Chapter One: Properties and Testing of Metals

1.1 PROPERTIES OF METALS

The important properties of an engineering material determine the utility of the material which influences quantitatively or qualitatively the response of a given material to imposed stimuli and constraints. The various engineering material properties are given as under.

1. Physical properties
2. Chemical properties
3. Thermal properties
4. Electrical properties
5. Magnetic properties
6. Optical properties
7. Mechanical properties

1.1.1 Physical Properties

The important physical properties of the metals are density, color, size, and shape (dimensions), specific gravity, porosity, luster etc.

1.1.2 Chemical Properties

The study of chemical properties of materials is necessary because most of the engineering materials, when they meet other substances with which they can react, suffer from chemical deterioration of the surface of the metal. Some of the chemical properties of the metals are corrosion resistance, chemical composition and acidity or alkalinity.

1.1.3 Thermal Properties

The study of thermal properties is essential to know the response of metal to thermal changes i.e., lowering or raising of temperature. Different thermal properties are thermal conductivity, thermal expansion, specific heat, melting point, thermal diffusivity.

1.1.4 Electrical Properties

The various electrical properties of materials are conductivity, temperature coefficient of resistance, dielectric strength, resistivity, and thermoelectricity.

1.1.5 Magnetic Properties

Magnetic properties of materials arise from the spin of the electrons and the orbital motion of electrons around the atomic nuclei. Many materials except ferromagnetic material which can form permanent magnet, exhibit magnetic affects only when subjected to an external electro-magnetic field.

1.1.6 Optical Properties

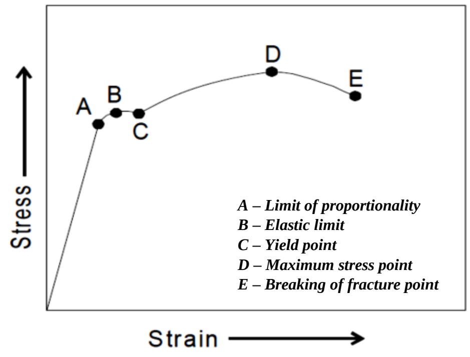
The main optical properties of engineering materials are refractive index, absorptivity, absorption co-efficient, reflectivity and transmissivity.

1.1.7 Mechanical Properties

The mechanical properties of materials are of great industrial importance in the design of tools, machines, and structures

1. **Elasticity**
   It is defined as the property of a material to regain its original shape after deformation when the external forces are removed. It can also be referred as the power of material to come back to its original position after deformation when the stress or load is removed.

2. **Proportional limit**
   It is defined as the maximum stress under which a material will maintain a perfectly uniform rate of strain to stress.



3. **Elastic limit**
   Many metals can be put under stress slightly above the proportional limit without taking a permanent set. The greatest stress that a material can endure without taking up some permanent set is called elastic limit.
4. **Yield point**
   At a specific stress, ductile metals particularly cease, resisting tensile forces. This means, the metals flow and a relatively large permanent set takes place without a noticeable increase in load. This point is called yield point.

5. **Strength**

   Strength is defined as the ability of a material to resist the externally applied forces with breakdown or yielding. This property of material therefore determines the ability to withstand stress without failure. Strength varies according to the type of loading. It is always possible to assess tensile, compressive, shearing, and torsional strengths. The maximum stress that any material can withstand before destruction is called its ultimate strength.

6. **Stiffness**

   It is defined as the ability of a material to resist deformation under stress. The resistance of a material to elastic deformation or deflection is called stiffness or rigidity.

7. **Plasticity**

   Plasticity is defined the mechanical property of a material which retains the deformation produced under load permanently. This property of the material is required in forging, in stamping images on coins and in ornamental work. Plastic deformation takes place only after the elastic range of material has been exceeded.

8. **Ductility**

   Ductility is termed as the property of a material enabling it to be drawn into wire with the application of tensile load. A ductile material must be strong and plastic. The ductility is usually measured by the terms, percentage elongation and percent reduction in area which is often used as empirical measures of ductility.

9. **Brittleness**

   Brittleness is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. The materials having less than 5% elongation under loading behavior are said to be brittle materials. Brittle materials when subjected to tensile loads, snap off without giving any sensible elongation. Glass, cast iron, brass and ceramics are considered as brittle material.

10. **Hardness**

    Hardness is defined as the ability of a metal to cut another metal. A harder metal can always cut or put impression to the softer metals by virtue of its *hardness. It is a very important property of the metals and has a wide variety of meanings.*

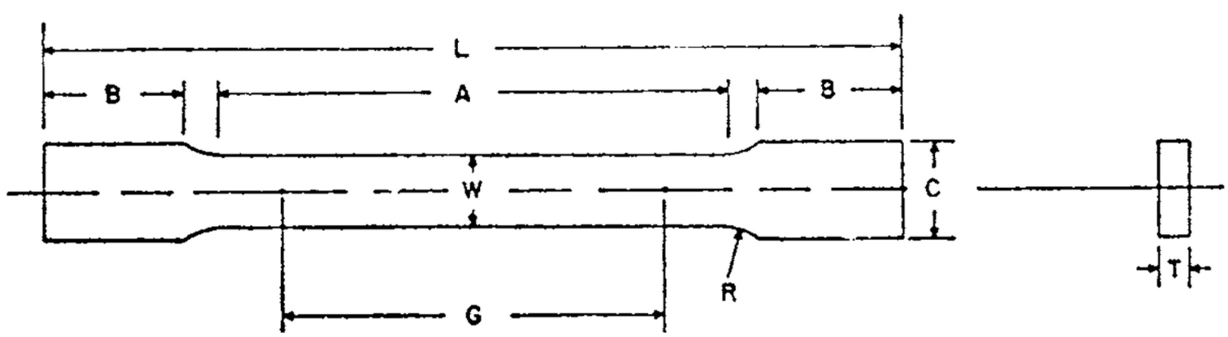
1.2 Destructive and Non-Destructive Tests

The purpose of metal testing is estimating the behavior of metal under loading (tensile, compressive, shear, torsion and impact, cyclic loading etc.). Also, it is very important that the material shall be tested so that their mechanical properties especially their strength can be assessed and compared.

- Destructive tests of metal include various mechanical tests such as tensile, compressive, hardness, impact, fatigue, and creep testing.
- Non-destructive testing includes visual examination, radiographic tests, ultrasound test, liquid penetrating test and magnetic particle testing.

1.2.1 Tensile test

A tensile test is carried out on standard tensile test specimen in universal testing machine. A standard test specimen for tensile test is shown in Fig. 1.1 according to ASTM E8/E8M standard while Fig. 1.2 shows a schematic set up of universal testing machine reflecting the test specimen griped between two cross heads. Fig. 1.3 shows the stress strain curve for ductile material. Fig. 1.4 shows the properties of a ductile material.



Tensile Test Plate Specimen [ASTM E8/E8M]	
Item	mm
G—Gauge length	200
W—Width	40
T—Thickness	-
R—Radius of fillet, min	25

L—Overall length, min	450
A—Length of reduced section, min	225
B—Length of grip section, min	75
C—Width of grip section, approximate	50

Fig. 1.1 Tensile test specimen

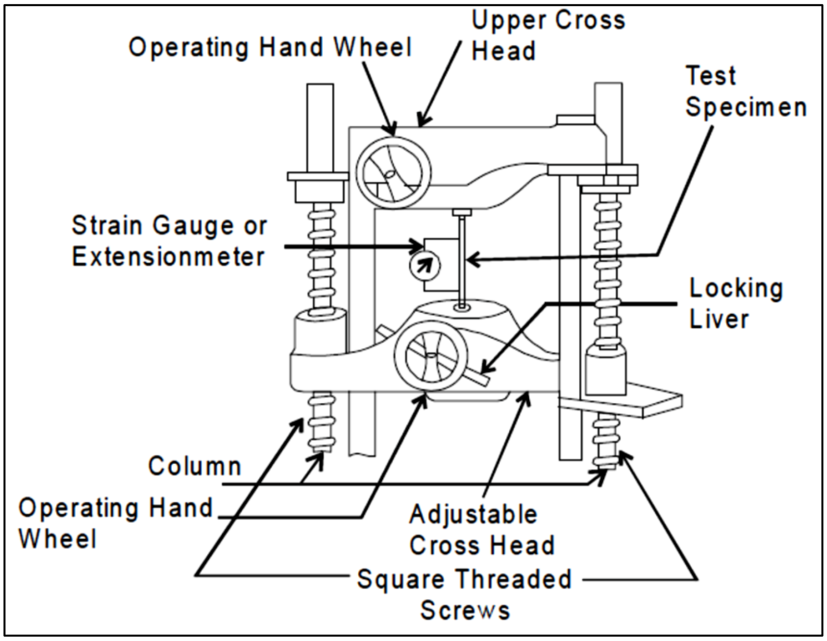


Fig. 1.2 Stress strain curve for ductile material

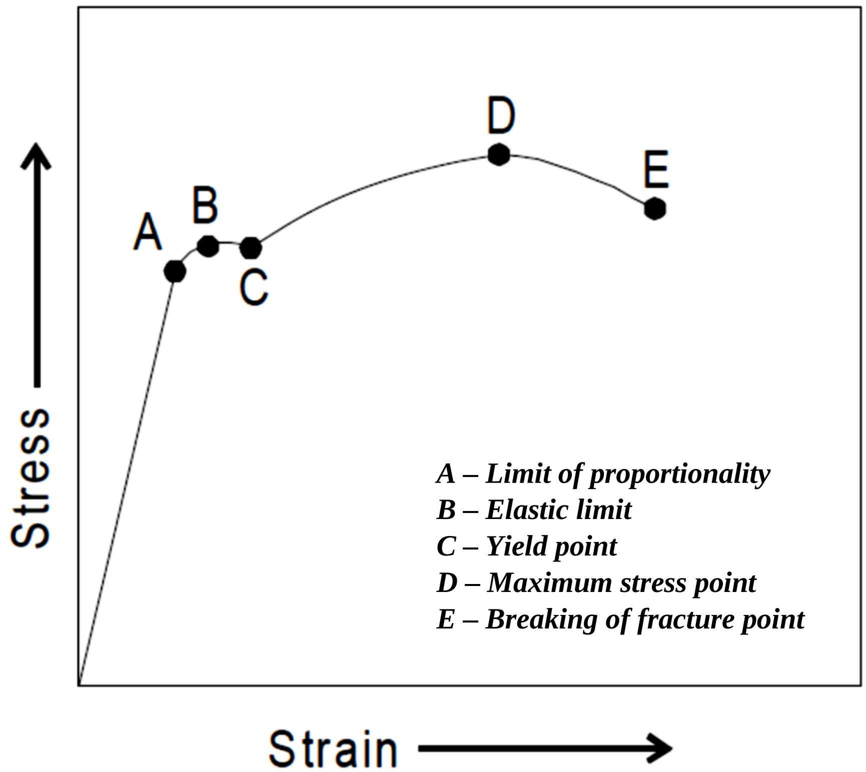


Fig. 1.3 Stress strain curve for ductile material

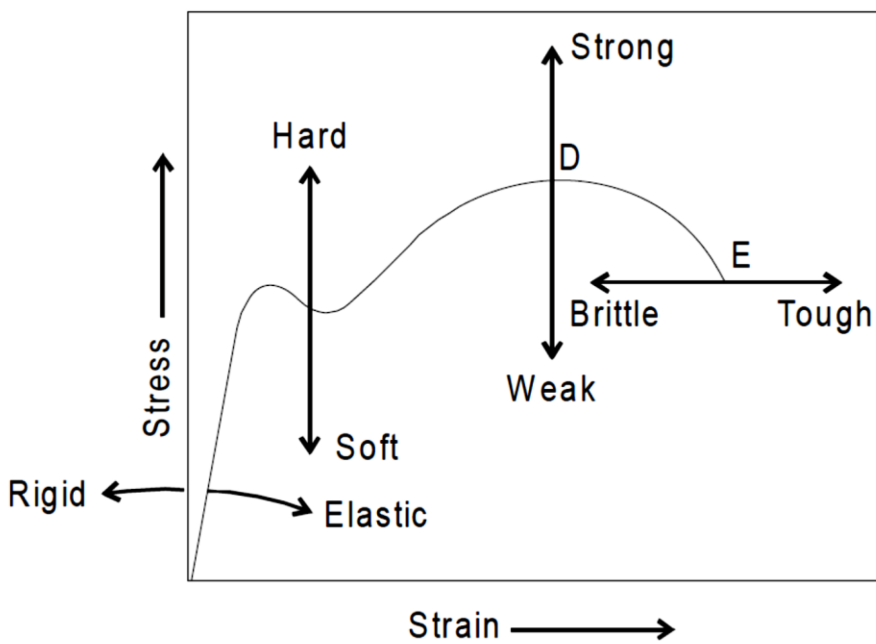


Fig. 1.4 Properties of a ductile material

Tensile Strain: The ratio of increase in length to the original length.
The stress can be calculated by two formulae which are distinguished as engineering stress and true stress, respectively.

Engineering Stress $\sigma = P/A_o$

P = load (N)
A_o = original cross-sectional area (m^2)

True Stress $\sigma_T = P/A_i$

P = load (N)
A_i = instantaneous cross-sectional area (m2)

Strain: is the ratio of change in dimension to the original dimension.

Engineering Strain $\varepsilon = (l_f - l_o)/ l_o = \Delta l / l_o$

l_f = final gage length (m)
l_o = original gage length (m)

True Strain $\varepsilon T = \ln (l_i / l_o) = \ln (1 + \varepsilon)$

l_i = instantaneous gage length (m)
l_o = original gage length (m)
ln = natural logarithm

Hook's Law: states that when a material is loaded within elastic limit (up to proportional limit), stress is proportional to strain.
Compressive Strain: The ratio of decrease in length to the original length.
Modulus of Elasticity: The ratio of tensile stress to tensile strain or compressive stress to compressive strain. It is denoted by E. It is also called as Young's modulus of elasticity.

E = Tensile Stress/Tensile Strain

Modulus of Rigidity: The ratio of sheer stress to shear strain. It is denoted by G.

G = Shear Stress/Shear Strain

YouTube: **https://youtu.be/Lg0JnsNyON8**