Introduction to Strength of Materials:

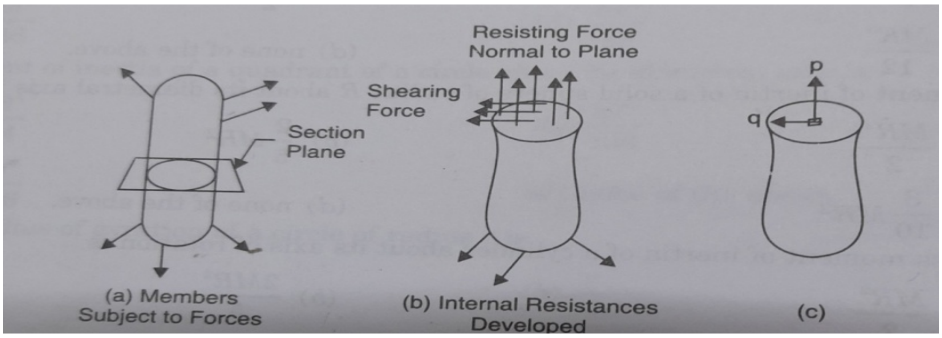
Before going to start we must keep in mind that our intention to study this topic for those body are of deformable in nature. Which means under the action of external load or force there will be appreciable deformation. Bodies are of deformable in nature, rather than the concept of rigid body , which in case of Engineering Mechanics we considered. In this chapter the formal definition of stress is explained. The expression for stress and strain are derived with the following assumptions.

1. For the range of forces applied the material is elastic i.e. it can regain it's original shape and size, if the applied force is withdrawn.
2. Material is homogeneous i.e. every particle of the material possesses identical mechanical properties.
3. Material is isotropic in nature, i.e. the material possess identical mechanical property at any point in any direction.

   Presenting the typical stress-strain curve for a typical Mild steel(MS), the commonly referred terms like limits of elasticity and proportionality, yield points, ultimate strength and strain hardening are explained.

   Concept of Stress:

   When a member is subjected to loads it develops resisting forces. To find the resisting forces developed a section plane may be passed through the member and equilibrium of any one part may be considered. Each part is in equilibrium under the action of applied forces and internal resisting forces. The resisting forces may be conveniently split into normal and parallel to the section plane. The resisting force parallel to the plane is called shearing resistance. The intensity of resisting force normal to the sectional plane is called intensity of normal stress.(Ref fig 1(b))



<u>Figure-1</u>

In practice, intensity of stress is called as "stress" only. And expressed as mathematically

Normal Stress $= p = \lim_{\Delta A \to 0} = \frac{\Delta R}{\Delta A}$

$= p = \frac{dR}{dA}$ … … … … … … … … … [1]

Where R is normal resisting force.

Intensity of resisting force parallel to the sectional plane is called shearing stress(q).

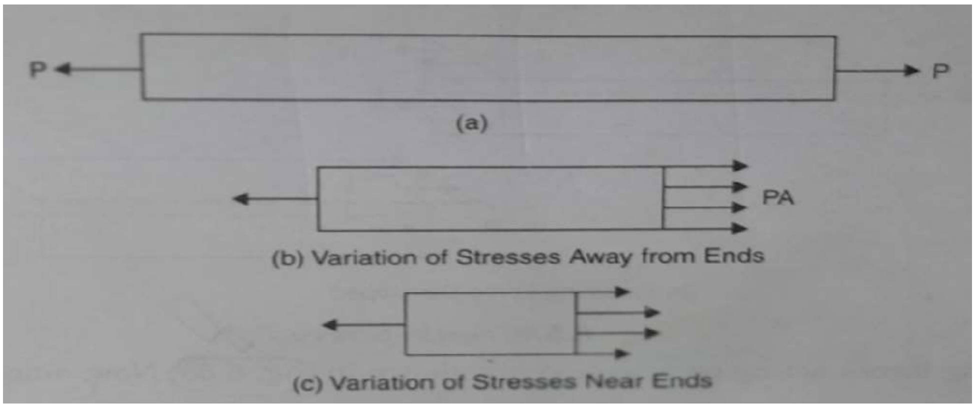
$$Shearing\ Stress = q = \lim_{\Delta A \to 0} \frac{\Delta Q}{\Delta A} = \frac{dQ}{dA} \dots \dots \dots \dots \dots [2]$$

Thus, stress at any point may be defined as resistance developed per unit area. From eqn[1] and eqn[2] it follows that $dR = pdA$

$$R = \int pdA \dots \dots \dots \dots [3a]$$

$$and\ Q = \int qdA \dots \dots . [3b]$$

At any cross-section, stress developed may or may not be uniform. In a bar of uniform cross-section subjected to axial concentrated loads as shown in fig 2(a), the stress is uniform at a section away from the



applied loads(2(b)); but there is variation of stress at the section near applied loads (2c).

Figure-2

Axial Stress :

Let us consider a bar of rectangular cross-section is subjected to force P as per figure -3 . To maintain the equilibrium the force applied at the endfaces must be same, say P.

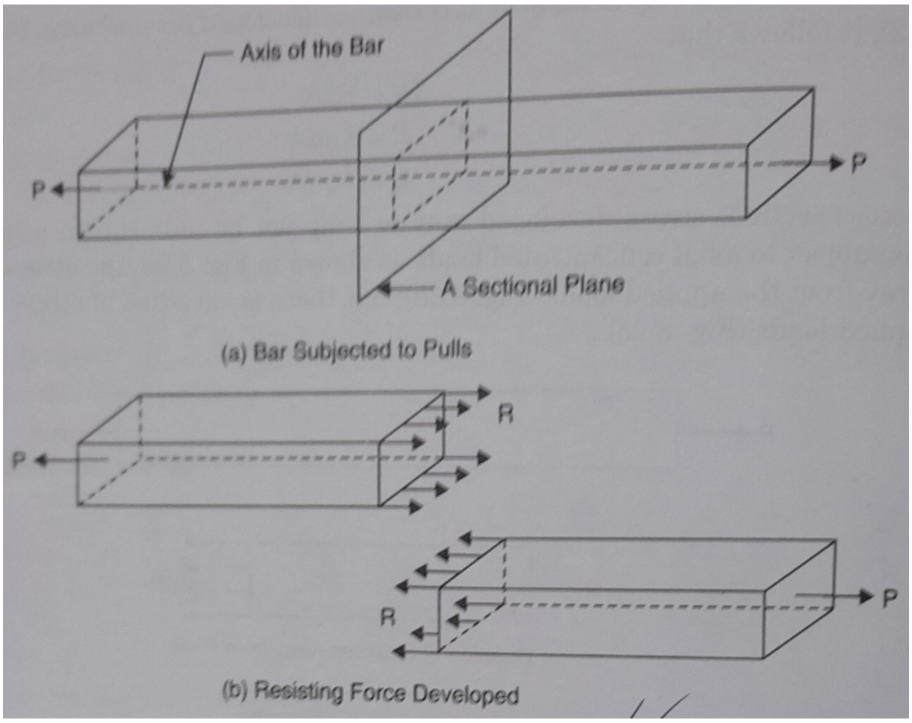


Figure-3

The resisting force acting on a section are shown in figure-3(b). Now, Science the stress are uniform .

$$R = \int pdA = p\int dA = pA \ldots\ldots [4]$$

Where A is the cross sectional area. Considering equilibrium of cut piece of the bar, we get $P = R \ldots\ldots\ldots.. [5]$

From eqn [4] & [5] we get

$P = pA$ or $p = \frac{P}{A} \ldots\ldots\ldots [6]$

Thus, in case of axial load P the stress developed is equal to the load per unit area. Under this type of normal stress the bar is being extended. Such stress which is causing extension of the bar is called tensile stress.

A bar subjected to equal forces pushing the bar is shown in fig-4 it causes shortening of the bar. Such forces which are causing shortening, are known as compressive forces and corresponding stress as compressive stresses.

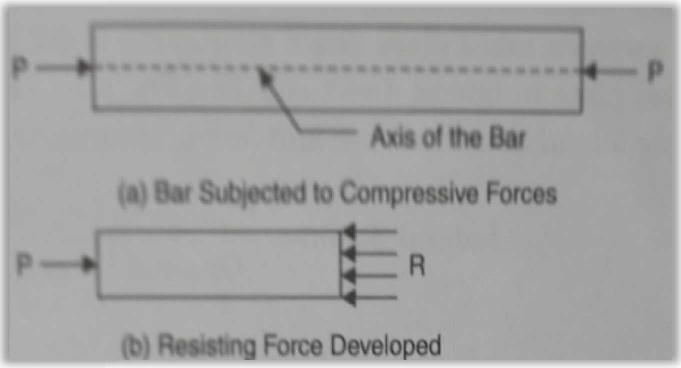


Figure-4

Now, $R = \int pdA = p \int dA$ $(As\ stress\ assumed\ uniform)$

For equilibrium of the piece of the bar $P = R = pA$

Or, $p = \frac{P}{A}$ $as\ in\ equation$ ... [6]

Thus, Whether it is tensile or compressive, the stress developed in a bar subjected to axial forces, is equal to load per unit area.

The studies have shown that the bars extend under tensile force and shorten under compressive forces as shown in fig-5. The change in length per unit length is known as linear strain. Thus,

$$Linear\ Strain = \frac{Change\ in\ Length}{Original\ Length}$$

$$e = \frac{\Delta}{L} \ldots [7]$$

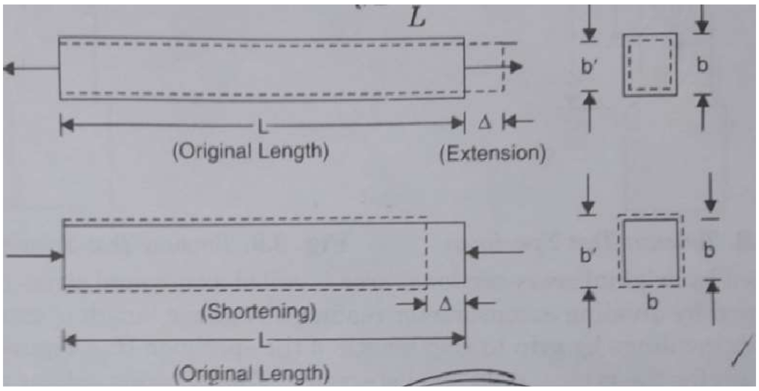


Figure-5

When changes in longitudinal direction is taking place changes in lateral direction also takes place. The nature of these changes in lateral direction are exactly opposite to that of changes in longitudinal direction i.e , if extension is taking place in longitudinal direction, the shortening of lateral dimension takes place and if shortening is takes place in lateral directions (as per figure-5). The lateral strain may be defined as changes in the lateral dimension per unit lateral dimension.

Thus,

$$Lateral\ Strain = \frac{Change\ in\ Lateral\ Dimension}{Original\ Lateral\ Dimension}$$

$$= \frac{b' - b}{b} = \frac{\delta b}{b} \dots\dots [8]$$

Stress-Strain Relation:

The stress-strain relation of any engineering material is obtained by conducting tensile testing in the laboratories on standard specimen. Different materials behaves differently and their behavior in tension and in compression differ slightly.

Behaviour in Tension :

Mild Steel[] [figure-6]shows a typical tensile test specimen of mild steel. It's end are gripped into universal testing machine. Extensometer []is fitted to test specimen which measures extension over the length L_1,(shown in figure-6). The length over which extension is measured is called gauge length. The load is applied gradually and at regular interval of loads and extension is measured . It is observed that after certain load, extension increases at faster rate and capacity of extensometer to measure extension comes to at an end, and hence, it is removed before this stage is reached and extension is measured from the scale on the universal testing machine[As shown in Figure-13]. Further load is increased gradually till the specimen breaks.

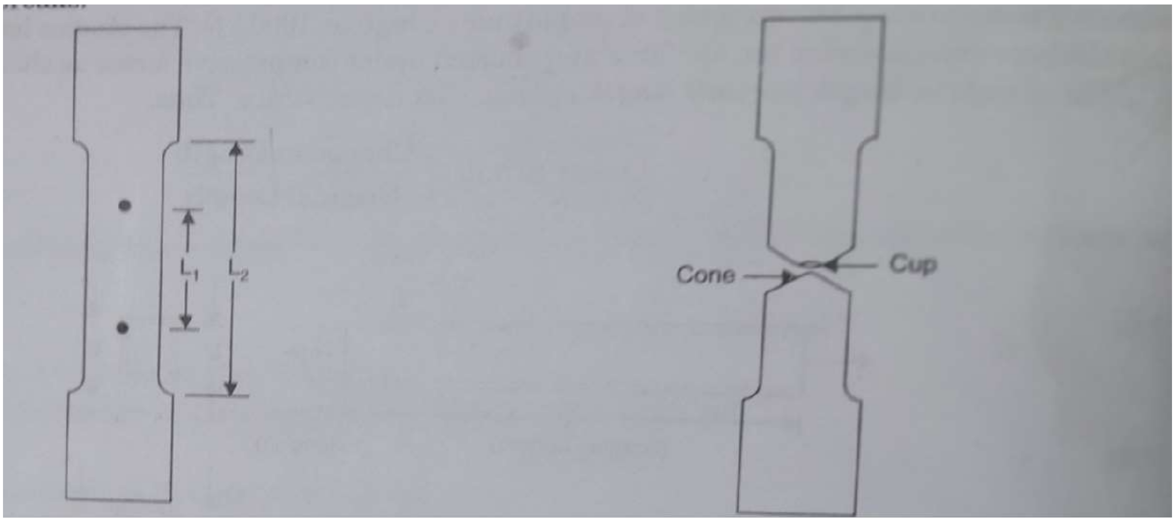


Figure-6 and Figure-7

Load divided by original cross-sectional area is called as nominal stress or simply as stress. Strain is obtained by dividing extensometer readings by gauge length(L1).

In investigation of mechanical properties of materials the relation between stress and corresponding strain is usually represented graphically by stress-strain diagram obtained experimentally from a standard tensile test[]. A typical stress-strain diagram for Mild steel (MS)[] is plotted from experimental data,(as shown in figure-8a)where the axial strain are plotted as abscissa and the corresponding stress is given by ordinates of the curve OABCDE. From O to A the stress is proportional to the strain. Beyond A, the deviation from Hook's law becomes marked; hence the stress at A represents the proportional limit. This is usually found to lie some where in between 206 N/mm^2 and 248 N/mm^2(30000psi and 36000 psi) for a low carbon steel. Upon loading of the specimen beyond the proportional limit, the elongation incase more rapidly and the diagram becomes nonlinear. At B, elongation of the specimen begins to take place without any appreciable increase in load and the material is said to be become plastic. This phenomena called yielding, continues until the test bar may stretch up to the proportional limit. The stress at which this yielding begins is called the yield point of the steel. This behavior results from the slip associated with the appearance of Lueder Lines[will be discussed later on] . This indicates that the phenomena of yielding is really an indirect manifestation of failure of the material in shear plane along 45⁰ (with the longitudinal axis of specimen) planes of maximum shear stress. At point C, the material begins to strain harden[], recovers some of it's elastic property, and with further elongation the stress-strain curve climbs to point D, representing the maximum tensile stress or the ultimate strength. Beyond point D, further stretching of the bar is accompanied by a decrease in the load and fracture takes place suddenly at a point E. The fact that the nominal stress at E is less than the ultimate strength at D is somewhat misleading. As failure develops between D and E, the test bar gradually necks down in short region somewhere along it's length as shown in figure in figure-9 . This phenomena again is the result of shear slip along 45⁰ - planes which causes a pronounced decrease in the cross sectional area at the narrowest part of the neck. If for each value of the strain between C and E, the tensile load P is divided by the reduced cross sectional area, it will be found that the true stress-strain curve will follow the dotted line CE'. However, it is established practice to calculate the ultimate strength on the basis of the original or nominal cross sectional area A of the specimen without regard to the reduction of area. Structural steel is the only material that exhibits a pronounced yield point. Other materials show a more or less gradual transition from the linear to the nonlinear range, and even the proportional limit is rather indefinite. As an example of the tensile behavior of a brittle material, a stress-strain diagrams for cast- iron[] Is shown in figure-11. This material has a very low proportional limit and shows no yield point.

Stress-strain diagrams for axial compression of various materials can also be obtained and such characteristic stresses as the proportional limit, yield point, and ultimate strength can be found. In the case of steel this characteristics for compression are found to have the same values as for tension.

Working Stress or Allowable Stress or Design Stress:

A tensile stress diagram gives valuable information on the mechanical properties of a material. Knowing the limit of proportionality, the yield point, and the ultimate strength of material, it is possible to establish for each particular engineering problem the magnitude of the stress which may be considered a safe stress. This stress is usually called the working stress.

In choosing the magnitude of the working stress for steel it must be taken into consideration that at stresses below the proportional limit the material may be considered as perfectly elastic, and beyond this limit a part of the strain usually remains after unloading the bar ,i.e., permanent set occurs. In order to have the structure in an elastic condition and to remove the possibility of a permanent set, it is usual practice to keep the working stress well below the proportional limit. In the experimental determination of this limit, sensitive measuring instruments(extensometers) are necessary and the position of the limit depends to some extent upon the accuracy with which the measurements are made. In order to eliminate this difficulty, one usually takes the yield point or the ultimate strength of the material as a basis for determining the magnitude of the working stress. Denoting p_w, $p_{y.p}$, p_{ult} respectively the working stress , the yield point, and the ultimate strength of material, the magnitude of the working stress will be determined by one of the two following equations:

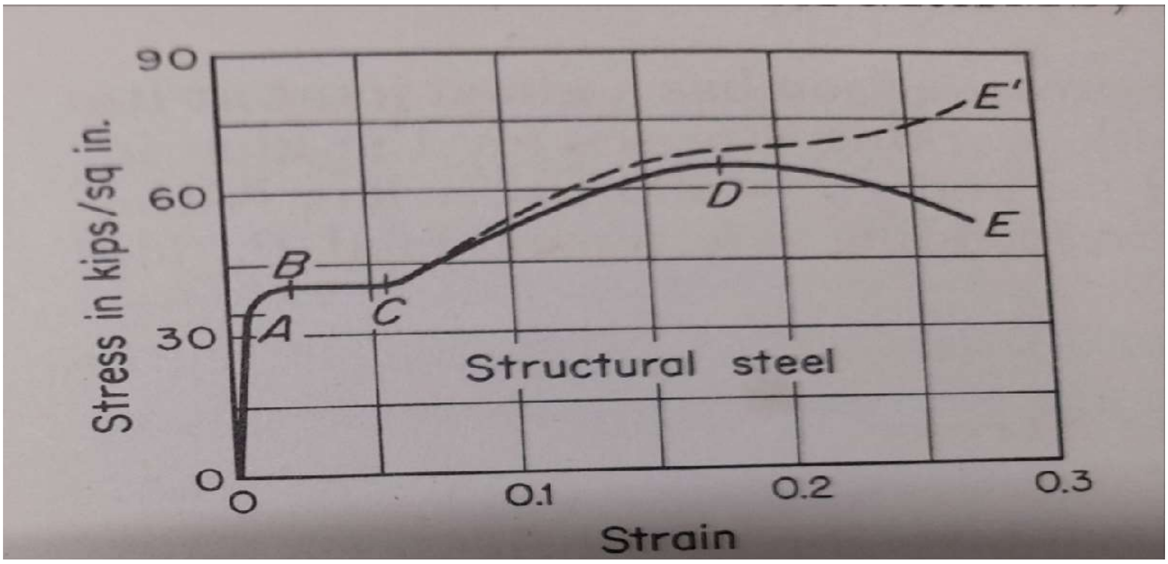
$p_w = \frac{p_{y.p}}{n}$, or $p_w = \frac{p_{ult}}{n_1}$ ……………………………………………..[9]

Here , n and n_1 are usually called factors of safety, which determine the magnitude of working stress. In the case of structural steel, it is logical to take the yield point as the basis for calculating the working stress, because here a considerable permanent set may occur which is not permissible in engineering structures. In such a case a factor of safety n=2 will give a conservative value for the working stress provided that only constant loads are acting upon the structure. In the cases of suddenly applied loads or variable loads(and these occur very often in machine parts) , larger factors of safety may be necessary. For brittle material such as cast iron, concrete , and various kind of stone and for such material as wood, the ultimate strength is usually taken as a basis for determining the working stresses.

The magnitude of the factor of safety depends very much upon the accuracy with which the stresses the external forces acting upon a structure are known, upon the accuracy with which the stress in the members of a structure may be calculated , and also upon the homogeneity of materials used. The common practice of speaking of working stresses and factors of safety based on some characteristic stress such as the yield point of steel or ultimate strength of cast iron is somewhat dangerous and misleading. IF P_1, P_2, P_3,……P_k are a set of external loads for a structure , what we really mean by a factor of safety n is that if all these loads are increased to nP_1, nP_2, nP_3,……., nP_k, the structure will be just on the verge of failure, where “failure” of course must be clearly defined. It may mean, in the case of a steel structure, that collapse due to yielding of some members can occur, or , in case of a concrete structure, that some members is on the verge of fracture.

The Yield strength is defined as the maximum stress at which a marked increase in elongation occurs without increase in the load. Many varieties of steel, especially heat-treated steels and cold drawn steels, do not have a well defined yield point on the stress-strain diagram. As in figure-10, the material yields gradually after passing through the elastic limit E. If the loading is stopped at the point Y at a stress level slightly higher than the elastic limit E, and the specimen is unloaded and readings taken, the curve would follow the dotted line and a permanent set or plastic deformation will exist. The strain corresponding to this permanent deformation is indicated by OA. For such materials, which do not exhibit a well-defined yield point, the yield strength ids defined as the stress corresponding to a permanent set of 0.2% of gauge length. In such cases, the yield strength isb determined by the offset method. A distance OA equal to 0.002 mm/mm strain(corresponding to 0.2% of gauge length) is marked on the X-axis. A line is constructed from the point A parallel to straight line portion OP of the stress-strain curve. The point of intersection of this line and stress-strain curve is called Y or the yield point and the corresponding stress is called 0.2% yield strength.

The term proof load or proof strength are frequently used in design of fasteners. Proof strength is similar to yield strength. It is determined by the offset method ; However the offset in this case is 0.001 mm/mm corresponding to a permanent set of 0.1% of gauge length. 0.1% Proof strength denoted by a symbol Rp0.1, is defined as the stress which will produce a permanent extension of 0.1% in the gauge length of the test specimen. The proof load is the force corresponding to proof stress.



90
60
30
0
Stress in kips/sq in.
E'
D
E
B
A
C
Structural steel
0
0.1
0.2
0.3
Strain

Figure-9(a)

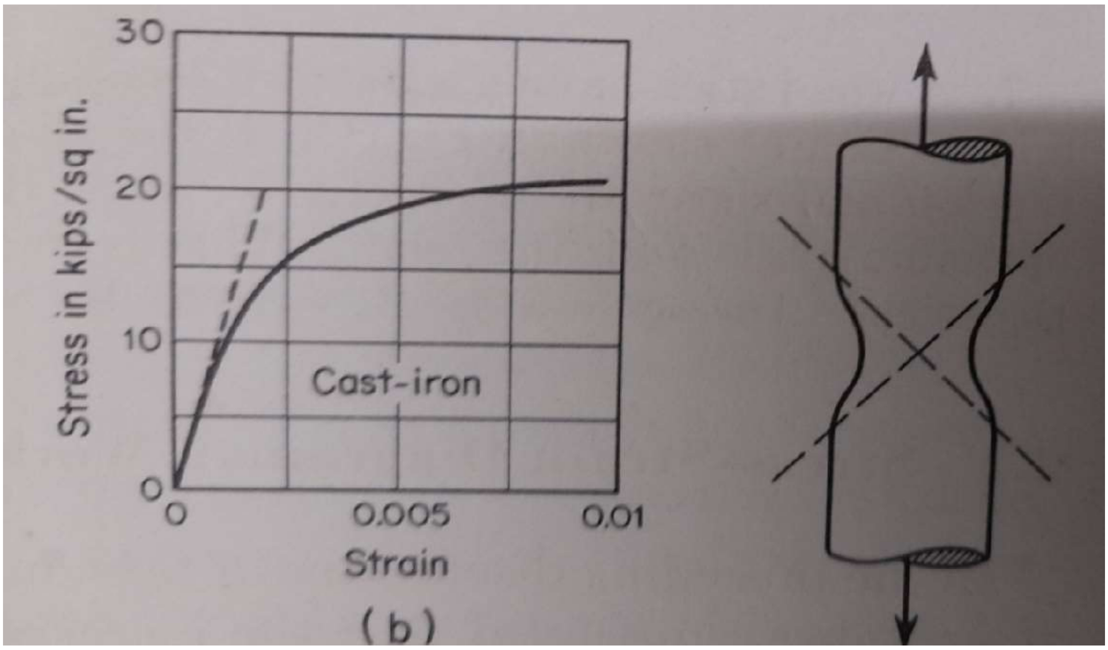


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Figure-9(b) & (c)

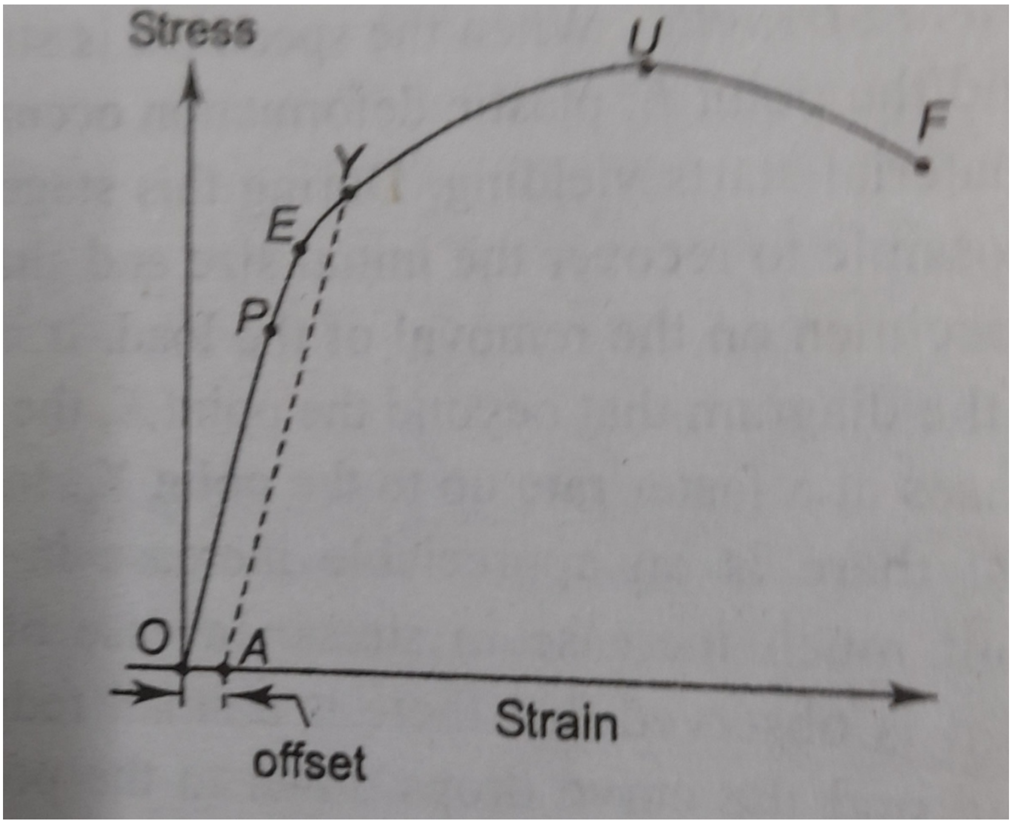


Figure-10

Factor of Safety:

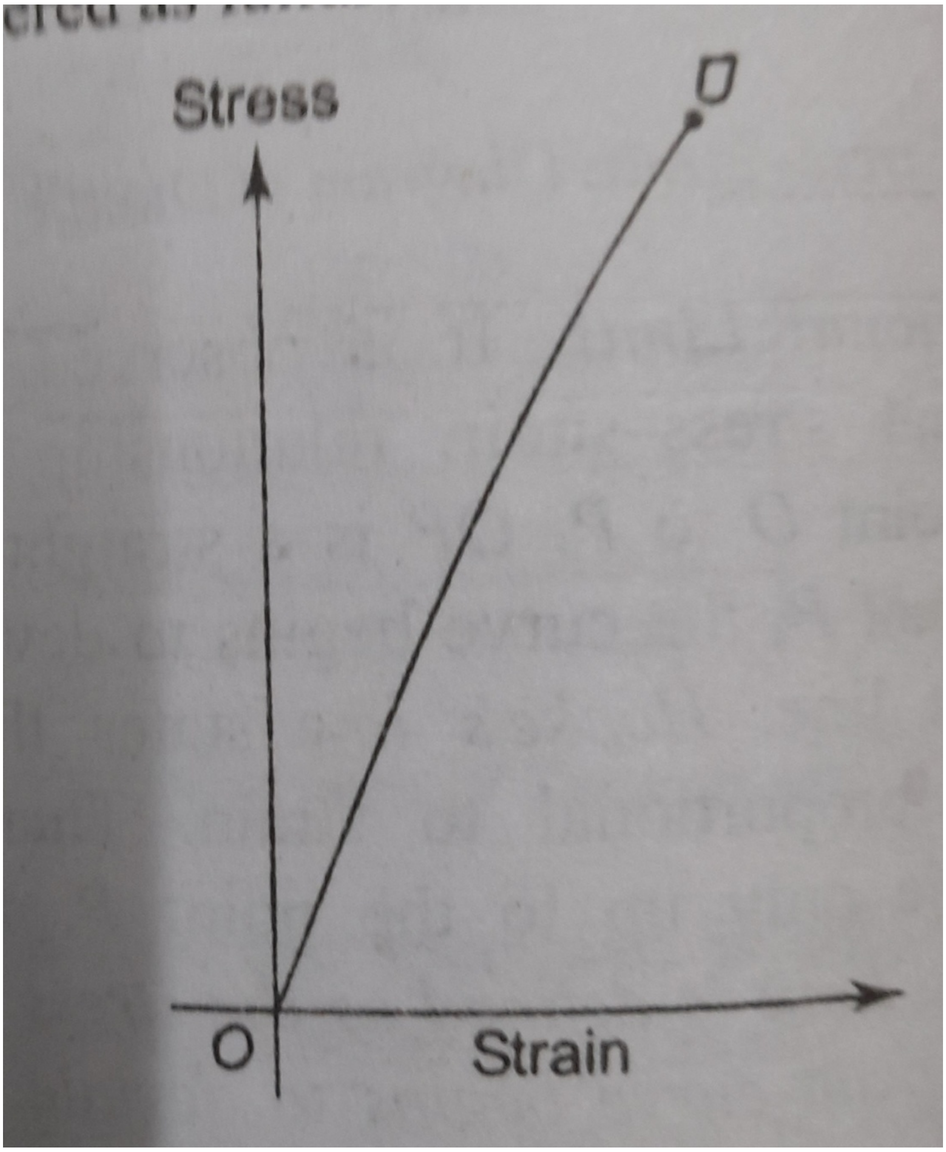
Factor of Safety is defined as the ratio of maximum stress to working stress. This provides safety margin (to avoid failure) by keeping working stress much lower than maximum or ultimate stress of the metal. In case of ductile material (% elongation more than 15%) (like mild steel) where yield point is well defined, factor of safety is based on yield point of the metal.

$$Factor\ of\ Safety = \frac{Yield\ point\ stress}{working\ or\ design\ or\ allowable\ stress}$$

For brittle materials(%elongation less than 5%)(like cast iron), the yield point is not well defined and therefore the factor of safety is based on the ultimate stress.

$$Factor\ of\ Safety = \frac{Ultimate\ Stress}{Working\ or\ design\ or\ allowable\ stress}$$

The value of factor of safety depend on material and type of loading and may vary from 4 to 20.



<u>Figure-11 : Stress-Strain diagram of brittle material(cast iron)</u>

Computing various tensile properties from tensile test results.
Based on information from tensile test various tensile properties of the metal that can be calculated are , elastic limit, yield strength, ultimate

tensile strength, Young's modulus of elasticity, percentage elongation, percentage reduction in area, breaking strength. These as calculated as follows with reference to Figure-12.

$$Elastic\ Limit = \frac{Maximum\ load\ at\ point\ B(in\ figure-12)}{Original\ area\ of\ the\ specimen}$$

Modulus (or Young's modulus) of elasticity or co-efficient of elasticity(E)

$$E = \frac{Stress\ at\ a\ given\ point\ on\ line\ OA(in\ figure-12)}{strain\ at\ that\ point}$$

$$Yield\ Strength = \frac{Load\ at\ yield\ point(C)(In\ figure-12)}{Original\ area\ of\ the\ Specimen}$$

$$Ultimate\ tensile\ Strength(UTS) = \frac{Ultimate\ load\ corresponding\ to\ point\ (E)(In\ Figure-12)}{Original\ area\ of\ the\ specimen}$$

$$Breaking\ Strength = \frac{Breaking\ load\ corresponding\ to\ pointF(In\ figure-12)}{Original\ area\ of\ the\ specimen}$$

$$Percentage\ elongation = \frac{Final\ gauge\ length - Original\ gauge\ length}{Original\ gauge\ length} \times 100$$

$$Percentage\ Reduction\ in\ area = \frac{Original\ area\ of\ the\ specimen - Final\ area\ at\ breaking\ point}{Original\ area\ of\ the\ Specimen} \times 100\%$$

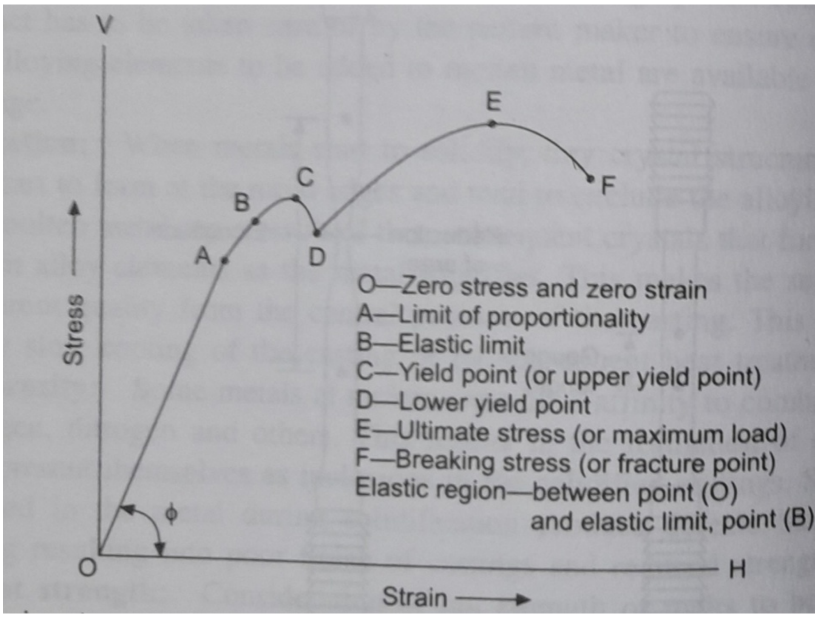


Figure-12

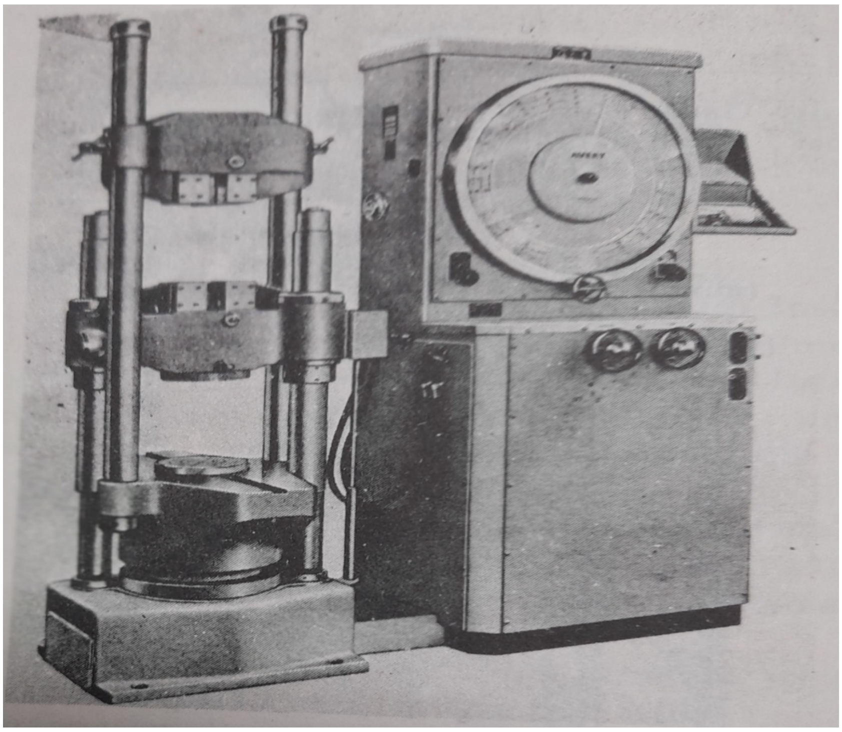


Figure-13:-Universal Testing Machine

Numerical

1. Determine the result of a test on a BS test piece, 14 mm test diameter, 70 mm gauge length which gave the following results when tested. Load at yield point 51kN. Maximum load 82 kN. Length between gauge points with broken ends put together 90 mm and diameter of fracture 11.5 mm.

Solution:

$$Cross\ sectional\ area\ (A) = \frac{\pi}{4} d^2 = \frac{\pi}{4} 14^2 = 154 mm^2$$

$$Tensile\ Strength = \frac{Maximum\ Load}{Area(A)}$$

$$Tensile\ Strength = \frac{82 \times 10^3}{154} N/mm^2 = 532.68 N/mm^2$$

$$Stress\ at\ Yield\ point (p_{y.p}) = \frac{P_{y.p}}{A} = \frac{51 \times 10^3}{154} = 331.2 N/mm^2$$

$$\%\ elongation = \frac{l' - l}{l} \times 100\% = \frac{90 - 70}{70} \times 100\% = 28.6\%$$

$$\%\ Reduction\ in\ area = \frac{(154 - \frac{\pi}{4} \times 11.5^2)}{154} \times 100\% = 32.4\%$$

2. A mild steel bar specimen of diameter 20 mm is subjected to a tensile test. The bar was found to yield under a load of 82.5 kN and the specimen attained a maximum load of 155 kN and ultimately at a load of 72.5 kN .Find the followings
   Tensile test at yield point. The ultimate stress. The average stress at breaking point the diameter of the neck is 10.75 mm.

Solution:

$$The\ original\ cross\ sectional\ area\ of\ specimen(A) = \frac{\pi}{4} d^2 A$$

$$= \frac{\pi}{4} 20^2 = 314.2 mm^2$$

$Tensile\ Stress\ at\ Yield\ Point(p_{y.p}) = \frac{P_{y.p}}{A} = \frac{82.5 \times 10^3}{314.2} N/mm^2$=262.57 N/$mm^2$

$$UTS = \frac{Maximum\ load}{A} = \frac{155 \times 10^3}{314.2} N/mm^2 = 493.32 N/mm^2$$

$$Area\ of\ the\ specimen\ in\ the\ neck\ portion = \frac{\pi d^2}{4}$$

$$= \frac{\pi}{4} \times 10.75^2\ mm^2 = 90.76 mm^2$$

$$Average\ stress\ at\ breaking\ point(p_b) = \frac{72.5 \times 10^3}{90.76} N/mm^2$$

$$= 798.81 \mathrm{N/mm}^2$$

3. A mild steel rod of 12 mm diameter and gauge length 60 mm is tested for tensile strength. The following observations are done Final length is 78 mm. Final diameter is 7 mm. Yield load is 34 kN. Ultimate load is 61 kN. Calculate yield Stress, Ultimate Stress, Percentage reduction of area, Percentage elongation.

Solution :

$Original\ area(A) = \frac{\pi}{4} d^2 = \frac{\pi}{4} 12^2 = 113 \mathrm{mm}^2$.

$$Yield\ Stress = \frac{Yield\ Load}{A} = \frac{P_{y.p}}{A} = \frac{34000}{113} N/mm2$$

$$p_{y.p} = 301\ N/mm^2$$

$$UTS = \frac{Maximum\ load}{A} = \frac{61 \times 10^3}{113}\ N/mm^2 = 540 N/mm^2$$

$$percentage\ reduction\ of\ area = \frac{113 - \frac{\pi}{4} \times 7^2}{113} \times 100\%$$
$$= 66\%$$
$$percentage\ elongation = \frac{l' - l}{l} \times 100\% = \frac{78 - 60}{60} \times 100\%$$
$$= 30\%$$

4. A mild steel bar specimen of diameter 15 mm is subjected to a tensile test. The bar yield under a load of 47.25 kN and the specimen attained a maximum load of 87.20 kN and ultimately broke at a load of 40.65 kN. Find followings.
   Tensile stress at yield point, The UTS, Average stress at the breaking point of the diameter, if neck is 8.05 mm.

   Solution:
   Initial diameter d is 15 mm.
   $Area\ of\ cross\ section\ (A) = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 15^2\ mm^2 = 177\ \text{mm}^2$
   $$Area\ of\ the\ neck(A') = \frac{\pi}{4} \times d'^2 = \frac{\pi}{4} \times 8.05^2 \text{mm}^2 = 50.9\ \text{mm}^2$$
   $$Tensile\ Stress\ at\ yield\ point(p_{y.p}) = \frac{P_{y.p}}{A} = \frac{47.25 \times 10^3}{177}$$
   $$= 267\ N/mm^2$$
   $UTS = \frac{Maximum\ load}{A} = \frac{87.20 \times 10^3}{177} N/\text{mm}^2 = 492.65\ \text{N/mm}^2$.
   $$Average\ Stress\ at\ breaking\ point(p_{b.p}) \frac{P_{b.p}}{A'}$$
   $$= \frac{40.65 \times 10^3}{50.9} mm^2 = 798.7\ \text{N/mm}^2$$
5. Following observation were made during tensile test of mild steel sample in UTM. Diameter of the sample is d=20 mm. Gauge length is 200 mm. Load at yield point is 66 kN. Maximum is 128 kN. Deformation at yield point is 0.9545 mm. final length is 267 mm . Diameter over neck is measured as 15.67mm . Calculate the following.

Modulus of elasticity(E),Yield Point, Ultimate Stress ,% elongation, % reduction in area, working stress based on yield point, considering factor of safety as 2.25.

Solution:

Diameter of the sample is d=20 mm.

$$Area\ of\ cross\ section\ of\ sample(A) = \frac{\pi}{4} \times d^2$$

$$= \frac{\pi}{4} \times 20^2\ mm^2 = 314.16\ \text{mm}^2$$

$$Yield\ point\ stress(p_{y.p}) = \frac{P_{y.p}}{A} = \frac{66 \times 10^3}{314.16} mm^2$$

$$= 210\ \text{N/mm}^2$$

$$Modulus\ of\ Elasticity(E) = \frac{P_{y.p}/_A}{\Delta/_L} = \frac{66\times10^3/_{314.16}}{0.9545/_{200}} = 44\ \text{kN/mm}^2$$

$$UTS = \frac{Maximum\ load}{A} = \frac{128 \times 10^3}{314.16} N/mm^2$$

$$= 407.4357\ \text{N/mm}^2$$

$$\%\ elongation = \frac{l'-l}{l} \times 100\% = \frac{267-2}{200} \times 100\% = 33.5\%$$

Diameter over neck is measured as 15.67 mm . $Cross\ Section\ of\ the\ neck(A') = \frac{\pi}{4} \times d'^2 = \frac{\pi}{4} \times 15.67^2 mm^2 = 192.854\ mm^2$

$$Percentage\ reduction\ in\ area = \frac{A - A'}{A}$$

$$= \frac{314.16 - 192.854}{314.16} \times 100\% = 38.61\%$$

$$Working\ Stress(p_w)basedon\ yield\ point = \frac{P_{y.p}/_A}{n}$$

$$= \frac{66 \times 10^3/_{314.16}}{2.25} = 93.37 N/mm^2$$

6. While carrying out experiment(tensile test) in the laboratory; following observations were made . Diameter of the specimen d=12.5 mm. length of the specimen(gauge length) is 50 mm, load at proportionality limit is 3000 kg and load at yield point is 3100 kg. Maximum load is 5250kg. Strain at proportionality limit is 0.11%. final length (l') is 64 mm . Diameter over neck is measured as 9.72mm . calculate the following
   Modulus of Elasticity(E),Proportional limit, Ultimate stress, % elongation, % reduction in area and allowable Stress based on yield point , considering factor of safety as 1.75.

Solution:

Initial diameter is d=12.5 mm.

$$Area\ of\ cross\ section(A) = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 1.25^2 = 1.227\ \text{cm}^2$$

$$Strain\ at\ Proportionality\ limit(\epsilon) = 0.11\% = 0.0011$$

$$Stress\ at\ proportionality\ limit(p_{p.l}) = \frac{3000}{1.227} kg/cm^2$$

$$= 2445\ kg/cm^2$$

$$Modulus\ of\ elasticity(E) = \frac{p_{p.l}}{\epsilon} = \frac{2445}{0.0011} kg/cm^2$$

$$= 2.2 \times 10^6\ kg/cm^2$$

$$UTS = p_{UTS} = \frac{\text{Maximum load}}{\text{A}} = \frac{1550}{1.227} kg/cm^2$$

$$= 4279\ kg/cm^2$$

$$\%\ elongation = \frac{l' - l}{l} \times 100\% = \frac{64 - 50}{50} \times 100\% = 28\%$$

$$\% \, reduction \, in \, area = \frac{A - A'}{A} \times 100\% = \left(1 - \frac{9.72^2}{12.5^2}\right)$$

$$= 39.53 \,\%$$

$$Yield \, point \, Stress(p_{y.p}) = \frac{P_{y.p}}{A} = \frac{3100}{1.227} kg/cm^2$$

$$= 2526.5 \, kg/cm^2$$

$$Allowable \, Stress \, or \, Working \, Stress(p_w) = \frac{p_{y.p}}{n}$$

$$= \frac{2526.5}{1.75} kg/cm^2 = 1444 kg/cm^2$$

7. A Specimen of steel of 20 mm diameter with a gauge length of 200 mm is tested to destruction. It has an extension of 0.25 mm under a load of 80 kN and the load at elastic limit is102kN. The maximum load is 130kN. The total extension at fracture ois 56 mm and diameter at neck is 15 mm . Find the stress at elastic limit, Young's modulus,% elongation, % reduction in area and UTS.

<u>Solution</u>:

Diameter d is 20 mm.

$$Area(A) = \frac{\pi d^2}{4} = \frac{\pi \times 20^2}{4} mm^2 = 314.16 \mathrm{mm}^2$$

$$Stress \, at \, elastic \, limit = \frac{Load \, at \, elastic \, limit}{A}$$

$$= \frac{102 \times 10^3}{314.16} N/mm^2 = 324.675 \, N/mm^2$$

$$Young'smodulus(E) = \frac{P/_A}{\Delta/_L} = \frac{80 \times 10^3/_{314.16}}{0.25/_{200}}$$

$$= 203718 \, N/mm^2$$

$$\% \; elongation = \frac{final \; extension}{original \; length} = \frac{56}{200} \times 100\% = 28\%$$

$$\% \; reduction \; in \; area = \frac{A - A'}{A} \times 100\% = \left(1 - \frac{15^2}{20^2}\right) \times 100\%$$

$$= 43.75\%$$

$$UTS = \frac{Maximum \; load}{A} = \frac{130 \times 10^3}{314.16} N/mm^2 = 413.80 N/mm^2$$

8. Tension test was conducted on a specimen and following readings were recorded. Diameter is 25 mm.
   Gauge length of extensometer is 200 mm, Least count of the extensometer=0.001mm.
   At a load of 30kN, extensometer reading is 60 and at a load of 50kN , extensometer readings is 100. Yield load is 160 kN.
   Maximum load is 205 kN . Diameter of neck is 17 mm. Final extension over 125 mm , Original Length is 150 mm.
   Find Young's modulus, Yield Stress, Ultimate stress,% elongation,% reduction in area.

   Solution:

   Initial diameter of the specimen(d)=25 mm.

   $Area \; of \; crosssection = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 25^2 \; mm^2$=490.87 mm^2

   As yield point load is 160 kN, so loading with 30 kN and 50 kN is within proportional limit.

$$p_{30kN} = \frac{P_{30kN}}{A} = \frac{30 \times 10^3}{490.87} N/mm^2 = 61.12 \mathrm{N/mm^2}$$

   $At \; 30kN \; load \; extensometer \; reading \; is \; 60 \; with \; a \; least \; count \; of \; 0.001$

$$Strain(e) \frac{\Delta}{L} = \frac{60 \times 0.001}{200} = 0.0003$$

$$Young's modulus(E) = \frac{Stress}{Strain} = \frac{61.12}{0.0003} N/mm^2$$

$$= 203720 \mathrm{N/mm^2} = 2.0372 \times 10^5 \mathrm{N/mm^2}$$

$$p_{y.p} = \frac{P_{y.p}}{A} = \frac{160 \times 10^3}{490.87} N/mm^2 = 325.952 \mathrm{N/mm^2}$$

$$UTS = \frac{Maximum\ Load}{A} = \frac{205 \times 10^3}{490.87} N/mm^2$$
$$= 417.63 N/mm^2$$

$$\frac{\Delta l}{L} = \frac{p_{y.p}}{E} = \frac{325.95}{203720} = 0.0015999$$
$$\Delta l = 0.0015999 \times L = 0.0015999 \times 125\ mm = 0.19999\ mm$$
$$\%\ reduction\ in\ area = \frac{A - A'}{A} \times 100 = \frac{490.87 - 227}{490.87} \times 100\%$$
$$= 53.76\%$$

Exercise Problems

1. A tensile test uses a test specimen that has a gauge length of 50 mm and area =200 mm^2 .During the test the specimen yields under a load of 98,000 N .The corresponding gauge length =50.23 mm. This is the o.2% yield point. The maximum load =168,000 N is reached at a gauge length =64.2 mm. Determine yield strength, modulus of elasticity and tensile strength.
2. In problem 1 fracture occurs at a gauge length of 67.3 mm. Determine percentage elongation and if the specimen necked to an area =92 mm^2 , determine the percentage reduction in area.
3. During a tensile test in which the starting gauge length=125.0 mm and the cross-sectional area =62.5 mm^2 , the following force and gauge length data are collected.
   i. 17,793 N at 125.23 mm,
   ii. 23042 N at 131.25 mm
   iii. 27579 N at 140.05 mm
   iv. 28913 N at 147.01 mm
   v. 27578 N at 153 mm and
   vi. 20462 N at 160.10 mm

The maximum load is 28913 N and final data point occurred immediately prior to failure.

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