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# Mechanical Properties of Materials: Definition, Testing and Application

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**Abstract:** *Mechanical properties of the metals are associated with the ability of the material to resist mechanical forces and load. But basically, those properties are associated with stress and strain. The mechanical properties of a material indicate how it responds under specific stresses, which helps to determine its suitability for different applications. In this paper, the definition and applications are explained in an easy way and gives the overview of the importance of such properties. Every design engineers must know how to select the apt materials for their design applications and it is necessary to understand the mechanical properties of the material to select the material for the engineering applications.*

**Keywords:** *Strength, hardness, mechanical property, toughness, elasticity, cryo-treatment.*

## 1. Introduction

The mechanical properties are those which affect the mechanical strength and ability of a material to be molded in suitable shape. Some of the typical mechanical properties show huge applications in space and automobile industries. These properties are associated with the capability of the materials to resist mechanical forces and load and they are measured in terms of the behavior of the material when subjected to a force. Mechanical properties may be determined to provide either design data for the engineer or as a check on the standard of raw materials [1]. Mechanical properties may be changed by heat treatment process and the working temperature. Mostly, the strength, toughness and hardness of materials are to be measured after the metal forming process [2]. The main objective of the paper is to give the overview of the importance of mechanical properties of the materials, testing. This paper, includes the concepts of strength, plasticity, malleability, stiffness, elasticity, brittleness, ductility, toughness, resilience, fatigue, creep and shown how improper understanding of properties can lead to have confusion. The engineering concepts of mechanical properties dominate the teaching in the technological universities over natural sciences.

## 2. Mechanical Properties Definition

### 2.1. Strength and Stress-Strain Curve

Strength of the materials refers to the ability of a material to resist the externally applied forces without breaking or yielding. The maximum stress is that any material withstands before destructive is called its ultimate strength (D). Figure 1 shows the stress and strain relationship. Stress and strain curve of the material obtained during tensile test describe its ductility and yield strength [3]. According to figure 1, upto the elastic limit, the elasticity of material, that means the material would return to its original dimension, would be maintained, over it the plasticity would follow. Once the material exceeds the ultimate stress point (D), necking starts to have on the specimen [4]. The strain hardening is kept between yield points to ultimate tensile strength. A material obeys hooks law upto proportional limit accurately. The stress and strain curve is used to obtain Young's modulus of materials by comparing stress and strain value upto elastic limit. In the figure, A-B range is measured as elastic limit. The Ability of materials to sustain loads without undue failure or distortion is known as strength and it is known that the ability of a material to provide an equal reaction to an applied force (tensile, compression, shear) without rupture. Simply, the strength is a maximum resistance by the material to the deformation. Similarly, tenacity is the ability of a material to resist rupture due to a tensile force.

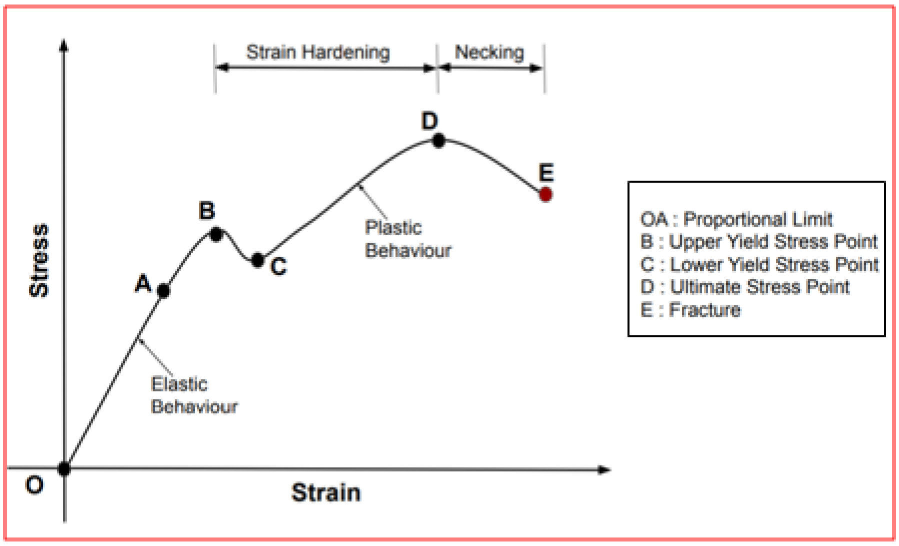


**Figure1.** *Stress- strain relationship curve*

### 2.2. Stiffness

It is the ability of a material to resist deformation under stress. Modulus of elasticity is the measure of stiffness. Material which suffers slight deformation under load has a high degree of stiffness or rigidity. Steel beam is stiffer or more rigid than aluminium beam. Finally, it means that the ability of material to resist elastic deflection is known as stiffness.

### 2.3. Elasticity

It is the property of materials to regain its original shape after deformation when the external forces are removed. Example is the extension or compression of a spring. This property is desirable for materials used in tools and machines. Steel is more elastic than rubber. Elasticity is a tensile property of the material. Proportional limit and elastic limit indicate elasticity. It is also known as Non-permanent deformation. It consists of two sub properties within this elastic region. They are proportional limit and elastic limit. Proportional limit is the maximum stress under which a material will maintain a perfectly uniform rate of strain to stress. Proportional limit applications are precision instruments, springs etc... The greatest stress that a material can endure without taking up some permanent set is called elastic limit. Beyond the elastic limit, material does not regain its original form and permanent set occurs.

### 2.4. Plasticity

It is the ability of material to undergo some degree of permanent deformation without rupture or failure [12]. That means, this is the property of a material to deform permanently under the application of a load. Plastic deformation will take place only after the elastic range has been exceeded by the process of slipping when the shear stress on the slip plane reaches a critical value. Displacement caused by slipping is permanent and the crystal planes do not return to their original positions even after the removal of the stresses. Applications are forming, shaping, extruding, hot & cold working process, forging, ornamental work, stamping, rolling, drawing, pressing, etc.. Aluminium is a good plasticity material.

### 2.5. Ductility

It is the property of a material which enables it to draw out into thin wire with the application of a tensile force. Ductile material must be both strong and plastic. Ductile materials are gold (most ductile material), mild steel, copper, aluminium, nickel, zinc, tin. Ductility usually measured by the terms, percentage elongation and percentage reduction in area. Ductility is thought of as a tensile quality. Ductile material combines the properties of plasticity and tensile strength. It is also mentioned as a capacity of a material to undergo deformation under tension without rupture or the ability of a material to withstand cold deformation without fracture. Ductility of a material is to stretch under the application of tensile load and retain the deformed shape on the removal of the load. If subjected to a shock load the material would yield and become deformed. Ductile material can be worked into a shape without loss of strength. All materials which are formed by drawing are required to be ductile, e.g.- drawing into wire form.

### 2.6. Brittleness

Breaking of a material with little permanent distortion simply states the property of brittleness. Brittle materials when subjected to tensile loads snap off without giving any sensible elongation [5]. Usually the tensile strength of brittle materials is only a fraction of their compressive strength. Examples of brittle materials are glass, bricks, cast iron etc… It is also a tendency of a material to fracture when subjected to shock loading or a blow. Material that shatters is also a brittle material.

### 2.7. Malleability

It is the ability of materials to be rolled, flattened or hammered into thin sheets without cracking by hot or cold working. Malleable material should be plastic but it is not essential to be strong and malleability is considered as a compressive quality. Examples for malleability Al, Cu, Sn, Pb, soft steel, wrought iron. This is the property of a material to deform permanently under the application of a compressive load. A material which is forged to its final shape is required to be malleable. Forging, Rolling processes are malleability.

### 2.8. Toughness and Testing

It is the ability of a material to withstand bending without fracture due to high impact loads. Toughness of material decreases when it is heated [16]. It is also measured by the amount of energy that a unit volume of the material has absorbed after being stressed up to failure point and is the area under stress strain curve. For example, if a load is suddenly applied to a piece of mild steel and then to a piece of glass, the mild steel will absorb much more energy before failure occurs. Thus mild steel is said to be much tougher than a glass. This property is desirable in parts subjected to shock and impact loads. *Notch toughness* is the measure of the metal’s resistance to brittle fracture in presence of flaw or notch and fast loading conditions [17]. Examples are Mn-steel, wrought iron, MS, etc…it can be also defined as property of absorbing energy before fracture. To the opposite of brittleness, the ability of a material is to resist fracture under shock loading. Basically, two main impact tests for measuring the toughness of material in Joule are available namely Izod and Charpy test. Figure 2 shows the three types of Notches used for fracture study. U type notch specimens can also be used for testing. In case of ductile materials, when the material is stressed, it plastically deforms by absorbing high energy and then the material fractures. But in the case of brittle materials, the cohesive strength of the material exceeds before getting plastically deformed and hence absorbs less energy before getting fractured. There are factors responsible for brittle behaviour; they are notch, low temperature, thickness and microstructure. When temperature falling, the failure mode of certain materials changes from ductile to brittle. For FCC materials, if the temperature increases, the energy absorbed also slightly increases. The factors responsible for the Charpy impact test are ductility, yield strength, notch, temperature, and fracture mechanism. Figure 3, shows the working procedure of impact testing. The pivoting arm is raised to a specific height, which is the potential energy and then this arm gets released. The arm swings down hitting a notched sample, available on the specimen holding vise, and breaking the specimen. The energy absorbed by the sample is measured from the height the arm swings to after hitting the sample. The fracture energy (Joule) is determined from the swing-up angle of the hammer and its swing-down angle. A notched sample is generally used to determine impact energy and notch sensitivity. Some of the standards are followed worldwide for the test they are ASTM D6110, ASTM E23, and ASTM D256 etc..., Figure 4 depicts the difference between Izod and Charpy test. In Charpy test (figure 4 a), a test specimen having a V-shaped notch (figure 5) is placed on the holder in such position that the notched section is in the center of the holder and the specimen is broken by striking the back of the notched section with the hammer. The Charpy impact value ($kJ/m^2$) is calculated by dividing the fracture energy by the cross-section area of the specimen. If a test specimen having a V-shaped notch is fixed vertically, and the specimen is broken by striking it from the same side as that of the notch by the use of the hammer, this is called Izod test (figure 4 b). The Izod impact energy value (J/m,) is calculated by dividing the fracture energy by the width of the specimen.

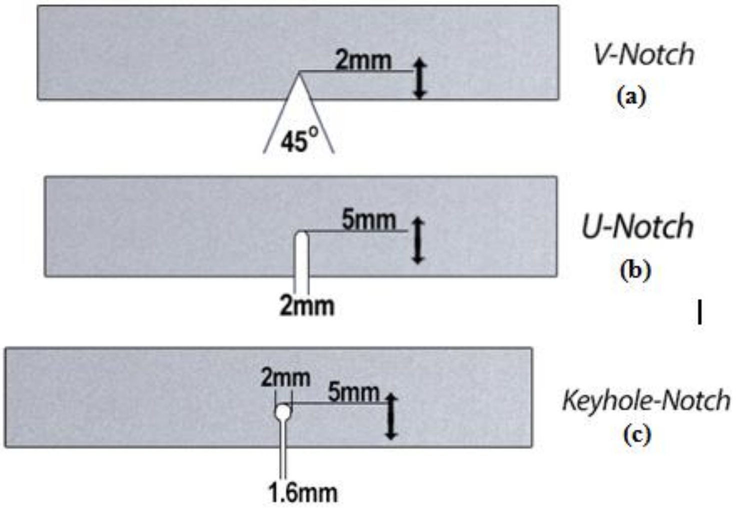


**Figure2.** *Different types of Notches (a, b, c)*

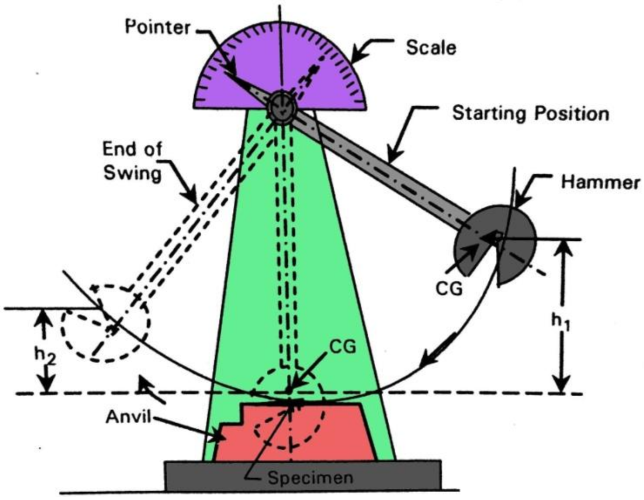


**Figure3.** *Working principle of impact testing*

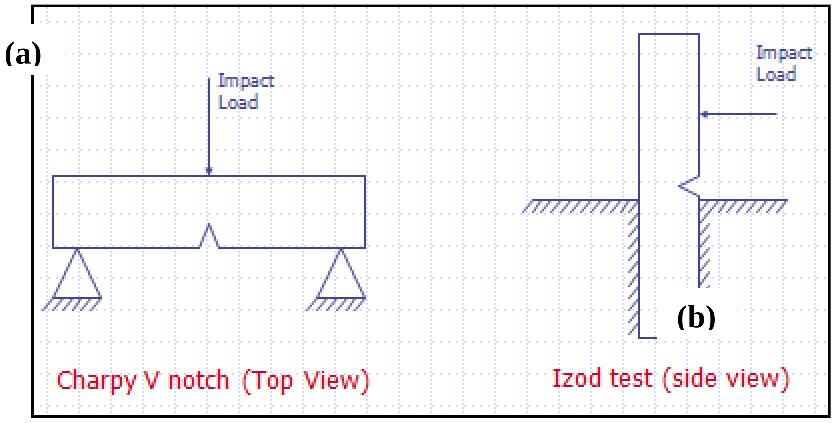


**Figure4.** *Impact loading and specimen difference for Charpy and Izod impact test*

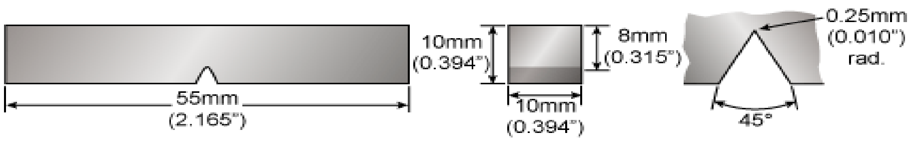


**Figure5.** *Standard specimen for Charpy V-notch test*

## 2.9. Resilience

The property of a material to absorb energy and to resist shock and impact loads are known as resilience. Generally, it is mentioned by the amount of energy absorbed per unit volume within elastic limit. This is essential for spring materials. Two kind of resilience are available. *Proof resilience:* Maximum energy which can be stored in a body up to elastic limit is called the proof resilience. But the Proof resilience per unit volume is called *modulus of resilience.*

### 2.10. 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. Property is considered in designing IC engines, boilers, turbines. Simplest type of creep deformation- viscous flow Plastics, rubber and amorphous materials are very temperature sensitive to creep. Stress for a specified rate of strain at a constant temperature is called creep strength. When a material sustains steady loads for long periods of time, the material may continue to deform until they may tend to fracture under the same load. This is called creep. If a load is applied and left on the sample for months or years, the sample will slowly extend. In metals with high melting temperatures, creep becomes a problem at higher temperatures. e.g.- gas turbines that operate at the highest temperature. ASTM E139 is the standard specimen test procedure for creep strength. Creep and Stress Rupture Testing are designed to analyze the amount of stress a material can safely withstand until failure and elongation. These are important indications for products in the aerospace, automotive, power generation, medical, oil & gas and many other industries. The three stages of classical creep curve is shown in figure 6. The primary Creep starts at a rapid rate and slows with time. But the secondary creep has a relatively uniform rate. While in the third stage, in the Tertiary Creep, creep rate has been accelerated and terminates when the material breaks or ruptures. It is associated with both necking and formation of grain boundary voids.

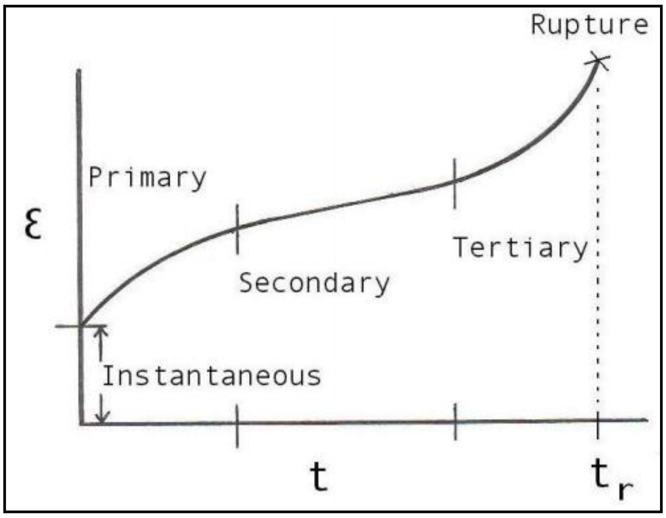


**Figure6.** *Classical Creep Curve*

### 2.11. Fatigue

It is a failure of materials under cyclic loads. When a part is subjected to a repeated or fluctuating stresses, the fracture takes place under a stress whose maximum value is less than the tensile strength of the material. For instance, the components of high speed aero and turbine engine are of this type. This is the property of a material to withstand continuously varying and alternating loads. If a part is loaded once to a stress near the yield stress, it will not break. However, if it is loaded repeatedly to this level, it will eventually break. This failure is called fatigue. Fatigue is an important goal in the design of moving machinery [18]. Basically three stages of fatigue processes are i) Initial fatigue damage which leads to crack nucleation and crack initiation. Stage ii) Progressive cyclic growth of a crack, this is the crack propagation stage, until the remaining un-cracked cross section of a part becomes too weak to withstand the loads applied. iii) Final stage is the sudden fracture.

### 2.12. Hardness

Property of a material to resist penetration by another material is known as hardness. It embraces many different properties such as resistance to wear, scratching, deformation etc.. Hardness of materials can be meant like resistance to abrasion, deformation or indentation. There are many hardness measurement methods available namely, Moh's scale, Vicker's hardness, Rockwell hardness, Knoop test, and Brinell hardness. Usually, hardness of material is measured by the depth or area of an indentation left by an indenter with a specific force applied for a specific time [19]. Three kind of forces for hardness measurement available, with that force it is classified as macro hardness (force >30 N), small hardness (force 3-30 N) and micro hardness (<0.5N). In, Brinell hardness test (BHN), an iron ball of tempered steel or carbide steel with a known diameter is pressed vertically with a test force 'F' on the testing surface of specimen [19, 20]. Test force is exerted during a defined time called dwell time. Brinell hardness (figure 7 a) is calculated by the pressure diameter and the test force. The Brinell hardness measurement is used for the soft metals and medium hard metals. In Vickers hardness test (HV), indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136° between opposite faces subjected to a load of different kgf for 10 to 15 seconds. After removal of the load, two diagonals of the indentation left (figure 7 b) on the surface of material are measured using a microscope and their average is calculated. Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation. Knoop Hardness Test employed on miniature material feature that cannot be put on test by other methods. It uses a testing load of 1 Kg or less. Just like the Brinell hardness test, the Knoop is performed by applying force to an indenter in a rhombus-shape over a period of time. Meticulous measurement of the impression is done, and is employed alongside test load for calculation of value on the scale. Rockwell Hardness test consists of indenting the test material with a diamond cone or hardened steel ball indenter. The standard for this test is ASTM E18. For B, C, A (hard and very hard materials) and N versions (for thin walls) a diamond ball is used. For B and F version or T (for thin walls) steel ball is used. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number. The abbreviations used for Rockwell hardness measurement are HRC, HRA, HR30N, etc.. The ASTM standards for hardness test are Brinell (ASTM E10), Knoop (ASTM E92, ASTM E384) and Vickers (ASTM E92, ASTM E384).

Brinell hardness (BHN) calculation is given in equation 1, 2

$$BHN = \frac{\text{Load on ball}}{\text{Area of indentation}} \tag{1}$$

$$BHN = \frac{2P}{nD\,(D-(D^2-d^2)^{0.5})} \tag{2}$$

*where, P- Applied load (kgf), D- Diameter of the indentor ball (mm), d- Diameter of the impression (mm)*

Moh's scale of hardness measurement is given in table 1. The measurement can be calculated by the element and the acting of load as shown in table 1. Diamond is the hardest material; it can be penetrated or cut by another diamond.

**Table1.** *Moh's scale of Hardness (Scale value in number)*

| Scale | Element | Applying load for penetration |
|---|---|---|
| 1 | Talc | Can be crushed by a finger nail |
| 2 | Gypsum | Scratched by a finger nail |
| 3 | Calcite | By a bronze coin |
| 4 | Fluorite | By glass |
| 5 | Apatite | By penknife |
| 6 | Orthoclase | By Quartz |
| 7 | Quartz | By Hard steel file |
| 8 | Topaz | By Corundum |
| 9 | Corundum | By Diamond |
| 10 | Diamond | Only by diamond |

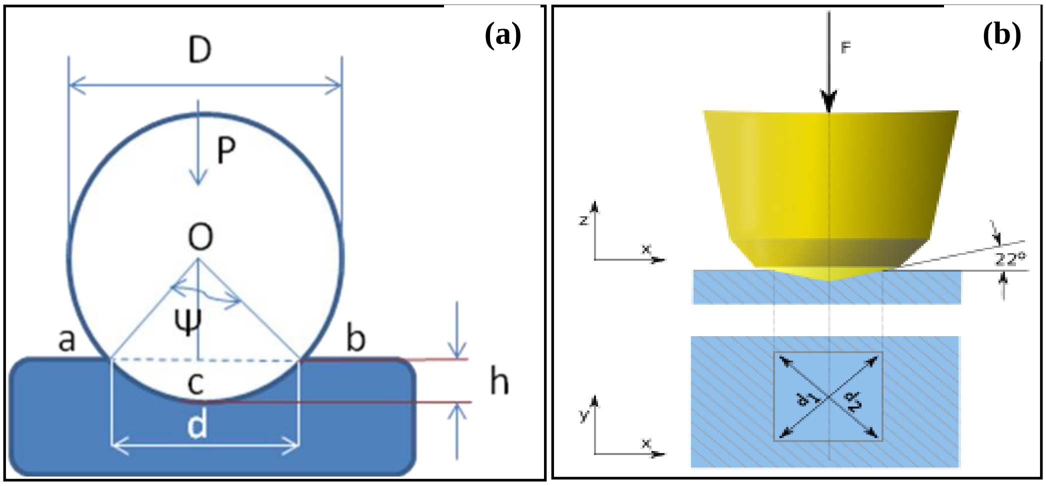


**Figure7.** *Hardness measurement principle (a- Brinell, b- Vicker)*

### 2.13. Machinability

Machinability is defined as the 'ease' with which a material can be machined such as drill, lathe work, cutting etc…. Machinability of metal is indicated by percentage (%) that is known as machinability index [15]. Standard metal used for the 100% machinability rating is the free-cutting steel. Materials with good machinability may be cut with relatively little power and low cost. Alloys containing more than 10% Si are the most difficult to machine because hard particles of free silicon cause rapid tool wear. Machinability can be improved by cold working. ASTM E618, while developed primarily to evaluate the machinability of steels, appears to be equally applicable to non-ferrous alloys [21]. Table 2 shows the machinability of different materials, the American Iron and Steel Institute (AISI) tested machinability and compared the values with B1112 [22].

**Table2.** *Machinability index for various materials*

| Sl no. | Material | Machinability index |
|---|---|---|
| 1. | SS | 25 |
| 2. | Al | 300-1500 |
| 3. | Copper | 70 |
| 4. | Mg alloy | 600-2000 |
| 5. | C 45 steel | 60 |
| 6. | C 20 steel | 65 |
| 7. | Brass | 180 |
| 8. | Cast iron | 70 |
| 9. | Al 6063, 6061 | 190 |

## 3. APPLICATIONS OF MECHANICAL PROPERTIES

The mechanical properties of materials are fundamentally important in terms of materials science [6]. Every mechanical property has specific applications in designing components in manufacturing industries [7, 14], automobile, forging, power plant, aerospace etc…Some of the applications and its properties are given in table 3.

**Table3.** *Properties and applications*

| Sl.no. | Properties | Applications |
|---|---|---|
| 1 | Proportional limit | Precision instruments, springs |
| 2 | Plasticity | forming, forging, shaping, extruding, hot & cold working, ornamental work, stamping, rolling, drawing, pressing |
| 3 | Elasticity | Desirable for materials used in tools and machines. |
| 4 | Malleability | rolling, hammering |
| 5 | Toughness | Desirable for shock & impact loads. |
| 6 | Resilience | springs |
| 7 | Creep | in designing IC engines, boilers, turbines |
| 8 | Hardness | resistance to wear, scratching, deformation |
| 9 | Fatigue | high speed aero and turbine engine |

## 4. METALS /ALLOYS AND THEIR PROPERTIES

Figure 8 list out the materials and their useful properties for industrial applications. In this table the data are given in descending order regarding their property susceptibility. In ductility point of view, gold has maximum value and lead has least value.

| TOUGHNESS | BRITTLENESS | DUCTILITY | MALLEABILITY | CORROSION RESISTANCE |
|---|---|---|---|---|
| Copper | White Cast Iron | Gold | Gold | Gold |
| Nickel | Gray Cast Iron | Silver | Silver | Platinum |
| Iron | Hardened Steel | Platinum | Aluminum | Silver |
| Magnesium | Bismuth | Iron | Copper | Mercury |
| Zinc | Manganese | Nickel | Tin | Copper |
| Aluminum | Bronzes | Copper | Lead | Lead |
| Lead | Aluminum | Aluminum | Zinc | Tin |
| Tin | Brass | Tungsten | Iron | Nickel |
| Cobalt | Structural Steels | Zinc | | Iron |
| Bismuth | Zinc | Tin | | Zinc |
| | Monel | Lead | | Magnesium |
| | Tin | | | Aluminum |
| | Copper | | | |
| | Iron | | | |

* Metals/alloys are ranked in descending order of having the property named in the column heading

**Figure8.** *Metals and alloys comparison on properties*

## 5. MECHANICAL PROPERTIES AND APPLICATIONS OF CAST IRON

The strongest structural component in cast iron is Pearlite, its ultimate tensile strength (UTS) is 640 MPa, similarly for ferrite is 400 MPa at 2% Si and for Cementite is 20 Mpa, Pearlite refining is a method to increase the strength of cast iron. Graphite in cast iron has strong effect on the principle properties of cast iron especially on the strength and ductility [9]. Graphite inclusions act as stress concentrators. Graphite in cast iron decreases the UTS, yield strength, ductility, elongation, elastic modulus, impact strength. Alloying elements Al, C, Si, Ti, Ni, Cu, P are favorable for graphitization. Alloying elements such as S, Cr, V, Mg, Mn, inhibit the process. Silicon favors graphitization by lowering the solubility of carbon in liquid and the solid solution lowers $C^{e} = 4.26 - 0.3$ Si, $C^{eq} = C + 0.3$ Si. Increase of the $C^{eq}$ value increases the concentration of graphite and decreases the Pearlite. Decrease of the concentrations of carbon, silicon raise the cast iron strength by decreasing the ferrite, and diminishes the graphite inclusion. Content of C, Si can be lowered only to a definite limit beyond which free Cementite appear and decrease the mechanical properties, increase the hardness and worsen the metal workability. Mn & S inhibits graphitization in cast iron, 1.5% Mn positive effect on the mechanical properties of cast iron. Increasing concentration of Phosphorous first improves the mechanical properties and then, in high concentrations decreases the strength due to the formation of the Phosphide. Compacted graphite iron (CG) with ferritic matrix exhibits good impact property of 33J. But the impact energy of the pearlitic CG iron is lower than ferritic [10]. Table 4 shows the physical properties of cast iron [23].

**Table4.** *Properties of Cast iron*

| Sl. no | Properties | value |
|---|---|---|
| 1 | Melting point, °C | 1150-1300 |
| 2 | Brinell hardness | 149-241 |
| 3 | Tensile strength , $N/mm^2$ | 190-420 |
| 4 | Density, $g/cm^3$ | 7.25 |
| 5 | Youngs modulus E , $N/mm^2$ | $1x10^5$ |
| 6 | Modulus of rigidity, $N/mm^2$ | $0.35x10^5$ |
| 7 | Thermal conductivity, K cal/s cm °C | 0.130 |
| 8 | Coefficient of linear expansion, µm/m°C | 9.0 |
| 9 | Poisson’s ratio | 0.23 |
| 10 | Charpy impact Joule | 40 (max) |

### 5.1. Applications of Cast Iron (CI)

The cast iron widely popular in engineering machine manufacturing. The CI is classified into 5 different categories. The applications of CI types are given in table 5.

**Table5.** *Cast iron types and their applications*

| # | Cast iron type | Applications |
|---|---|---|
| 1 | Gray cast iron | It is to resist wear even when lubrication supply is limited (e.g. upper cylinder wall in engine blocks). It is used for making engine blocks, manifolds, cylinder heads, gear blanks, gas burners, etc… |
| 2 | White cast iron | It is used to make mill linings, shot-blasting nozzles, railroad brake shoes, slurry pump housings, rolling mill rolls, crushers, slurry pump housings. |
| 3 | Ductile iron applications | It can be used to make steering knuckles, plow shares, crankshafts, heavy duty gears, automotive and truck suspension components, hydraulic components, and automobile door hinges. |
| 4 | Malleable iron applications | Different grades of malleable iron correspond to different microcrystalline structures. Specific attributes that make malleable iron attractive are its ability to retain and store lubricants, the non-abrasive wear particles, and the porous surface which traps other abrasive debris. Malleable iron is used for heavy duty bearing surfaces, chains, sprockets, connecting rods, drive train and axle components, railroad rolling stock, and farm and construction machinery. Malleable iron is used for heavy-duty bearing surfaces such as drive train and axle components. |
| 5 | Compacted graphite iron applications | Compacted graphite iron is beginning to make its presence known in commercial applications. The combination of the properties of gray iron and white iron create a high strength and high thermal conductivity product—suitable for diesel engine blocks and frames, cylinder liners, brake discs for trains, exhaust manifolds, and gear plates in high pressure pumps. |

## 6. TECHNOLOGY FOR IMPROVING THE MECHANICAL PROPERTIES OF MATERIALS [24]

LPSC (Bang) and IISc, Bangalore, India developed a facility for studying the effects of Cryo-treatment on the dimensional stability of diaphragms of pressure sensors. Experiments consisted of subjecting the samples to low temperatures (upto 98 K) for prolonged periods. They studied the hardness, tensile strength, residual stress & material crystal structure, before and after the cryo treatment on the samples. Whenever material is subjected to manufacturing operations like melting, forming, machining etc.. It undergoes stress. As the level of stress increases, the density of defects increases, cracks develop in materials and failure takes place. For space scientists this could spell disaster. Hence the need for developing technologies that helps improve stability. The technology is gaining respect as a technique for increasing the durability and dimensional stability of materials and helped significantly improve wear-resistance of materials through cryogenic treatment.

## 7. MECHANICAL PROPERTIES OF MATERIALS [25]

The properties of materials can be compared among them to understand the need of engineers for developing machine components. Table 6 compares the properties of metals.

**Table6.** *Mechanical properties value comparison*

| Material | Elastic Modulus (GPa) | Shear Modulus (GPa) | Poisson's Ratio |
|---|---|---|---|
| Aluminum | 70 | 26 | 0.33 |
| Aluminum Alloy | 70 - 79 | 26 - 30 | 0.33 |
| Brass | 96 - 110 | 36 - 41 | 0.34 |
| Bronze | 96 - 120 | 36 - 44 | 0.34 |
| Ceramic | 300 - 400 | - | - |
| Concrete | 18 - 30 | - | 0.1 - 0.2 |
| Copper | 110 - 120 | 40 - 47 | 0.33 - 0.36 |
| Copper Alloy | 120 | 47 | - |
| Iron (Cast) | 83 - 170 | 32 - 69 | 0.2 - 0.3 |
| Iron (Wrought) | 190 | 75 | 0.3 |
| Magnesium Alloy | 45 | 17 | 0.35 |
| Nickel | 210 | 80 | 0.31 |
| Nylon; Polyamide | 2.1 - 2.8 | - | 0.4 |
| Steel | 190 - 210 | 75 - 80 | 0.27 - 0.3 |
| Tin | 42 | - | 0.36 |
| Titanium | 110 | 40 - 40 | 0.33 |

## 8. Conclusion

This paper discusses the different classifications of mechanical properties and their application with their testing procedure. It is mandatory to know them to convert the concept design into a product in an industry since the success of the material selection is completely depending on how an engineer selects a material for their designing products. The new technology developed in India for property improvement is also quoted here. The mechanical properties of CI and their applications are also given here. The standards for the various mechanical testing are also given here. Titanic ship drowning into sea is also due to one of the reasons of materials properties failure. In the development of new materials, we need to learn a lot more from what exists in nature.

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