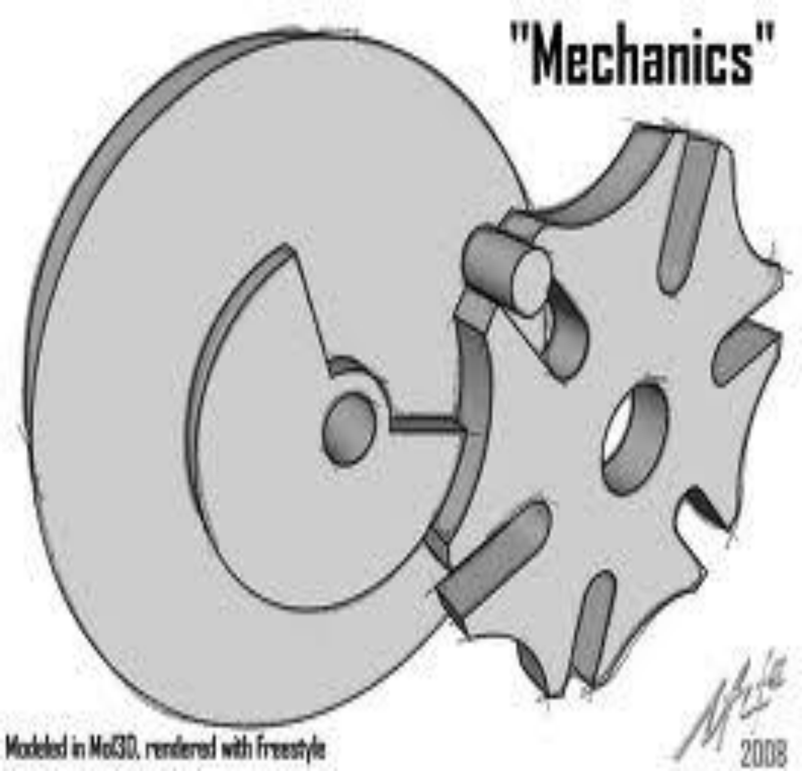
Behaviour of materials under load

The Geneva wheel-based mechanism is used for achieving intermittent motion. The mechanism has two wheels. There is a projection called the drive pin mounted on one of the wheels. The other wheel, called the Geneva wheel, has four slots. However, more slots can be designed depending upon the need. When the drive wheel rotates, the projection pin is inserted into the slot, making the Geneva wheel rotate in the appropriate direction. Afterwards, the pin disengages from the Geneva wheel. During one rotation of the drive wheel, the drive pin engages with the Geneva wheel and rotates the Geneva wheel by one step. The Geneva wheel rotates stepwise.

Behaviour of materials under load



(f) Geneva mechanism



Behaviour of materials under load

Gear trains are mechanisms used in almost all machines to facilitate the transmission of power and motion. They help increase or decrease torque or speed, and can change the direction of the axis of rotation. Depending upon the teeth, gears are grouped as

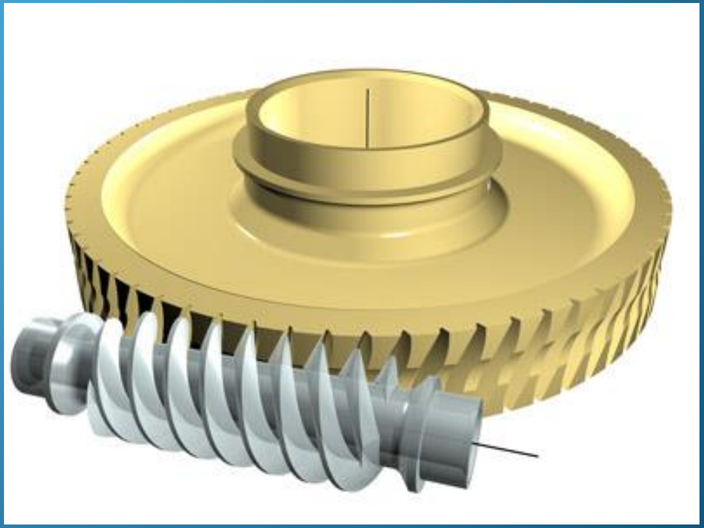
(a) spur gears,

(b) bevel gears,

(c) helical gears,

(d) worm gears.

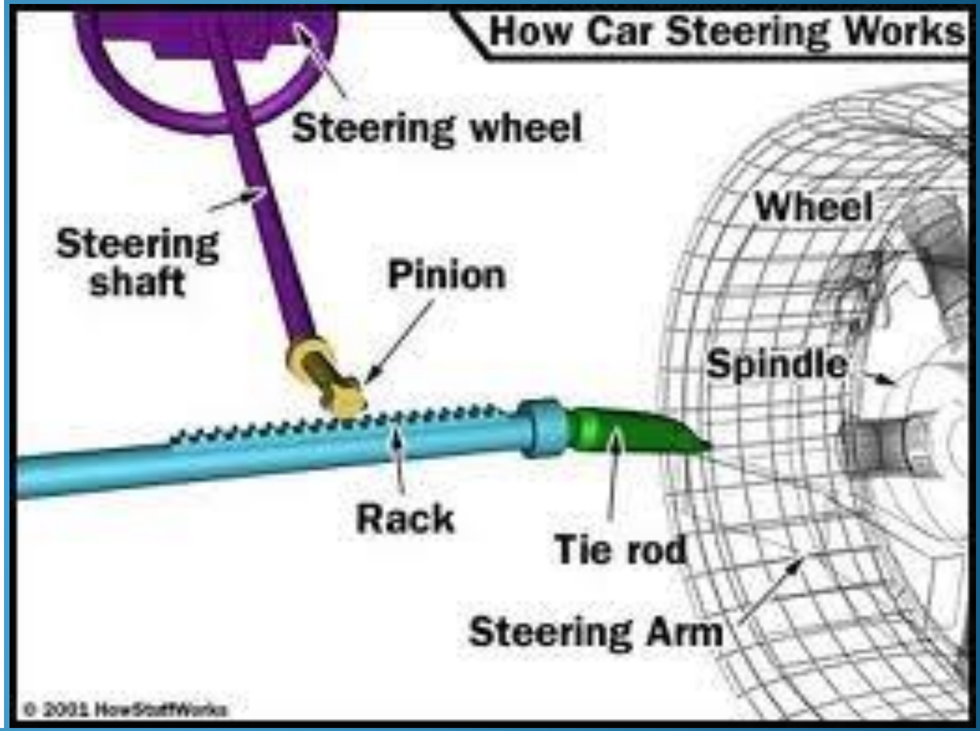
Behaviour of materials under load



Behaviour of materials under load

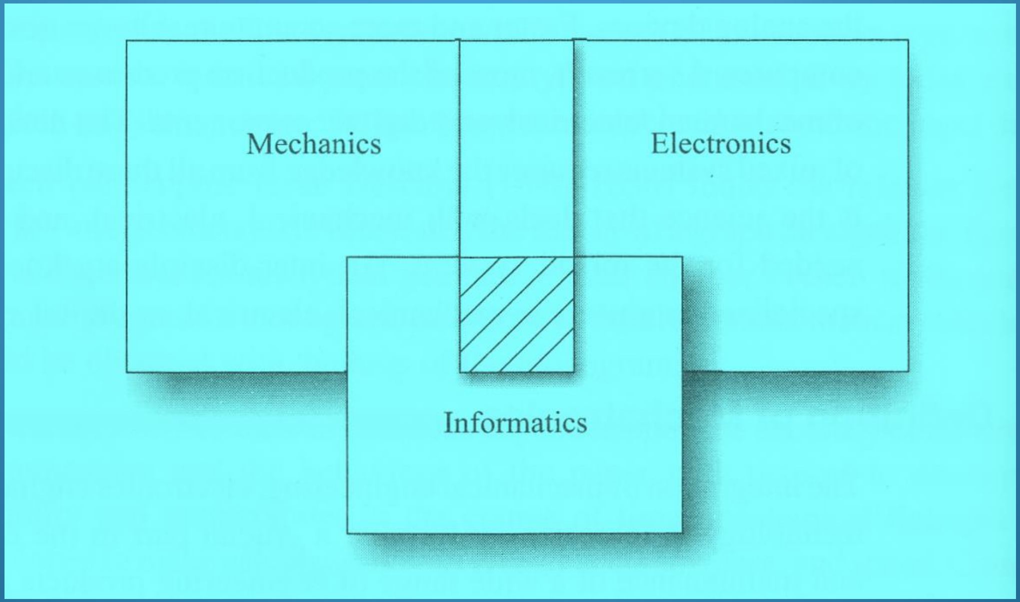
The **rack-and-pinion** drive mechanism is a special type of gear mechanism in which rotary motion in converted into linear motion and vice versa. It consists of a rack and pinion. The rack is a long, flat piece of metal. The flat side contains teeth running throughout the length of the rack. The teeth are perpendicular to the edge of the rack. The pinion is like a gear that also has teeth on it. These teeth run parallel to the length of the shaft. The pinion has rotary motion, whereas the rack gives linear motion just like any gear train. A rack and pinion is lubricated in order to minimize wear.

Behaviour of materials under load



Definition of mechatronics

The term 'mechatronics' was first coined by the Japanese scientist Yoshikaza in 1969. The trademark was accepted in 1972. Mechatronics is a subject which includes mechanics, electronics, and informatics



Definition of mechatronics engineer

A mechatronic engineer designs mechanical devices that incorporate electrical, software and mechanical components. The combination of these three key areas has resulted in the development and design of mechatronic or smart products. Examples include a more efficient washing machine, automated robotic assembly lines, cameras, laser printers, photocopiers, stair-climbing wheelchairs, hybrid autos and garage door openers.

Perhaps the most striking example of mechatronics is the development of the Mars rover used by NASA to take samples and photographs of the Martian surface.

Definition of mechatronics

Mechanics involves knowledge of mechanical engineering subjects, mechanical devices, and engineering mechanics. Basic subjects such as lubricants, heat transfer, vibration, fluid mechanics, and all other subjects studied under mechanical engineering directly or indirectly find application in mechatronic systems. Mechanical devices include simple latches, locks, ratchets, gear drives, and wedge devices to complicated devices such as harmonic and Norton drives, crank mechanisms, and six bar mechanisms used for car bonnets.

Definition of mechatronics

Engineering mechanics discusses the kinematics and dynamics of machine elements. Kinematics determines the position, velocity, and acceleration of machine links. Kinematic analysis helps to find the impact and jerk on a machine element. Change in momentum, causes an *impact,* whereas change in acceleration causes a *jerk.* Dynamic analysis gives the torque and force required for the motion of link in a mechanism. In dynamic analysis, friction and inertia play an important role.

Definition of mechatronics

Electronics involves measurement systems, actuators, power electronics, and microelectronics. Measurement systems, in general, are made of three elements, namely, the sensor, signal conditioner, and display unit. A sensor responds to the quantity being measured, giving an electrical output signal that is related to the input quantity. The signal conditioner takes the signal from the sensor and manipulates it into conditions which is suitable for either display or control any other systems. In a display system, the output from the signal conditioner is displayed. Actuation systems comprise the elements which are responsible for transforming the output from the control system into the controlling action of a machine or device.

Definition of mechatronics

Power electronic devices are important in the control of power-operated devices to actuate through a small gate power of the order milliwatts. The silicon controlled rectifier (thyristor) is an example of a power electronic device which is used to control dc motor drives. The technology of manufacturing microelectronic devices through very large scale integrated (VLSI) circuit designs is also gathering momentum. Microsensors and microactuators are subdomains of the mechatronic system, which are used in many applications.

Definition of mechatronics

Informatics includes automation, software design, and artificial intelligence. The programmable logic controller (PLC) or microcontroller, or even personal computers, are widely used as informatic devices. A completely automated plant reduces the burden on human beings in respect of decision-making and plant maintenance, among other things. Software is used not only for solving complex engineering problems but also in finance systems, communication systems, or virtual modelling.

Definition of mechatronics

Wide area networks, such as internet facilities, have large data storage facilities and the data can be retrieved from anywhere in the world. Informatics systems can make decisions using artificial intelligence. Artificial neural networks, genetic systems, fuzzy logic, hierarchical control systems, and knowledge-base systems are effective tools used in artificial intelligence.

Objectives, Advantages, and Disadvantages of Mechatronics

The objectives of mechatronics are the following:

1. To improve products and processes
2. To develop novel mechanisms
3. To design new products
4. To create new technology using novel concepts

Objectives, Advantages, and Disadvantages of Mechatronics

Earlier the domestic washing machine used cam-operated switches in order to control the washing cycle. Such mechanical switches have now been replaced by microprocessors.

A microprocessor is a collection of logic gates and memory elements whose logical functions are implemented by means of software.

The application of mechatronics has helped to improve many mass-produced products such as the domestic washing machine, dishwasher, microwave oven, cameras, watches, and so on.

Objectives, Advantages, and Disadvantages of Mechatronics

Mechatronic systems are also used in cars for active suspension, antiskid brakes, engine control, speedometers, etc.

Large-scale mprovements have been made using mechatronic systems in flexible manufacturing engineering systems (FMS) involving computer controlled machines, robots, automatic material conveying and, overall supervisory control.

Objectives, Advantages, and Disadvantages of Mechatronics

There are many advantages of mechatronic systems. Mechatronic systems have made it very easy to design processes and products. Application of mechatronics facilitates rapid setting up and cost effective operation of manufacturing facilities. Mechatronic systems help in optimizing performance and quality. These can be adopted to changing needs.

Mechatronic systems are not without their disadvantages. One disadvantage is that the field of mechatronics requires a knowledge of different disciplines. Also, the design cannot be finalized and safety issues are complicated in mechatronic systems. Such systems also require more parts than others, and involve a greater risk of component failure.

Examples

A thermostatically controlled heater or furnace is a mechatronic system. The input to the system is the reference temperature. The output is the actual temperature. When the thermostat detects that the output is less than the input, the furnace provides heat until the temperature of the enclosure becomes equal to the reference temperature. Then the furnace is automatically turned off. Here, the bimetallic strip of the thermostat acts as informatics since it automatically turns the switch on or off. The lever-type switch is mechanical system whereas the heater acts as an electrical system.

Examples

Most washing machines are operated in the following manner. After the clothes to be washed have been put in the machine, the soap, detergent, bleach, and water are put in required amounts. The washing and wringing cycle time is then set on a timer and the washer is energized. When the cycle is completed, the machine switches itself off.

When the required amount of detergent, bleach, water, and appropriate temperature are predetermined and poured automatically by the machine itself, then the machine is a mechatronic system. The microprocessor used for this purpose acts as the informatics system. The electrical motor actuated for wriggling is an electrical system. The agitator and timer are mechanical systems. The washing machine is an ideal example of a mechatronic system.

Examples

The automatic bread toaster is a mechatronic system, in which two heating elements supply the same amount of heat to both sides of the bread. The quality of the toast can be determined by its surface colours. When the bread is toasted, the colour detector sees the desired colours, and the switch automatically opens and a mechanical lever makes the bread pop up. Mechanical, electrical, and informatics systems are involved in the operation of the bread toaster.