- Malleability is defi ned as the ability of a material to deform to a greater extent before the sign of crack, when it is subjected to compressive force. The term 'malleability' comes from a word meaning 'hammer', and in a narrow sense, it means the ability to be hammered out into thin sections. Malleable metals can be rolled, forged or extruded because these processes involve shaping under compressive force. Low carbon steels, copper and aluminium are malleable metals. In general, malleability increases with temperature. Therefore, processes like forging or rolling are hot working processes where hot ingots or slabs are given a shape.

- Ductility is defi ned as the ability of a material to deform to a greater extent before the sign of crack, when it is subjected to tensile force. In other words, ductility is the permanent strain that accompanies fracture in a tension test. Ductile materials are those materials which deform plastically to a greater extent prior to fracture in a tension test. Mild steel, copper and aluminium are ductile materials. Ductile metals can be formed, drawn or bent because these processes involve shaping under tension. Ductility is a desirable property in machine components which are subjected to unanticipated overloads or impact loads. Ductility is measured in units of percentage elongation or percentage reduction in area in a tension test. The ductility of metal decreases as the temperature increases because metals become weak at increasing temperature. All ductile materials are also malleable; however, the converse is not always true. Some metals are soft but weak in tension and, therefore, tend to tear apart under tension. Both malleability as well as ductility are reduced by the presence of impurities in the metal.

- The difference between malleability and ductility is as follows:
- (i) Malleability is the ability of a material to deform under compressive force. Ductility is the ability to deform under tensile force
- (ii) Malleability increases with temperature, while ductility decreases with increasing temperature.
- (iii) All ductile materials are also malleable, but the converse is not true.
- (iv) Malleability is an important property when the component is forged, rolled or extruded.
- Ductility is desirable when the component is formed or drawn. It is also desirable when the machine component is subjected to shock loads.

- Brittleness is the property of a material which shows negligible plastic deformation before fracture takes place. Brittleness is the opposite to ductility.
- A brittle material is that which undergoes little plastic deformation prior to fracture in a tension test. Cast iron is an example of brittle material. In ductile materials, failure takes place by yielding.
- Brittle components fail by sudden fracture. A tensile strain of 5% at fracture in a tension test is considered as the dividing line between ductile and brittle materials.

- The difference between ductility and brittleness is as follows:
- (i) Ductile materials deform to a greater extent before fracture in a tension test. Brittle materials show negligible plastic deformation prior to fracture
- .(ii) Steels, copper and aluminium are ductile materials, while cast iron is brittle.
- (iii) The energy absorbed by a ductile specimen before fracture in a tension test is more, while brittle fracture is accompanied by negligible energy absorption.
- (iv) In ductile materials, failure takes place by yielding which is gradual. Brittle materials fail by sudden fracture.

Lecture Machine Design

- Hardness is defi ned as the resistance of the material to penetration or permanent deformation. It usually indicates resistance to abrasion, scratching, cutting or shaping.

- Hardness is an important property in the selection of material for parts which rub on one another such as pinion and gear, cam and follower, rail and wheel and parts of ball bearing.
- Wear resistance of these parts is improved by increasing surface hardness by case hardening. There are four primary methods of measuring hardness—Brinell hardness test, Rockwell hardness test,
- Vicker hardness test and Shore scleroscope. In the fi rst three methods, an indenter is pressed onto the surface under a specifi c force. The shape of the indenter is either a ball, pyramid or cone.
- The indenters are made of diamond, carbide or hardened steel, which are much more harder than the surface being tested. Depending upon the cross-sectional area and depth of indentation,
- hardness is expressed in the form of an empirical number like Brinell hardness number.
- In a Shore scleroscope, the height of rebound from the surface being tested indicates the hardness. Hardness test is simpler than tension test.
- It is nondestructive because a small indentation may not be detrimental to the performance of the product. Hardness of the material depends upon the resistance to plastic deformation.
- Therefore, as the hardness increases, the strength also increases.
- For certain metals like steels, empirical relationships between strength and hardness are established. For steels, Sut = 3.45 (BHN) where Sut is ultimate tensile strength in N/mm2.

- CAST IRON
- Cast iron is a generic term, which refers to a family of materials that differ widely in their mechanical properties. By defi nition, cast iron is an alloy of iron and carbon, containing more than 2% of carbon. In addition to carbon, cast iron contains other elements like silicon, manganese, sulphur and phosphorus.
- There is a basic difference between steels and cast iron. Steels usually contain less than 1% carbon while cast iron normally contains 2 to 4% carbon. Typical composition of ordinary cast iron is as follows: carbon = 3.0 – 4.0% silicon = 1.0 – 3.0% manganese = 0.5 – 1.0% sulphur = up to 0.1% phosphorus = up to 0.1% iron = remainder The mechanical properties of cast iron components are inferior to the parts, which are machined from rolled steels.
- However, even with this drawback, cast iron offers the only choice under certain conditions. From design considerations, cast iron offers the following advantages:
- (i) It is available in large quantities and is produced on a mass scale. The tooling required for the casting process is relatively simple and inexpensive. This reduces the cost of cast iron products.
- (ii) Cast iron components can be given any complex shape without involving costly machining operations.
- (iii) Cast iron has a higher compressive strength. The compressive strength of cast iron is three to fi ve times that of steel. This is an advantage in certain applications.
- (iv) Cast iron has an excellent ability to damp vibrations, which makes it an ideal choice for machine tool guides and frames.
- (v) Cast iron has more resistance to wear even under the conditions of boundary lubrication.
- (vi) The mechanical properties of cast iron parts do not change between room temperature and 350°C
- (vii) Cast iron parts have low notch sensitivity.
- Cast irons are classifi ed on the basis of distribution of carbon content in their microstructure. There are three popular types of cast iron—grey, malleable and ductile.
- Grey cast iron is formed when the carbon content in the alloy exceeds the amount that can be dissolved.

- BIS SYSTEM OF DESIGNATION OF STEELS
- A large number of varieties of steel are used for machine components. Steels are designated by a group of letters or numbers indicating any one of the following three properties: 5, 6
- (i) tensile strength
- (ii) carbon content; and
- (iii) composition of alloying elements.
- Steels, which are standardised on the basis of their tensile strength without detailed chemical composition, are specifi ed by two ways—a symbol Fe followed by the minimum tensile strength in N/mm2 or a symbol FeE followed by the yield strength in N/mm2. For example, Fe 360 indicates a steel with a minimum tensile strength of 360 N/mm2. Similarly, FeE 250 indicates a steel with a minimum yield strength of 250 N/mm2.
- The designation of plain carbon steel consists of the following three quantities:
- (i) a fi gure indicating 100 times the average percentage of carbon;
- (ii) a letter C; and
- (iii) a fi gure indicating 10 times the average percentage of manganese. As an example, 55C4 indicates a plain carbon steel with 0.55% carbon and 0.4% manganese. A steel with 0.35–0.45% carbon and 0.7–0.9% manganese is designated as 40C8. The designation of unalloyed free cutting steels consists of the following quantities:
- (i) a fi gure indicating 100 times the average percentage of carbon;
- (ii) a letter C;
- (iii) a fi gure indicating 10 times the average percentage of manganese;
- (iv) a symbol ‘S’, ‘Se’, ‘Te’ or ‘Pb’ depending upon the element that is present and which makes the steel free cutting; and
- (v) a fi gure indicating 100 times the average percentage of the above element that makes the steel free cutting.
- As an example, 25C12S14 indicates a free cutting steel with 0.25% carbon, 1.2% manganese and 0.14% sulphur. Similarly, a free cutting steel with an average of 0.20% carbon, 1.2% manganese and 0.15% lead is designated as 20C12Pb15. The term ‘alloy’ steel is used for low and medium alloy steels containing total alloying elements not exceeding 10%. The designation of alloy steels consists of the following quantities: (i) a fi gure indicating 100 times the average percentage of carbon; and (ii) chemical symbols for alloying elements each followed by the fi gure for its average percentage content multiplied by a factor. The multiplying factor depends upon the alloying element. The values of this factor are as follows: