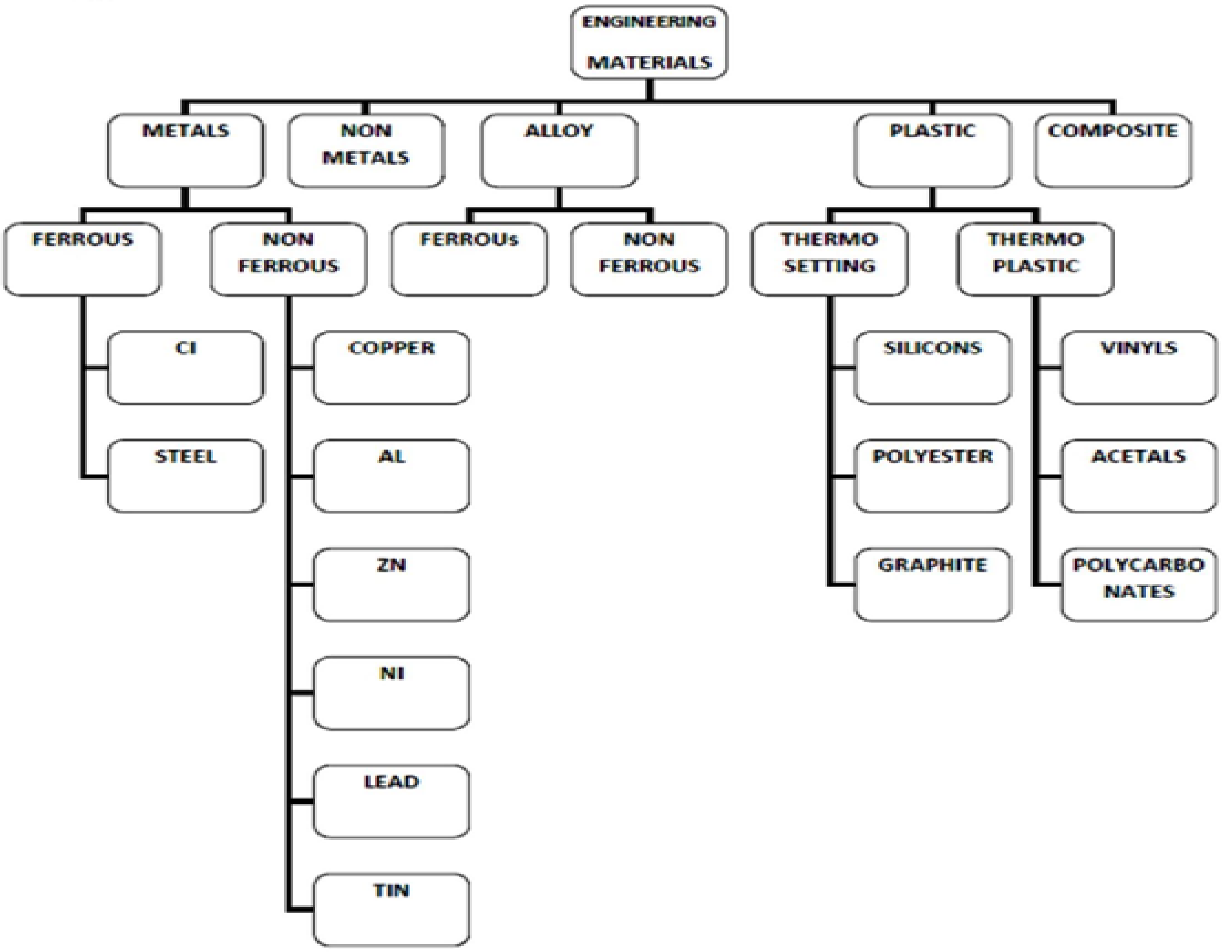
UNIT-1
INTRODUCTION AND CLASSIFICATION OF MATERIALS

Introduction

A material is a thing which can make anything or by the help of materials we can process any component of our requirement. Various types of materials are available but all material are not considered as engineering materials, Because engineering materials are those materials which are use for synthesis of engineering component as like crank ,piston cylinder ,crank shaft, machine structures etc.

Classification of materials.[RGPV June- 09 (20,10,marks) June 12, 14 (10,3 marks)Nov& May 2019 (7 marks)]



How the engineering materials differ from other materials [RGPV - Dec. 17]

The main engineering requirements of materials which make the differ from other materials are follows-

Fabrication requirements: - Two basic Fabrication requirements of engineering materials are that it should be able to get shaped and joined with other materials. Service requirements:-the material selected for the purpose must stand up to service requirement. It should have an adequate dimensional stability, corrosion requirement strength toughness hardness, heat resistance, low electrical resistance

etc.
Economic requirements: - economic requirement demand that the engineering part should be made with minimum overall cost.
Metals: Metals are further classified into two types they are
Ferrous & non-ferrous
Ferrous: Ferrous are alloys or metals, which contain a high amount of iron elements. These are very strong materials, used for the application where high strength is required and at low cost. Ferrous metals are used in the large buildings, locomotives, bridge buildings and railway lines. Ferrous are divided in to two types they are: Steels Cast irons Steels: Steels are divided in to two types they are: Alloy steels Plain Carbon steel Cast iron: Cast iron is divided in to four types they are: Gray cast iron White cast iron Malleable cast iron Ductile cast iron

Non - ferrous: Non - ferrous metals are pure metals which are rarely used as structural materials, and they lack mechanical strength. The non - ferrous metals are used where their special properties such as electrical conductivity, resistance and thermal conductivity are required. Aluminum and copper are used as electrical conductors, along with sheet lead and sheet zinc that are used as roofing materials. Non - ferrous metals are divided in to several types they are Aluminum Cu Mg W Zinc Lead Nickel
Non - metals:
Non-metals are divided in to two types they are Ceramics Organic polymers Combination of the materials Composite alloys Composites Ceramic polymers Polymer cement concert Carbon reinforced Metal ceramic Metal reinforced metal Whisker reinforced metal Alloys: Alloys are divided in to two type's they are Non-ferrous alloys Ferrous alloys

Plastic [RGPV NOV 2019 (7 Marks)]

In a broad sense plastics can be defined as non-metallic material that can be moulded to desired shape. In a general way plastics can be defined as natural or synthetic resins, or their compounds, which can be moulded to any desired shape by the application of heat and pressure.
Most plastics are of organic nature and composed of hydrogen, carbon, oxygen and nitrogen. Properties of Plastics - Plastics have following special properties -

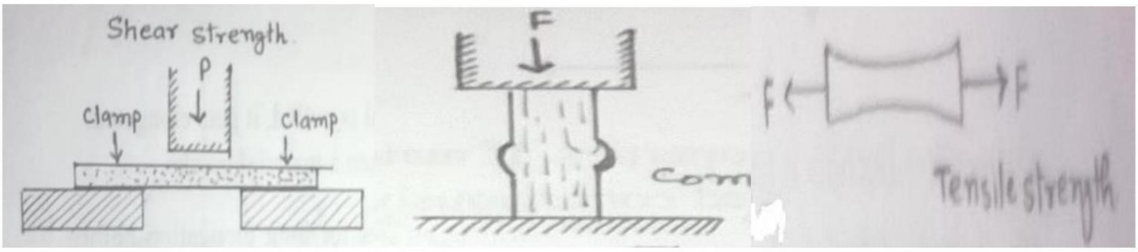
Light Weight - Their specific gravity varies from 1 to 2.4. That makes them the most suitable for various automobile and aircraft parts.
(ii) Good thermal and electric insulation i.e., they possess very low thermal and electrical conductivity.
(iii) Corrosion resistance is very high.
(iv) Chemically inert to the attack of inorganic acids, bases and salts.
(v) Adhesiveness - Adhesives, made out of plastic resins, produce very thin films, which are quite strong, durable and adhesive.

(vi) Easy Workability - Plastics can be easily molded into intricate and complicated forms and shapes at low cost. Drilling, sawing and machining of plastics can be done easily.
(vii) Plastics in many cases are non-inflammable, self-extinguishing and burn very slowly.
(viii) They have good tensile strength and good dimensional stability.
(ix) Good shock and sound absorption properties. Some plastics can absorb shock even better than steel.
(x) Low thermal expansion coefficient.
(xi) High resistance to abrasion - Plastics like teflon are highly resistant to abrasion.
(xii) They are transparent, transluscent or opaque.
(xiii) Toughness - Some plastics can be made so tough that a bullet may pierce it without breaking or cracking it.
(xiv) They are available in various colours and shades and they do not fade easily.
(xv) They have excellent surface finish.
(xvi) They are not affected by insects, moth, fungi, vermin, etc.
(xvii) Low maintenance cost. Do not require any protective coat of paints.

Properties of engineering materials [RGPV feb.06(14 marks) June 05, 08 (8,10 marks) June 11,13, (7 marks), Dec 17, June 2020 (7marks)]

(1) Physical properties
(2) Chemical properties
(3) Dimensional properties
(4) Manufacturing properties Machinability, castability, weldability
(5) Mechanical properties
(1) Strength
(2) Elasticity
(3) Plasticity
(4) Ductility
(5) Hardness
(5) Malleability
(6)Hardness
(7) Creep
(8)Fatigue
(9) Toughness
(10)Brittleness

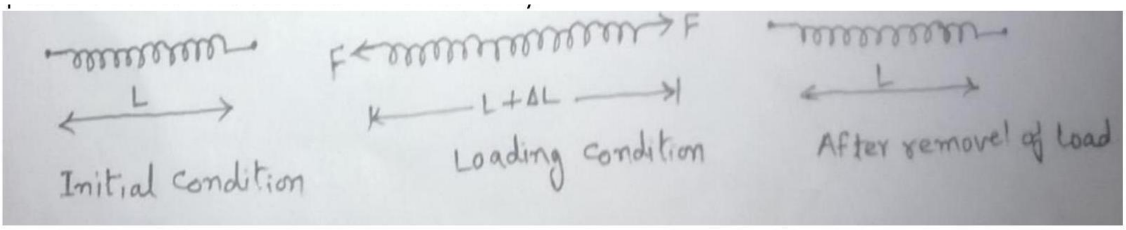
(1) Strength: - [RGPV May 2018] it is the ability of material to withstand the external force without destruction or breaking. A stronger material can withstand greater load.



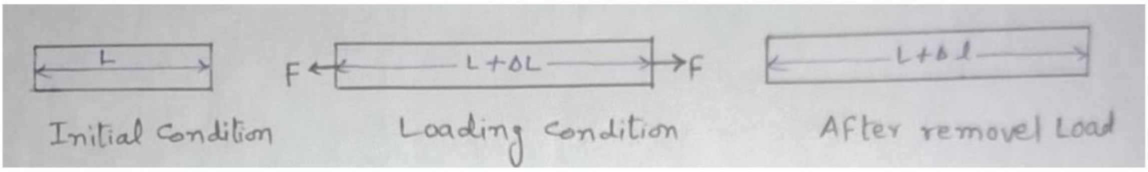
Shear strength compressive strength tensile strength

The strength of materials varies according to the type of loading i.e., tensile strength, compressive strength.

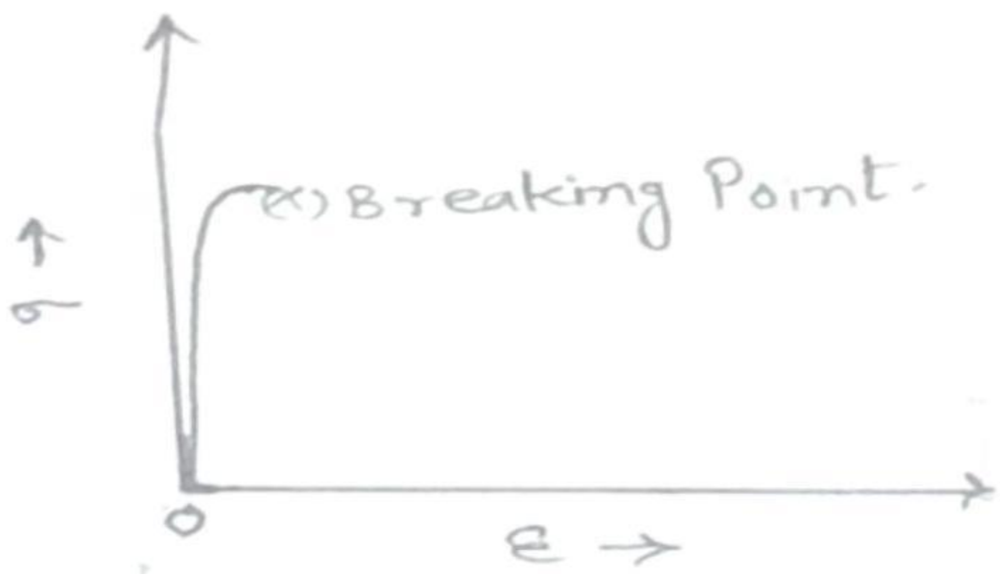
(2) Elasticity: - When a material is subjected to load, it undergoes deformation, during deformation internal forces are generated between the molecules, which oppose the external force. This properties of material oppose the external force is known as the elasticity.



(3) Plasticity: - When a material is subjected to a load, then it undergoes permanent deformation. This properties of material undergoes permanent deformation is known plasticity.



(4)Brittleness: - When load is subjected to brittle material, then brittle material dose not deform much when
loaded or very minor deformation take place. It simply breaks when subjected load reach certain limit. Brittle materials are weak in tension but strong in compression.



Difference between Ductility and Malleability [RGPV June 2014]

(5)Ductility:- [RGPV May 18, May 2019 (2 Marks)] Ductility is tensile properties. If material is pulled, it gets elongated. If magnitude of the force is increased continuously, then a material breaks. A material which undergoes for long elongation before breaking is called ductile material and this property is called ductility.

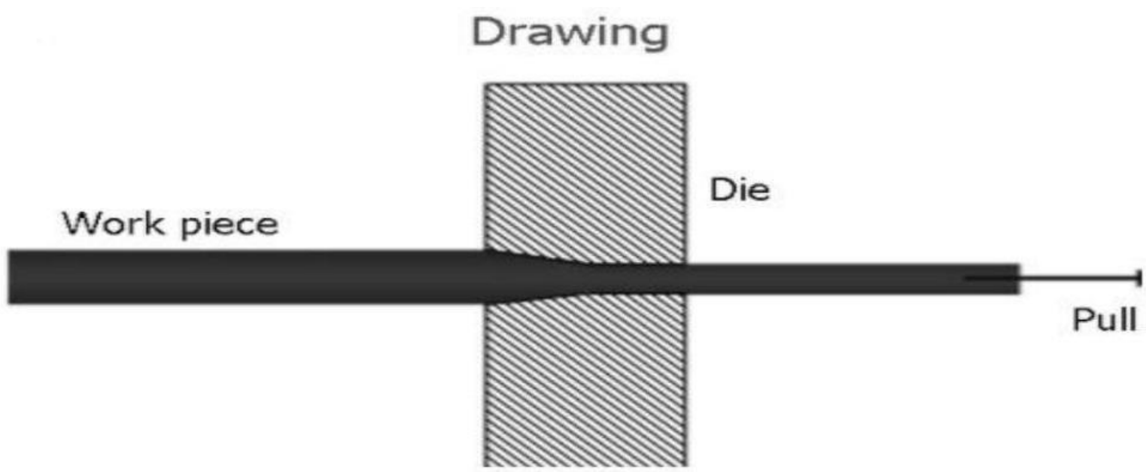


Fig: Drawing metal forming method of wire

(6)Malleability: - Malleability is compressive properties material is called malleable if it can be hammered to make thin sheet. Lead and Al have high malleability.

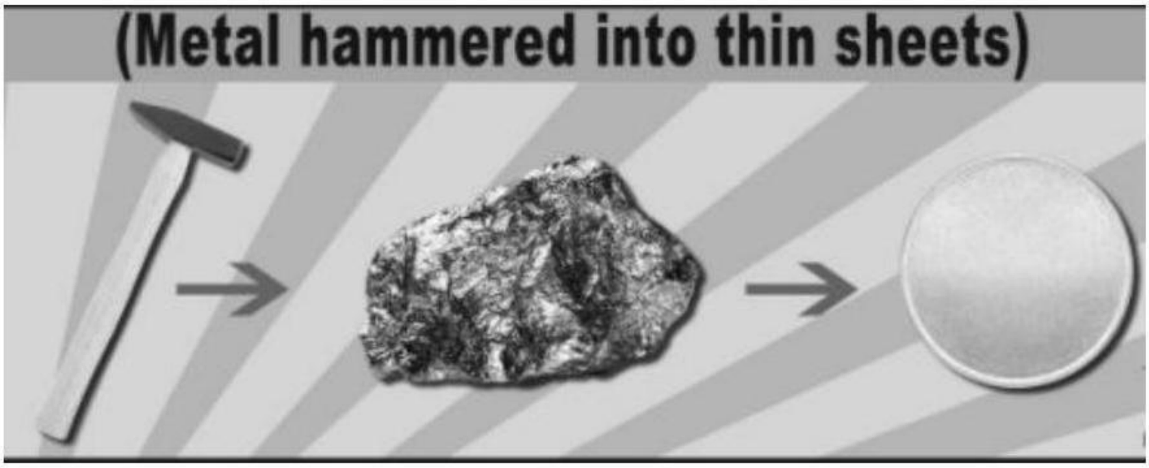
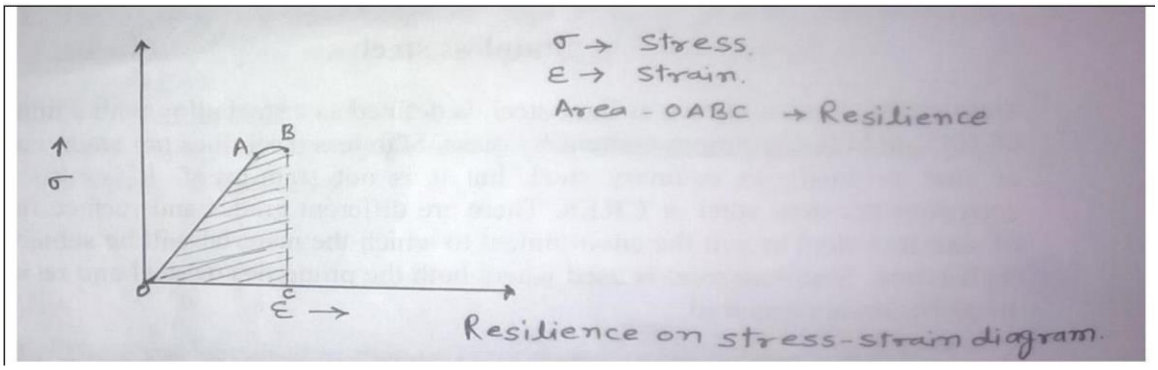


Fig: Sheet formation

(7) Resilience: - [RGPV - June 10]

This property of engineering material to absorb energy before undergoing plastic deformation. This phenomenon is known resilience.

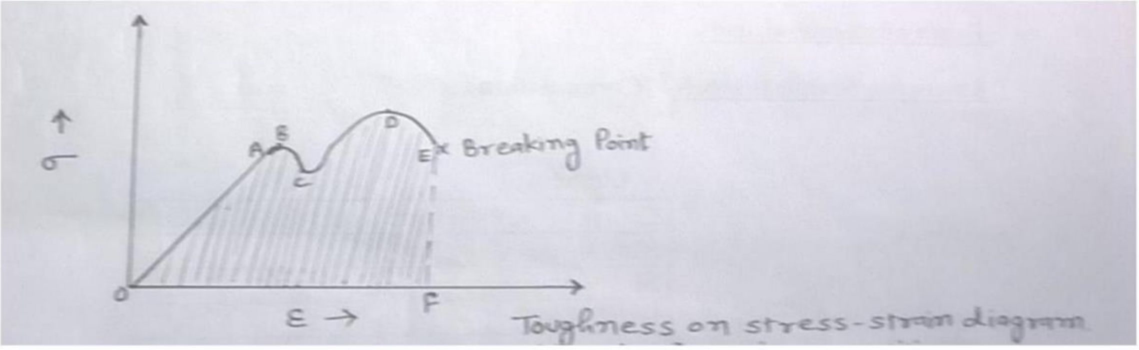
The strain energy stored in the body due to external loading within elastic limit is known as resilience, and maximum energy which can be stored in a body up to elastic limit is called proof resilience.



(7)Creep: - [RGPV - June 10]

When a material is subject for long time period at constant load, then material start slow and permanent deformation called creep.

(8)Toughness:-[RGPV May18, May 2019] When a material is subjected to load, it undergoes deformation. Toughness (tenacity) is the strength with which the material opposes rupture. It is due to the attraction which the molecules have for each other giving them power to resist tearing apart.



(9) Fatigue: - When a machine component subjected to fluctuating or repetitive or variable loading, it fails even when the applied load is very high. Such failure takes places due to fatigue.

(10) Hardness: - [RGPV May 18 ,May 2019] hardness may be defined as properties of engg. Materials which resists scratching, wear, abrasion, cutting abrasion, cutting, machining indention. High carbon steel, high speed steel and steel alloyed with titanium have high hardness.

Steel- [RGPV June 02, April 09,11 Dec 03, 07, 08 Jun 2020]

The term steel is used for many different alloys of iron. These alloys vary both in the way they are made and in the proportions of the materials added to the iron. All steels, however, contain small amounts of carbon and manganese. In other words, it can be said that steel is a crystalline alloy of iron, carbon and several other elements, which hardens above its critical temperature. Like stated above, there do exist several types of steels which are (among others) plain carbon, stainless steel, alloyed steel and tool steel.

Plain carbon steel.[RGPV May 2019 (7 marks)]

Carbon steel is by far the most widely used kind of steel. The properties of carbon steel depend primarily on the amount of carbon it contains. Most carbon steel has a carbon content of less than 1%. Carbon steel is made into a wide range of products, including structural beams, car bodies, kitchen appliances, and cans. In fact, there are 3 types of plain carbon steel and they are low carbon steel, medium carbon steel, high carbon steel, and as their names suggests all these types of plain carbon steel differs in the amount of carbon they contain. Indeed, it is good to precise that plain carbon steel is a type of steel having a maximum carbon content of 1.5% along with small percentages of silica, sulphur, phosphorus and manganese.

Types of Plain carbon steel.

Low carbon steel or mild steel, containing carbon up to 0.25% responds to heat treatment as improvement in the ductility is concerned but has no effect in respect of its strength properties.

Medium carbon steels, having carbon content ranging from 0.25 to 0.70% improves in the machinability by heat treatment. It must also be noted that this steel is especially adaptable for machining or forging and where surface hardness is desirable.

High carbon steels, is steel-containing carbon in the range of 0.70 to 1.05% and is especially classed as high carbon steel. In the fully heat-treated condition it is very hard and it will withstand high shear and wear and will thus be subjected to little deformation.

Stainless steel

Stainless steel - Stainless steel, also known as inox steel, is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass. Stainless steel does not stain, corrode, or rust as easily as ordinary steel, but it is not stain-proof. It is also called corrosion-resistant steel or CRES. There are different grades and surface finishes of stainless steel to suit the environment to which the material will be subjected in its lifetime. Stainless steel is used where both the properties of steel and resistance to corrosion are required.

Stainless steel differs from carbon steel by the amount of chromium present. Carbon steel rusts when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide. Stainless steels contain sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure.

Types of stainless steels

Austenitic Stainless steel- (Composition)

Element %		
	C	0.05 to 0.15
	Mn	2 to 10
	Si	1 to2
	Cr	16 to 26
	Ni	8 to 22
Properties		

1. These steel possess austenitic structure at room temp. because of containing Ni 2. These steels possess greatest strength and scale resistance at high temp. 3. These steel are non magnetic and possess greatest resistance to corrosion and good mechanical properties at elevated temp. 4. These steels can be easily welded. 5. These steel are very tough and can be forged and rolled offer great difficulty in machining. Uses 1. These steel are used in chemical processing, paper making and dairy industries. 2. Used in engine parts of aircrafts, trailers and railway cars etc.		
Martenstic stainless steel- (composition)		
Element %		
	C	0.03 to 0.25
	Mn	2 to 10
	Si	1 to2
	Cr	16 to 26
	Ni	3.5 to 22
Properties- 1. These steel are magnetic in all condition and possess the best thermal conductivity of stainless type. 2. These steel can be easily welded and machined. 3. These steels can be cold worked without difficulty. 4. These steels have good toughness and good corrosion resistance to weather. Uses These are used for cutlery, spring, and surgical, dental instrument.		
Ferritic stainless steels- (Composition) Element %		

C	0.08 to 0.20
Mn	1 to 1.5
Si	1

$Cr\ 11\ to\ 28$

Properties-

1. These steel are magnetic and have good ductility.
2. These steel are more corrosion resistance than martensitic steels.

3. These steels have lower strength elevated martensitic steels.
4. These steels develop their maximum softness, ductility, and corrosion resistance in annealed condition.

Uses-

These steels are mainly used as sheet for cold forming and pressing operation for the purpose where moderate corrosion resistance is required.
These steels are widely used for pump shaft, spindles and valves.

Alloying element [RGPV June08, 10,Nov 2018]

Effect of alloying element and impurities in cast iron and steel

Carbon

Normally 2 to 4% carbon is present in cast iron. The carbon presents in cast iron either as cementite (Fe3c), a very hard constituent or graphite a soft element. The percentage presence of cementite makes the cast iron brittle and hard, while presence of graphite makes the cast iron tougher and ductile.

Silicon

Its presence in the cast iron increases grayness and fluidity and ensures softer and better castings and it may be present up to 3%.

Phosphorus

It is present in cast iron up to *0.3%*. Its presence in the cast iron lower the melting point, increases fluidity, reduces shrinkage in castings. It also increases the strength of cast iron.

Sulphur

It is present in cast iron up to 0.15%.It has hardening effect in cast iron.

Manganese

It is present in cost iron up to 1%. It increases the hardness and tensile strength of cast iron.

Nickel

When nickel is added to cast iron, it promotes the graphite formation. It increases hardness, strength, and machinability and corrosion resistance.

Chromium

It is present in cast iron upto3%. Its presence with cast iron promotes the formation of carbide (cementite), a hard element of carbon. It increases wear resistance, hardness, strength, but reduces ductility.

Molybdenum

Its small presence in cast iron improves strength and wear resistance. But its large presence increases hardness and reduces the machinability.

Vanadium

It is present in cast iron up to *0.5%*. It promotes carbide formation, thus increases the hardness and strength of cast iron.

Cast iron-[RGPV June 04,07,08,11 Dec 01, 07, 08, 11]

Cast iron- Cast iron: - Basically it is alloys of iron and carbon, containing up to *2.14%* carbon are called steel, and these alloys containing carbon above *2.14%* are called cast iron.

It is obtained by melting the pig iron with coke and lime stone in furnace. Carbon in the cast iron usually exists in two forms-
(1) Graphite
(2) Carbide

Composition:-

C	Si	S	P	Mn	Fe
2.14 - 6.67	*0.5 – 1.0*	*0.06 – 0.12*	*0.10 – 0.30*	*0.10 – 1.0*	balance

PROPERTIES:-

1. Low tensile strength, but high compressive strength
2. Good hardness and wear resistance.
3. Good castability.
4. Very low ductility.

Uses:-

Machine structure, frame for electric motors, cylinder block cylinder head

Types of cast iron:-

(1) Grey cast iron
(2) White cast iron
(3) Malleable cast iron
(4) Ductile cast iron

Grey cast iron: - if iron containing carbon in the form of graphite and this graphite are softer and easily machinable known as grey cast iron. Grey cast iron is obtained by allowing the molten metal to cool and solidify slowly.

Composition:-

C	Si	S	P	Mn	Fe
2.5 – 3.75	*1.0 – 2.75*	*.06 – 0.12*	*0.10 – 1.0*	*0.4 – 1.0*	balance

Properties:-
(1) Low tensile strength
(2) It has high resistance to wear
(3) It has good machinability
(4) Grey cast iron has high fluidity
(5) Good castability

Uses: - Machine frame, automobile cylinder block gears, fly ball etc.

White cast iron: - If iron containing carbon in the form of carbide, which is hard and difficult to

Machine is known as white cast iron It is obtained by rapid cooling.

Composition:-

C	Si	S	P	Mn	Fe
1.75 – 2.30	*0.85 – 1.20*	*0.12 – 0.35*	*.005 – 0.20*	*0.10 – 1.20*	balance

Properties:-
(1) It is very hard and brittle.
(2) Good wear resistance properties.
(3) Unmachinable.
(4) Solidification range of white cast iron is 2250-2065f.

Uses: - It is use for making wrought iron, roller of rolling mills, rail road wheel, grinding wheel, agriculture application etc.

Malleable cast iron:-Malleable cast iron is obtained from white cast iron by suitable heat treatment process. Due to hardness and brittleness of grey cast iron and white cast iron is not suitable for making the component subjected to shock and impact load, for such application malleable cast iron.

Composition:-

C	Si	S	P	Mn	Fe
2.20 – 3.60	*0.40 – 1.10*	*0.03 – 0.40*	*0.10 – 0.20*	*0.10 – 0.40*	balance

Properties:-

(1) It has very good machinability and weldability.
(2) It has low thermal expansion.
(3) It has good wear resistance and vibration damping.

Uses: - for making gear, casing, automotive crank shaft, universal joint etc.

Ductile cast iron

Composition:-

C	Si	P	Mn	Fe
3.2-3.4	*1.1 – 3.5*	*0.08 – 0.1*	*0.03 – 0.07*	balance

Properties:-

(1) Good wear resistance.
(2) Good damping capacity.
(3) It has good castability
(4) High fluidity

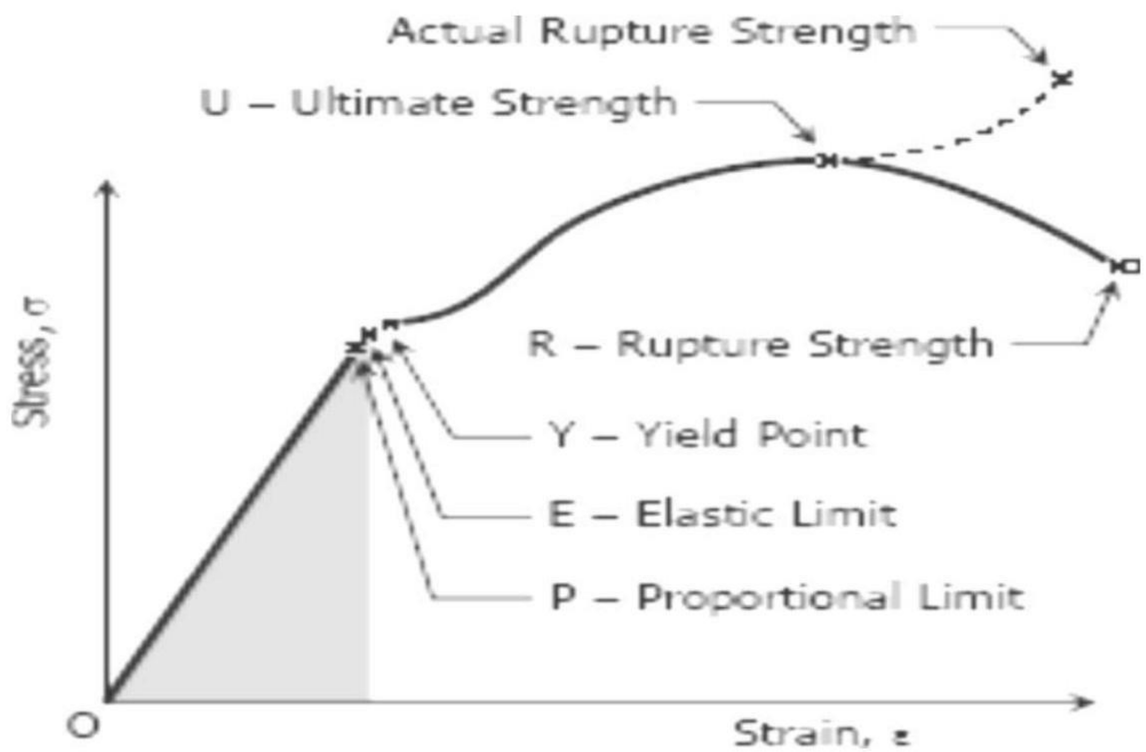
Uses: - it is use for making the crank shaft, cylinder head, press work equipment, IC engine parts, construction machinery gears etc.
The analysis of coal in which % of C, H, N, S and O elements are

Stress-Strain Diagram [RGPV - June 09, 08, 10, 11 Dec 02, , 08, 10, Nov 18 (7 Marks)]

Stress-strain diagram for mild steel

Suppose that a metal specimen be placed in tension-compression testing machine. As the axial load is gradually increased in increments, the total elongation over the gage length is measured at each increment of the load and this is continued until failure of the specimen takes place. Knowing the original cross-sectional area and length of the specimen, the normal stress σ and the strain ε can be obtained. The graph of these quantities with the stress σ along the y-axis and the strain ε along the x axis is called the stress-strain diagram. The stress-strain diagram differs in form for various materials. The diagram shown below is that for a medium carbon structural steel.

Metallic engineering materials are classified as either ductile or brittle materials. A ductile material is
one having relatively large tensile strains up to the point of rupture like structural steel and aluminum, whereas brittle materials has a relatively small strain up to the point of rupture like cast iron and concrete. An arbitrary strain of $0.05\,mm/mm$ is frequently taken as the dividing line between these two classes.



Proportional limit (Hooke's law)

From the origin O to the point called proportional limit, the stress-strain curve is a straight line. This linear relation between elongation and the axial force causing was first noticed by Sir Robert Hooke in 1678 and is called Hooke's Law that within the proportional limit, the stress is directly proportional to strain or

$$\sigma \alpha \varepsilon \;\; OR \;\; \sigma = k\varepsilon$$

The constant of proportionality k is called the Modulus of Elasticity E or Young's Modulus and is equal to the slope of the stress-strain diagram from O to P . Then

Elastic Limit

The elastic limit is the limit beyond which the material will no longer go back to its original shape when the load is removed, or it is the maximum stress that may e developed such that there is no permanent or residual deformation when the load is entirely removed.

Elastic And Plastic Ranges

The region in stress-strain diagram from O to P is called the elastic range. The region from P to R is called the plastic range.

Yield Point

Yield point is the point at which the material will have an appreciable elongation or yielding without any increase in load.

Ultimate Strength

The maximum ordinate in the stress-strain diagram is the ultimate strength or tensile strength.

Rapture Strength

Rapture strength is the strength of the material at rupture. This is also known as the breaking strength.

Iron carbon equilibrium diagram [RGPV/ Dec 08, 11, Nov 2018 (BT203) & Nov 18(BT 2003) (7 marks)]

- Iron carbon diagram indicates the phase changes that occur during heating or cooling.
- Iron carbon diagram establish the relation between the microstructure and properties of steel.

Allotropic

Iron, when cooling from a high temperature, displays two special points known as arrest points or critical points. These change points occur at $1390^{\circ}C$ and $910^{\circ}C$. Above $1390^{\circ}C$ Iron exists with a BCC
lattice but between $1390^{\circ}C$ and 910° Cit exists with a FCC lattice. Iron is said to be allotropic, which means that it can exist in two different forms depending on temperature.

Eutectic Point

- At this special change point, the liquid steel changes to the solid austenite + cementite phase without going through the pasty stage.
- This occurs at $1140^{\circ}C$ for steel when *4.3%* carbon is contained in the alloy.

Eutectoid Point

- At this special change point the solid austenite changes into solid pearlite.
- This occurs at $723^{\circ}C$ for steel when *0.83%* carbon is contained in the alloy.
- Eutectoid - solid.

Ferrite

- This is almost pure iron but contains about *0.02%* carbon.
- It has a BCC structure.

Cementite

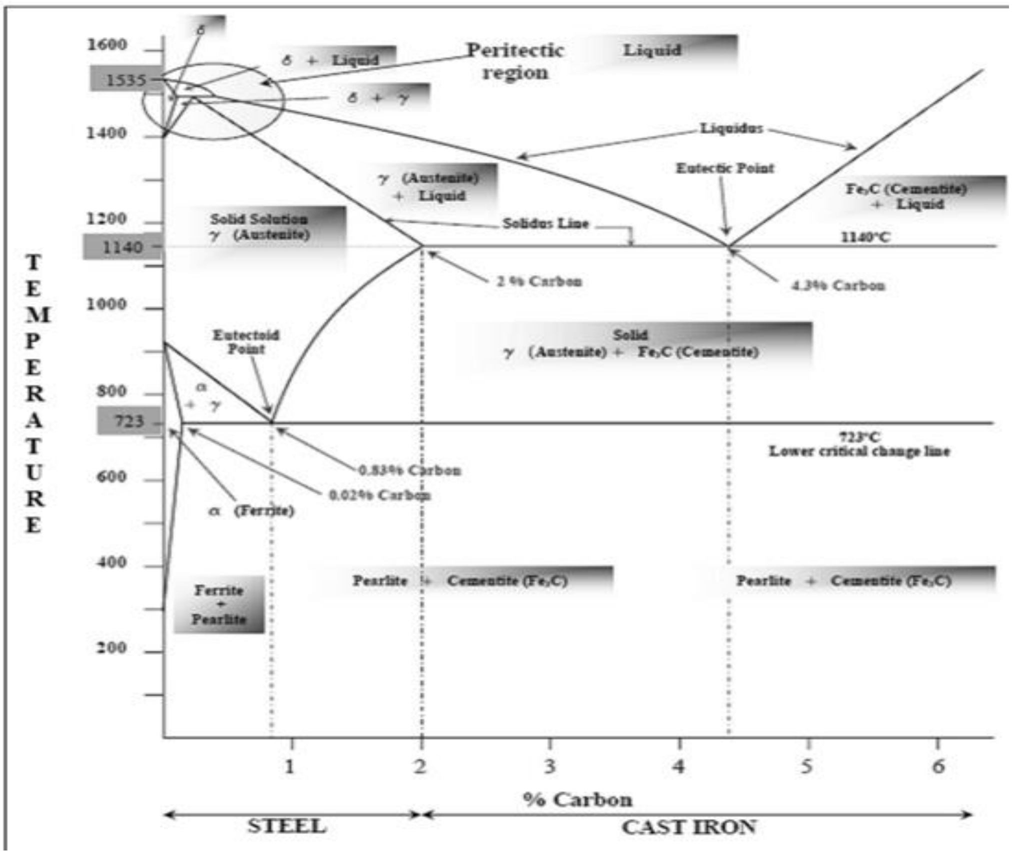
- This is a compound of iron and carbon.
- It is called Iron Carbide (Fe3C). It is a hard, brittle material.
- This is what gives the hardness to high carbon steel.
- It has a higher melting point than either of its elements

Pearlite

- At them eutectoid point (*0.83%* carbon) solid austenite changes into two solid phases - ferrite and cementite.
- These two solids combine to form pearlite.
- Pearlite is a layered structure of ferrite and cementoide.

Austenite

- This is an FCC solid solution structure which can contain up to *2%* carbon.
- It is a hard non-magnetic substance.



Testing of materials - [RGPV/Dec 10, 11)]

Testing of materials

Materials are tested for one or more of the following purpose:

(1)To calculate numerically the fundamental mechanical properties of ductility, malleability, toughness etc.

(2) To check chemical composition.

(3)To determine suitability of a material for a particular use.

(4)To determine stress-strain values for design purpose.

(5)To determine surface defects of materials.

Classification:

(A) Non - destructive tests

(B) Destructive test

Non - destructive tests: In non - destructive testing, the component does not break and even can be used after testing.

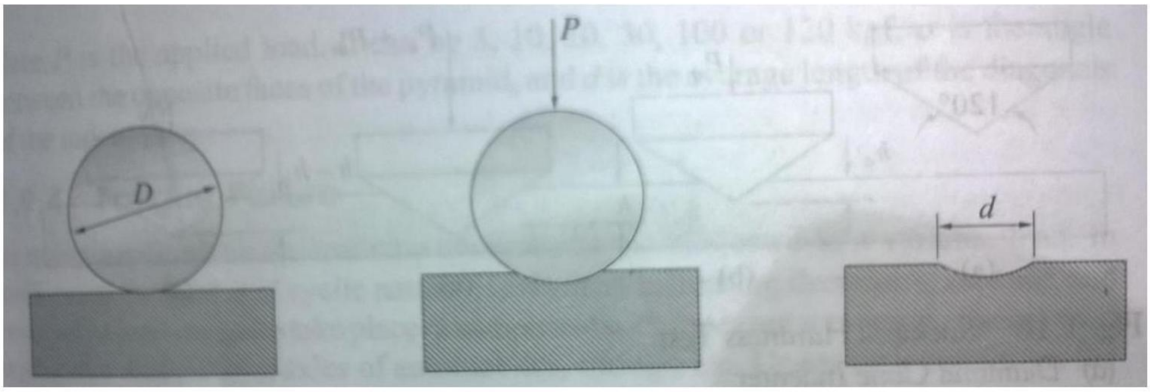
Examples. Radiography, ultrasonic inspection etc.

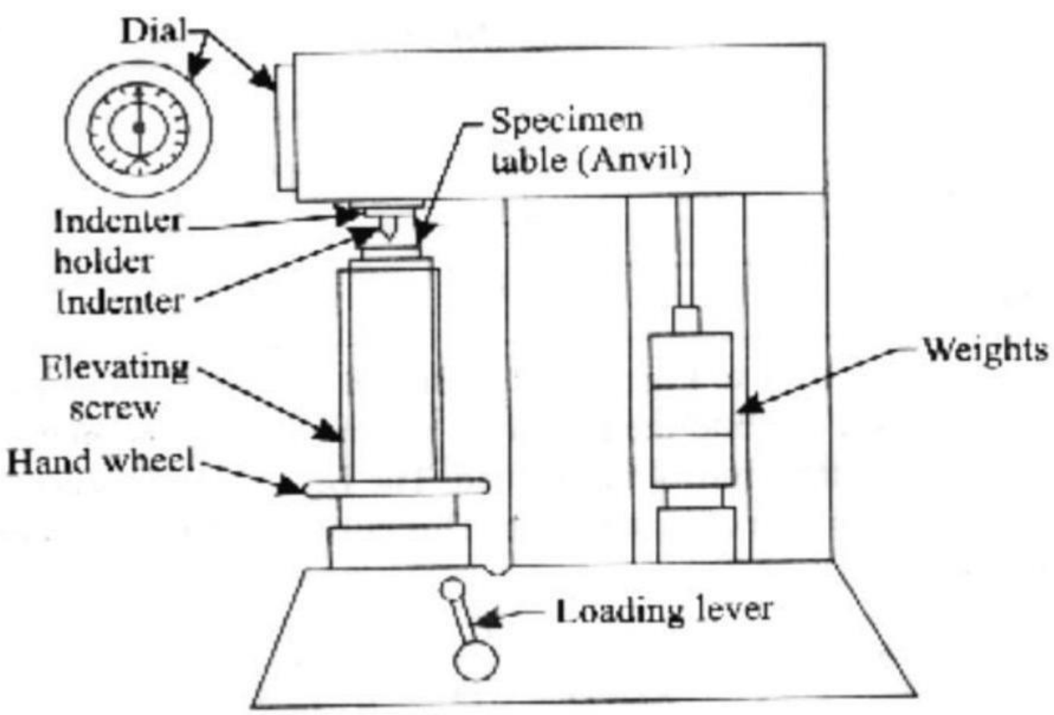
Destructive test: In destructive testing, the component either breaks or remains no longer useful for further application. Destructive test are also known as mechanical test. Examples. Tensile test, impact test, hardness test etc.

Brinell Hardness Test [RGPV Nov 2019 (7marks) Nov 2018, May 2019 (7 Marks)]

In this method, the indenter is a hard spherical ball, made of tungsten carbide. Diameter of this ball is generally 10 mm . this ball is pressed against the plane and polished surface of the materials. The applied load has a magnitude of 3000 kgf for steel and cast irons, 1000 kgf copper and its alloys, and 250 kgf for soft materials like aluminum, aluminum alloy, and babbit. The indenter creates a crater shaped impression on the materials. Geometrically this impression, or indentation, is a part of sphere .the diameter of indentation is measured. The value of hardness obtained by this method is denoted by Brinell Hardness Number. This number is determined by the formula,

$$BHN = \frac{2P}{\pi D(D - \sqrt{\ }(D^2 - d^2)}$$





Rockwell Hardness test

Theory: -

Hardness represents the resistance of material surface to abrasion, scratching and cutting, hardness after gives clear indication of strength. In all hardness tests, a define force is mechanically applied on the piece, varies in size and shape for different tests. Common indentors are made of hardened steel or diamond.

Rockwell hardness tester presents direct reading of hardness number on a dial provided with the m/c. principally this testing is similar to Brinell hardness testing. It differs only in diameter and material of the indentor and the applied force. Although there are many scales having different combinations of load and size of indentor but commonly ' C ' scale is used and hardness is presented as HRC. Here the indentor has a diamond cone at the tip and applied force is of 150 kgf . Soft materials are often tested in 'B' scale with a 1.6 mm dia. Steel indentor at 60 kgf . A hardness test can be conducted can be conducted on Brinell testing m/c, Rockwell hardness m/c or vicker testing m/c. The specimen may be a cylinder, cube, thick or thin metallic sheet. A Brinell-cum-Rocwell hardness testing m/c along with the specimen is shown in figure.

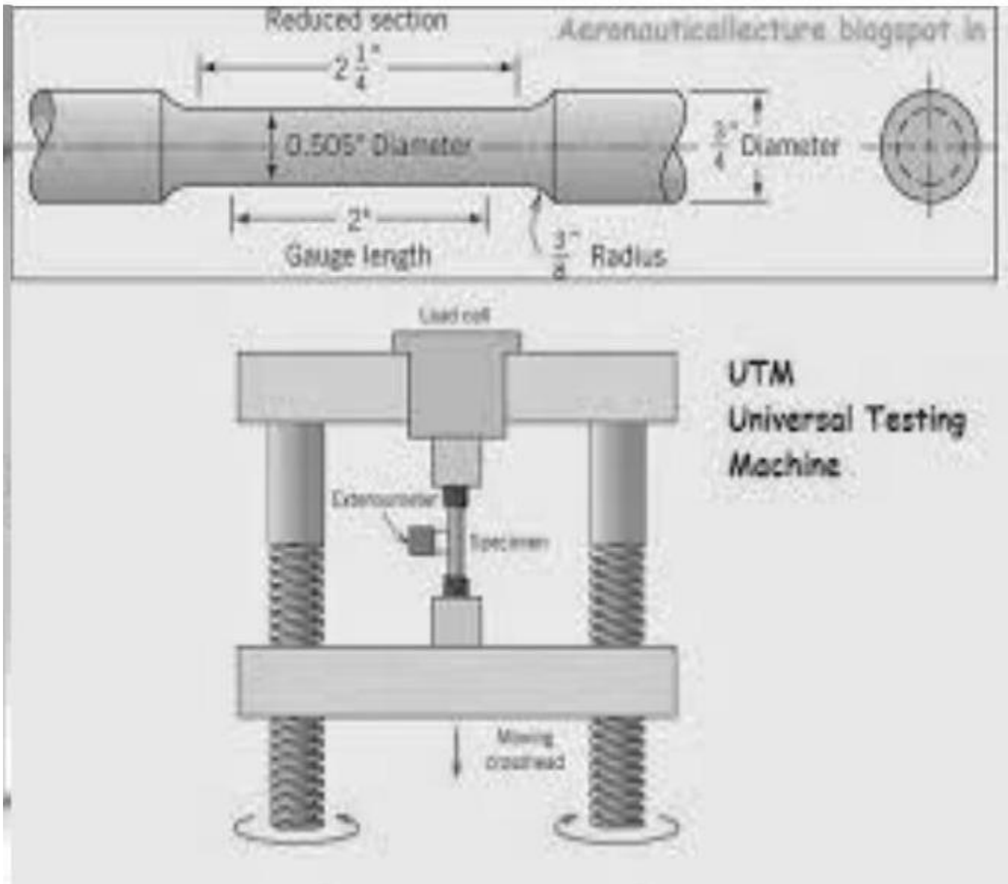
Tensile Test [RGPV May18 & 19 (7 marks)]

Theory:

Various m/c and structure components are subjected to tensile loading in numerous applications. For safe design of these components, their ultimate tensile strength and ductility one to be determine before actual use. Tensile test can be conducted on UTM. A material when subjected to a tensile load resists the applied load by developing internal resisting force. These resistances come due to atomic bonding between atoms of the material. The resisting force for unit normal cross-section area is known as stress. The value of stress in material goes on increasing with an increase in applied tensile load, but it has a certain maximum (finite) limit too. The minimum stress, at which a material fails, is called ultimate tensile strength. The end of elastic limit is indicated by the yield point (load). This can be sen during experiment as explained later in procedure with increase in loading beyond elastic limit original crosssection area goes on decreasing and finally reduces to its minimum value when the specimen breaks.

About of UTM & its specifications:

The tensile test is conducted on UTM. It hydraulically operates a pump, oil in oil sump, load dial indicator and central buttons. The left has upper, middle and lower cross heads i.e; specimen grips (or jaws). Idle cross head can be moved up and down for adjustment. The pipes connecting the lift and right parts are oil pipes through which the pumped oil under pressure flows on left parts to more the crossheads



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THANK YOU