CONTENTS

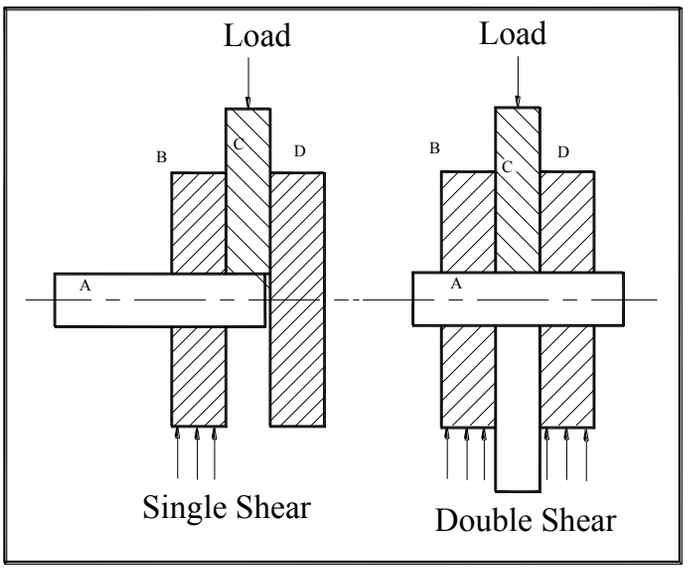
DIRECT SHEAR TEST ON MILD STEEL

AIM: To determine the Ultimate shear strength in single and double shear for the given mild steel specimen.

APPARATUS: Universal Testing Machine, Shear Shackle, Shear Block, Vernier caliper.

THEORY: Shear stress is caused by forces which act parallel to an area of cross section and tend to produce sliding of one portion past another. There are two main types of shear stresses used in laboratory test. One is called direct or transverse shear stress and corresponds to the type of stress encountered in rivets, bolts and beams. The other type of shear stress is called pure or torsional shear and represents the kind of shear stress encountered in a shaft subjected to pure torsion. Direct shear tests are usually conducted to obtain a measure of shear strength and the torsion tests are usually employed to evaluate the basic shear properties of a material.

For direct shear test of metal, a special shear attachment called shear shackle with shear block is used. It is as shown in the figure 1. A cylindrical specimen 'A' is placed in the center hold of the fixed block 'B' and the load is applied to the block 'C', there by producing single shear, since only one surface is subjected to shear (i.e. only one end is supported). If the specimen is extended to 'D' as shown in fig 2, the specimen will fail in double shear since two shear surfaces resist the load. It should be noted that the unit single shear strength of steel is usually greater than unit double shear strength.



TABULAR COLUMN:

Type of Test	Diameter (mm)	Area 'A' (mm^2)	Failure Load 'P'		Ultimate shear strength τ_u (N/mm^2)	Safe Shear Strength τ_s (N/mm^2)
			kg	N		
Single Shear						
Double Shear						

CALCULATIONS :

1. Area A = $\frac{\pi d^2}{4}$ mm^2

   = _____ mm^2

2. Single Shear:

   (a) Ultimate Shear Strength τ_u = $\frac{P}{A}$ N/mm^2

   = _____ N/mm^2

   (b) Safe Shear Strength τ_s = τ_u/ F.O.S. (N/mm^2)

   = _____ N/mm^2

3. Double Shear

   (a) Ultimate Shear Strength τ_u = $\frac{P}{2A}$ N/mm^2

   = _____ N/mm^2

   (b) Safe Shear Strength τ_s = τ_u/ F.O.S. (N/mm^2)

   = _____ N/mm^2

APPLICABILITY OF THE TEST :

The result obtained from the direct shear test is used to arrive at a safe shear stress of the material by adopting suitable factor of safety. This value of safe shear stress is used in design of rivets, crankpins etc.

Care should be taken to minimize the bending stress across the plane along which the shearing load is applied. This test has limitation of being useless to determine the modulus of rigidity owing to the impossibility of measuring strains.

PROCEDURE:

1. Measure the diameter of the specimen.
2. Place the specimen in the shear shackle with one end supported for single shear and two ends supported for double shear.
3. The shear assembly is placed in the UTM and load is applied at right angles to the axis of the specimen, through the central block, till failure.
4. Note down the failure load.
5. Calculate the ultimate shear strength in shear and also calculate the safe shear stress using a factor of safety of 3.

RESULTS:

1. For Single Shear:
   (a) Ultimate Shear Stress = τ_u = _____ N/mm^2

   (b) Safe Shear Stress = τ_s = _____ N/mm^2

2. For Double Shear:
   (a) Ultimate Shear Stress = τ_u = _____ N/mm^2

   (b) Safe Shear Stress = τ_s = _____ N/mm^2

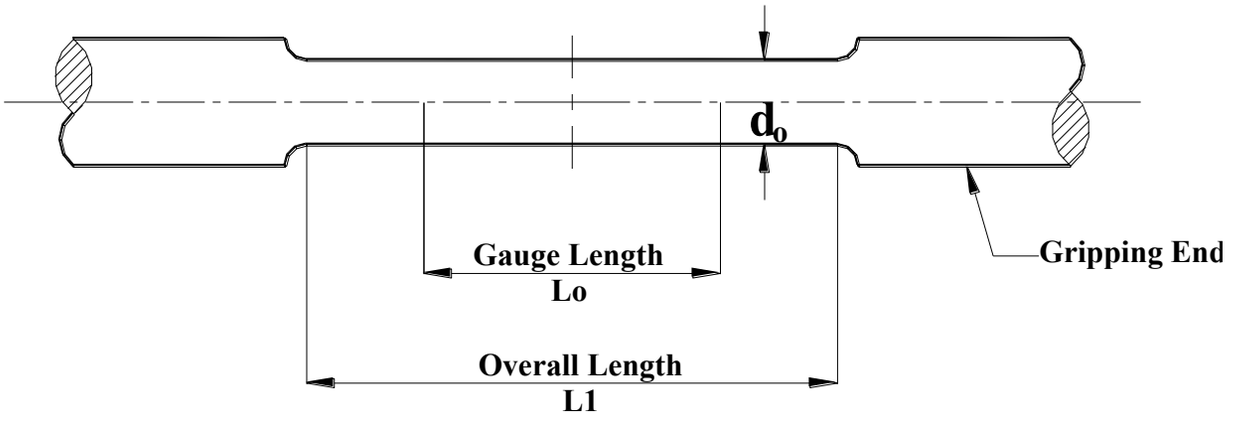
TENSILE TEST ON MILD STEEL USING U.T.M

AIM: To study the behaviour of the Mild Steel Specimen under the action of gradually increasing tensile load and to determine

1. Modulus of Elasticity
2. Percentage elongation in length and percentage reduction in area.
3. Yield Stress, Ultimate Tensile Strength and Breaking Or Fracture Strength.

APPARATUS: Universal Tensile Testing Machine, Extensometer, Dial gauge, Vernier caliper, scale, Gripping device etc.

TENSILE TEST SPECIMEN: Specimen must be selected and prepared so as to give reliable indication of the properties of the materials. Fig 1 shows the standard specimen for tension test on ductile material.



APPLICABILITY:

The tension test is done on a standard test piece by applying a gradually increasing uniaxial load. This is also called as Static tension test. It is one among the most commonly made simple mechanical tests to evaluate the fundamental mechanical properties like elasticity, ductility and tensile strength. These properties are important in the design of structural components, which are expected to undergo static tensile force. Tension test is also helps to understand the yielding and necking phenomenon and cup and cone type of fracture.

OBSERVATIONS:

1. Initial diameter d_1 = mm, d_2 = mm, d_3 = mm.
2. Average diameter d_0 = mm
3. Initial gauge length L_O = mm
4. Initial Overall length L_1 = mm
5. Final diameter d_u = mm
6. Final gauge length L_U = mm
7. Final Overall length L_2 = mm

CALCULATIONS:

1. Initial cross sectional area $A_O = \frac{\pi d_o^2}{4}$ mm^2

   = _____ mm^2

2. Final cross sectional area $A_U = \frac{\pi d_u^2}{4}$ mm^2

   = _____ mm^2

3. Yield Stress $\sigma_Y = \frac{P_Y}{A_O}$ N/mm^2

   = _____ N/mm^2

4. Ultimate Stress $\sigma_U = \frac{P_U}{A_O}$ N/mm^2

   = _____ N/mm^2

5. Nominal Breaking Stress $\sigma_B = \frac{P_B}{A_O}$ N/mm^2

   = _____ N/mm^2

6. True Breaking Stress $\sigma_{Bt} = \frac{P_B}{A_u}$ N/mm^2

   = _____ N/mm^2

IMPORTANT TERMS AND DEFINITIONS:

1. Gauge Length: It is the marked length over which elongation is measured during the test. As per the ISI specifications, the gauge length before the specimen is strained is given by the formula,
   $L = 5.65 \sqrt{A_O}$
   For cylindrical specimen, $L = 5d_o$

2. Yield Stress: It is the stress at which considerable elongation occurs in the test piece without increase in the load. Yield load is the load at which the load pointer of UTM stops moving for a while and there will be increase in extension at the constant load.

3. Tensile Strength: It is the ratio of Maximum load reached in the test divided by the original cross sectional area. It is also termed as maximum tensile strength or ultimate tensile strength.

4. Breaking Stress: The ratio of breaking load divided by the Original cross sectional area is termed as "Nominal Breaking Stress".
   The ratio of breaking load divided by the Final cross sectional area is termed as "True Breaking Stress".

5. Elasticity: It is the property by which a material regains its original shape after the removal of the applied load. Elastic limit is the stress limit below, which a material behaves as perfectly elastic.

6. Modulus of Elasticity: The ratio of axial stress to axial strain within elastic limit. It is the slope of the initial straight-line portion of the stress strain graph where stress is taken along Y-axis and strain along X-axis. The standard value of Modulus of Elasticity for mild steel is 2.1×10^5 N/mm^2.

7. Percentage Elongation: It is the ratio of change in gauge length to the original gauge length. This gives the measure of ductility.
   i.e. Percentage elongation $= \dfrac{(L_U - L_O)}{L_O} \times 100$
   Where, L_U = Final gauge length after fracture.
   L_O = Initial gauge length.

8. Percentage Reduction in Area: It is the change of c/s area which has occurred during the test at the neck, expresses as a percentage of the original c/s area.

7. Young's Modulus $E = \Delta\sigma / \Delta\varepsilon$ N/mm^2
(where $\Delta\sigma / \Delta\varepsilon$ is the slope of the Straight line portion of stress-strain graph)

$E =$ _____ N/mm^2

8. Percentage elongation $= \dfrac{(L_U - L_O)}{L_O} \times 100$

$=$ _____%

9. Percentage reduction in area $= \dfrac{(A_O - A_U)}{A_O} \times 100$

$=$ _____%

RESULTS:

1. Yield Stress $\sigma_Y =$ _____ N/mm^2
2. Ultimate Stress $\sigma_U =$ _____ N/mm^2
3. Nominal Breaking Stress $\sigma_B =$ _____ N/mm^2
4. True Breaking Stress $\sigma_{Bt} =$ _____ N/mm^2
5. Modulus of Elasticity $E =$ _____ N/mm^2
6. Percentage Elongation $=$ _____ %
7. Percentage Reduction in Area $=$ _____ %

i.e. Percentage reduction in area = $\frac{(A_O - A_U) \times 100}{A_O}$

Where, A_U = Final Cross-sectional area after fracture.

A_O = Initial Cross-sectional area.

EXTENSOMETER: The gauge length of the extensometer used is adjustable up to a maximum value of 120 mm. There are pair of knife-edges at the top and bottom, which are used to grip the specimen between gauge points. The top knife-edges are fixed while the extension of the specimen causes the bottom knife-edges to move down. The movement of these knife-edges are magnified by a lever and transmitted to two dial gauges (one on either side) by a rack and pinion mechanism. The least count of the extensometer is 0.001mm and it can measure up to 3mm**.**

PROCEDURE:

1. Measure the diameter of the test specimen by means of Vernier caliper at least at three sections and obtain the mean value. Also calculate the gauge length.
2. Locate the center point of the specimen
3. Insert suitable jaws in the grips and select load scale on the testing machine.
4. Firmly grip the specimen into the jaws of upper and lower cross heads in such a way that the gauge mark faces the front of the machine.
5. Mount the extensometer on the test specimen to measure the deformation with in the gauge length and adjust dial gauge reading to zero.
6. Set the dial gauge and note down its initial reading.
7. Start the machine by keeping the releasing value closed. Rate of loading is adjusted.
8. Note down the load values and the corresponding extensometer and dial gauge readings at regular intervals of load.
9. As the yield point approaches, the load pointer remains stationary and the extensometer runs rapidly. Note down the load at this stage as yield load F_Y and remove the extensometer (to avoid damage to the extensometer).
10. Continue to load the specimen and take readings of the extension on the dial gauge at regular intervals of load.
11. The load pointer reaches a maximum point and starts moving back, at this instant record the load as maximum load F_U.
12. Finally the specimen fails at a load lower than the maximum load. Note down this load as breaking or failure load F_B.
13. Remove the broken specimen from the machine. Observe the location and character of the fracture. Place the broken parts together and

measure the final gauge length (L_U) and the final diameter (d_u) at the failure section (neck).

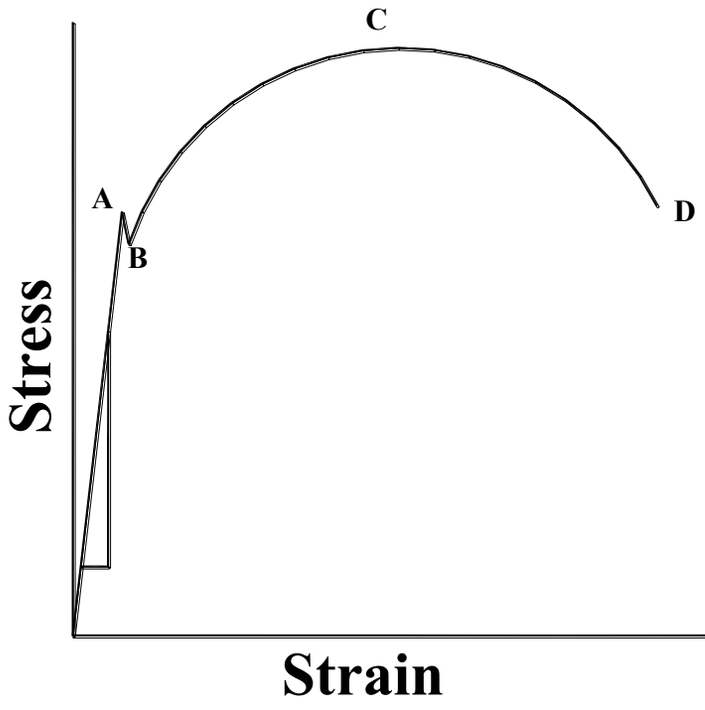
14. Plot stress-strain graph and determine all the required mechanical properties. Also study the failure pattern.

GRAPHS:

1. Plot the graph of Stress v/s Strain by taking Stress (N/mm^2) along y-axis and strain in dial gauge along x-axis.

2. Plot the graph of Load v/s Deformation by taking Load (N) along y-axis and Deformation (mm) of extensometer along x-axis.

Young's modulus is given by, $E = (\text{Slope} \times L_O)/ A_O$ N/mm^2



A corresponds to Upper Yield Stress
B corresponds to Lower Yield Stress
C corresponds to Ultimate Stress
D corresponds to Breaking Stress

TABULATION:

Sl. No	Load		Extensometer Reading			Extensometer Elongation	Dial Gauge Reading			Dial Gauge Elongation	Stain in Extenso-meter	Stain in Dial Gauge	Stress
	kg	N	IR	FR	**DIFF**	mm	IR	FR	**DIFF**	mm			N/mm^2
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													

COMPRESSION TEST ON CAST IRON

AIM: To conduct the compression test on a cast iron specimen and to

1. Study stress-strain characteristics
2. Find Compressive Strength
3. Find Initial Tangent Modulus
4. Find Secant Modulus and Tangent Modulus at any specified stress (load)
5. Find percentage reduction in length and percentage increase in area.

APPARATUS: Universal Testing Machine, Dial gauge, Vernier caliper.

THEORY: Compression test is a test in which a standard specimen subjected to a gradually increasing uniaxial compression load until failure occurs. This test helps to study the stress-stain characteristics of cast iron in compression. Compression strength, secant modulus and tangent modulus are the other design parameters, which can be obtained for the design of structural components which are expected to be under pure compression action in the working condition.

Compression test is to be done with utmost care. Any lack of alignment of the specimen causes increase in eccentricity of the load, which may result in lateral deflections and bending stresses. Height of the specimen is another important factor to be considered. Since the specimen is expected to fail under pure compression height is to be limited to such a value that bending due to column action (buckling) should not take place. Also the friction between the head of the machine and the end surface of the specimen, due to lateral expansion of the specimen may alter the result considerably.

SPECIMEN:

For uniform stressing of the compression specimen a circular section is preferred. Short specimens are generally used. If the height of the specimen is increased considerably with respect to diameter bending action takes place. When the height is very less compared to the diameter, the diagonal planes along which failure would take place intersect the base. So generally ratio of height to diameter of 2 or 3 is commonly employed.

OBSERVATIONS:

1. Initial diameter d_1 = mm, d_2 = mm, d_3 = mm.
2. Average diameter d_0 = mm
3. Initial height L_O = mm
4. Final diameter d_u = mm
5. Final height L_U = mm

TABULATION:

Sl. No.	Load		Dial Gauge Reading			Strain ε	Stress σ
	kg	N	Initial	Final	Difference		N/mm^2
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

PROCEDURE:

1. Measure the diameter and height of the specimen at three sections and obtain the mean value.
2. Place the specimen centrally between the 2 plates fixed to the cross heads of the U.T.M.
3. Set the dial gauge on the loading platform and note down its initial reading. The dial gauge has a range of 0 to 50mm. Its least count is 0.01mm.
4. Select a suitable range of load. Start applying the load gradually.
5. Note down the dial gauge reading for fixed load intervals.
6. Note down the failure or breaking load and the corresponding dial gauge reading.
7. Remove the specimen, measure the final diameter and height of the specimen. Also study the fracture.
8. Plot the stress-strain graph and compute all the required mechanical properties.

GRAPH:

1. Stress – Strain Graph: Plot the graph of stress v/s strain by taking stress (N/mm^2) along y- axis and strain along x-axis. The ideal graph is as shown in the figure (at the end of expt.-compression test on M.S.). Brittle materials like Cast Iron show a non-linear nature of curve starting from the origin itself. Initial tangent modulus and secant modulus are calculated for such materials as a measure of stiffness.

   Initial Tangent Modulus $= \Delta\sigma_1 / \Delta\varepsilon_1$ N/mm^2
   Tangent Modulus at any stress $= \Delta\sigma_2 / \Delta\varepsilon_2$ N/mm^2
   Secant Modulus corresponding to 0.2% strain $= \Delta\sigma_3 / \Delta\varepsilon_3$ N/mm^2

2. Load – Deformation Graph: Plot the graph of load v/s deformation by taking load (N) along y- axis and deformation (mm) along x-axis. The ideal graph is as shown in the figure.

   Initial Tangent Modulus $= (\Delta P_1 \times L_O) / (\Delta\delta_1 \times A_O)$ N/mm^2
   Tangent Modulus at any load $= (\Delta P_2 \times L_O) / (\Delta\delta_2 \times A_O)$ N/mm^2
   Secant Modulus corresponding to 0.2% deformation $= (\Delta P_3 \times L_O) / (\Delta\delta_3 \times A_O)$ N/mm^2

CALCULATIONS:

1. Initial cross sectional area $A_O = \frac{\pi d_o^2}{4}$ mm^2

   $= \_\_\_\_\_ mm^2$

2. Final cross sectional area $A_U = \frac{\pi d_u^2}{4}$ mm^2

   $= \_\_\_\_\_ mm^2$

3. Compressive Strength $= F_{max} / A_O$ N/mm^2

   $= \_\_\_\_\_ N/mm^2$

4. Percentage reduction in length $= \frac{(L_O - L_U) \times 100}{L_O}$

   $= \_\_\_\_\_ \%$

5. Percentage increase in area $= \frac{(A_U - A_O) \times 100}{A_O}$

   $= \_\_\_\_\_ \%$

RESULTS:

1. Compressive Strength = _____ N/mm^2

2. Allowable Compressive Strength = _____ N/mm^2
   using factor of safety of _____

3. Percentage reduction in length = _____ %

4. Percentage increase in area = _____ %

5. Initial Tangent Modulus = _____ N/mm^2

6. Secant Modulus = _____ N/mm^2
   at a strain of _____

7. Tangent Modulus = _____ N/mm^2
   at a stress of _____ N/mm^2

COMPRESSION TEST ON MILD STEEL

AIM: To study the behavior of the given material under compressive loading and to determine

1. Proportional limit
2. Modulus of Elasticity
3. Compressive strength
4. percentage of contraction
5. Percentage increase in area

APPARATUS: Universal Testing Machine, vernier caliper, scale, dial gauge.

THEORY: In this test short specimen is used. A specimen is said to be short if the ratio of length to the diameter of the specimen does not exceed 12 . In compression test, a short specimen is subjected to end loading (compressive), which produces crushing action. Although compressive mechanical properties in the plastic range cannot be determined for ductile materials because the ultimate and breaking loads cannot be determined, the elastic properties of strength, stiffness and resilience can be determined as for tension. The modulus of elasticity and yield strength for many metals and alloys are approximately equal in tension and compression. The determination of accurate stress-strain diagram in compression is considerably more difficult than for tension. Difficulties arise because of :

i) Introduction of lateral restraining forces at the ends of the specimen owing to the friction forces between the specimen ends and bearing plates.
ii) Possibility of failure produced by lateral buckling if the specimen is too long.
iii) Irregularities of alignment, which are accentuated with, increase in loading and result in lateral deflections and bending stresses.

The engineering stress-strain curve for ductile and brittle material in compression is shown in fig.

Observations:

I. Material of the specimen :

II. Initial length of the specimen l_1 : mm

III. Initial diameter of the specimen d_1 : mm

IV. Final length of the specimen l_2 : mm

V. Final diameter of the specimen d_2 : mm

TABULATION:

Sl. No.	Load P		Dial gauge Reading mm			Stress N/mm^2	Strain
	kgf	N	IR	FR	AR		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

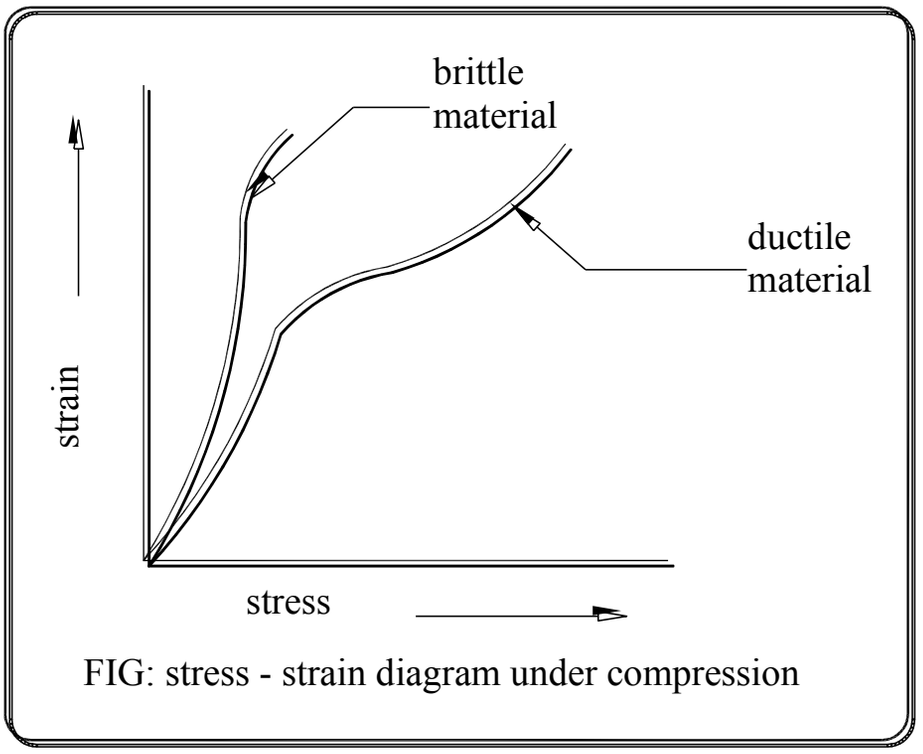
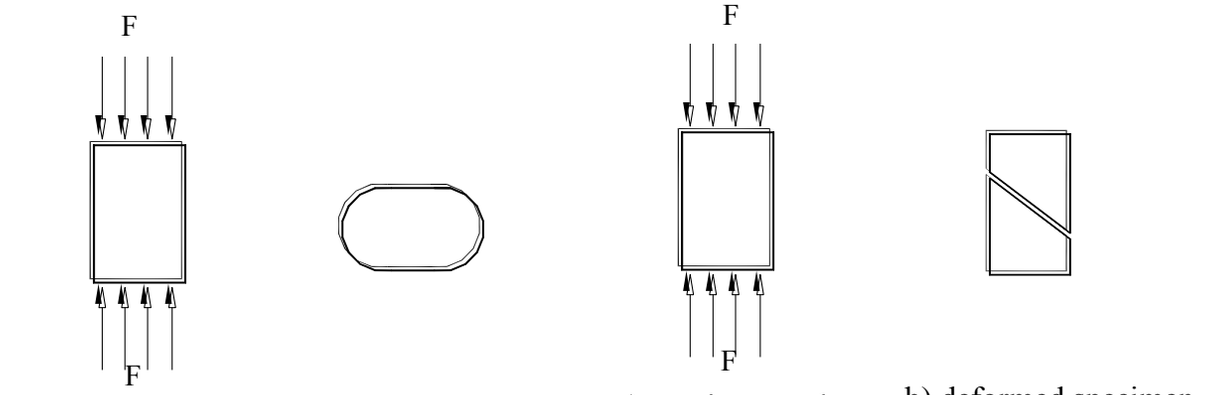


FIG: stress - strain diagram under compression

Specimen before and after fracture:



a) specimen at the begining of load

b) deformed specimen at maximum load

a) specimen at the begining of load

b) deformed specimen shear fractured at fracture load

CALCULATIONS:

1. Area of the specimen A : $\pi d^2/4$ mm^2

2. Stress σ : P / A N/mm^2

3. Strain ε : Δ / l_1

4. Compressive strength : $\frac{\text{Ultimate load}}{\text{Initial c/s area}}$ N/mm^2

5. Percentage of contraction in length : $\frac{(l_1 - l_2)}{l_1} \times 100$

6. Percentage increase in area : $\frac{(d_2 - d_1)}{d_1} \times 100$

GRAPH: Draw the graph of stress v/s strain.

Procedure:

1. Measure the diameter and length of the specimen using screw gauge or vernier caliper at least at three sections and calculate the mean value.
2. Fix the specimen properly between the table and the lower crosshead.
3. Fix the dial gauge on the loading platform and adjust the dial reading to zero.
4. Set the load dial of the machine to a suitable range.
5. Apply the load gradually and make simultaneous record of dial gauge reading at every equal interval of load.
6. Record the load at yield point and the maximum load in the case of ductile material and breaking or fracture load in the case of brittle material.
7. Remove the specimen (broken if it is brittle material) from the machine and observe the location and character of fracture (if brittle). Measure final diameter and length of the specimen.
8. Plot stress-strain diagram and compute all the required mechanical properties.

FRICTION WEAR TEST

AIM: To perform friction wear test on different materials and to find out Frictional force &wear rate.

APPARATUS: Friction wear test machine, Electronic weighing machine, vernier caliper.

INTRODUCTION TO FRICTION WEAR:

When attempt is made to slide one of the contact metal over the other resistance to motion is encountered, which is termed as 'Frictional resistance' or Friction. This resistance is equivalent to the sum of the shearing force required to break metal-to-metal junction.

Wear is a progressive loss or displacement of material from a surface as a result of relative motion between the surfaces.

The belief is that it is easier to replace a part rather than to design a part with adequate life may have been true one time. Today, However, this can be a costly practice.

Wear is closely related to friction and lubrication. In the wear test, which can be conducted in lubricated or dry conditions, the area of interest is the wear response of the wear material. A friction test measures friction force or the coefficient of friction. In addition friction test can be used to evaluate lubricate performance, and wear test often monitor friction.

DESCRIPTION OF MACHINE:

Essentially, the machine consists of disc shaped specimen carried on a mandrel and a pin, which is pressed in to contact with the top surface of the disc by means of loading lever. Loading end of the lever is attached to weight pan by a cable. Another end of the lever is provided with a slot, in which we can move the loading block to adjust the friction radius.

Dial gauge is fixed near the disc and the pointer is rested on the loading knob. Load cell bracket is fitted at another end.

A control panel box fitted on the frame consists of load indication, mains on off, and digital rpm indicator and timer unit.

OBSERVATIONS

1. Length and weight of specimen

Specimen	Length of pin mm		Weight of pin gm	
	Before test	After test	Before test	After test

2. Frictional force (P) : kgf

3. Sliding rpm (N) : rpm

4. Duration of test (T) : min

CALCULATION OF WEAR RATE AND WEAR FACTOR

1. Sliding distance (L) mm
   $L=2 \pi R N T$
   Where T=Time of run in min
   R=Radius of rotation of test specimen

2. Loss in linear dimension (X) = mm
   X=Difference between the initial and final length

TEST PROCEDURE

To study the frictional and wear behavior of combination follows steps given below:

1. Select a pin size and material under test.
2. Choice of diameter of test specimen is based on the material, which is softer. Select larger diameter for material, which is softer among set.
3. Physical dimensions (length of pins) and weight of each sample are to be taken and noted in the observation table.
4. Insert the test specimen (pin) in guide block and fix it to the lever.
5. Ensure a gap of 0.5mm between pin and face of disc.
6. Start the motor.
7. Switch the load indicator on.

3. Linear wear rate $K=X/L$

4. Loss in volume (V) mm^3
   $V= \pi D^2/4 * X$

   Where D= Diameter of pin
5. Wear factor (K)

$$K= \frac{V \times Hm}{P \times L}$$

Where Hm= hardness of softer material. The hardness of the test specimen to be checked before the test.

PREPARATION OF SPECIMEN FOR METALLOGRAPHIC EXAMINATION OF ENGINEERING MATERIALS AND STUDY OF MICROSTRUCTURE OF PLAIN CARBON STEELS, TOOL STEEL, GREY C.I, S.I.

AIM: 1. To prepare the given specimen (steel, cast iron) for metallographic examination.
2. To observe the structure under microscope for its characteristics and composition.
3. To determine the size of the grain.

APPARUTUS: Metallurgical microscope, polishing machine, Emery papers of various grades, enchants.

THEORY: Micrography is the study of the structures of metals and their alloys under a microscope at magnification of X75 to X7500. The observed structure is called microstructure. The aim of metallographic examination is to determine the size and shape of the crystallites which constitute an alloy, to discover the micro defects such as non metallic inclusions, microcracks etc, to reveal the structural characteristics of certain types of mechanical working operation (casting, forging, etc) and in some cases to determine the chemical content of alloys.

METALLURGICAL MICROSCOPE: The prepared metal is examined under a metallurgical microscope. Fig 1 shows the optical system of a metallurgical microscope.

As the specimens are opaque, a vertical illuminator, which will illuminate the specimens via the microscope eyepiece, must be used.

I. PREPARATION OF SPECIMEN (MICROSECTION) FOR METALLOGRAPHIC EXAMINATION.

In order to present the grain structure of metals, it is important that the samples for microscopic examination be carefully prepared. The steps in the preparation of examination are,

a) **Cutting:** The specimen (a square 10 mm or dia 15 mm) is cut to a height of about 15 mm using saw or a cutting machine.
b) **Grinding or polishing with emery paper**: The side of the specimen, which was roughly cut, is polished with emery paper, beginning with coarse and ending with fine paper. At intervals, the direction of polishing has to be changed to 90 degree. This will make he magnitude of the scratches formed in polishing to become smaller and smaller (because the sample is to held that the scratches made by each grade of emery paper are at right angles to the ones made by the preceding operation). On each occasion scratches are effaced (removed by rubbing) and new scratches of smaller magnitude are formed at right angles to the effaced scratches.
c) **Fine polishing**: The sample is then fine polished upon the rotating disc, to which a moist velvet cloth is attached and to which very finely ground abrasive material (usually alumina powder) is continuously applied. The alumina is so fine that the last traces of scratches made by fine emery paper are removed, and the specimen obtained has highly polished surface.
d) **Etching:** The polished specimen is then etched (etching is done to reveal the microstructure). The etching reagent reacts differently on different constituents of alloy.(Under microscope, hard constituents offering more resistance to etching reagent are usually seen as white and soft constituents as grey or black). Etchant is applied for few seconds and then rubbed off by smooth cotton cloth

Some of the common reagents are presented in the table below.

Material	Etchant	Etching time
Wrought iron	5% solution of nitric acid or saturated solution of nitric acid in alcohol	30 sec to 1 min
Carbon steel and cast iron	2% solution of nitric acid or 5% solution of picric acid in alcohol	10 sec to 30 sec
High speed steel	10 gm of potassium ferrocyanide+10 gm potassium hydroxide in 100 c.c of water.	20 sec to 6 min
Aluminium alloys	2% hydrofluoric acid + 25% nitric acid in water.	30 sec to 1 min
Brass, Bronze and copper	50 c.c ammonium hydroxide + 25 c.c hydrogen peroxide in 50 c.c of water.	30 sec to 1 min

II TO OBSERVE THE STRUCTURE UNDER MICROSCOPE FOR IT'S COMPOSITION AND CHARACTERISTICS.

1. The prepared specimen is placed on the table beneath the objective lens.
2. Put on the source of light.
3. Adjust the longitudinal and transverse movements of the table to focus the light on the specimen.
4. Make coarse and fine adjustments to focus.
5. Observe and record the microstructure.

MICROSTRUCTURE OF STEELS:

Pure irons (less than 0.03% C) containing ferrite only, show sharp grain boundaries as in fig.

With the increase of carbon content, pearlite appears in increasing quantity. Under the microscope, pearlite appears dark and may be distinguished clearly forms the ferrite as shown in the fig.

In hyper eutectoid steels, the primary cementite is concentrated on the former austenite grain boundaries and appears light between the dark pearlite as shown in the fig. The cementite layers of pearlite which appear dark at intermediate magnifications are actually etched at their boundaries only, and under

high magnification the boundaries may be resolved, showing white cementite in between.

MICROSTRUCTURE OF CAST IRON:

A cast iron containing all the carbon, as cementite is known as white cast iron, while a graphitized one is known as the grey cast iron. Graphitization is favoured by a slow rate of cooling and by the presence of silicon.

White cast iron, being largely cementite is extremely hard and brittle. It gives excellent wear resisting properties to the surfaces of casting.

In grey cast iron, the graphite is distributed as flakes, which break up the continuity of the metal matrix – a carbon steel of itself possessing considerable strength and ductility.

In ferritic grey cast iron, all the carbon is graphite. In pearlitic grey cast iron, some is in pearlite. The graphite flakes have no strength and act as internal cracks making the material weak and brittle and extremely liable to fracture under shock loads.

Malleable cast iron is made by annealing white cast iron for periods of several days under controlled conditions, when the graphite will separate as nodules of approximately spherical shape. The weakening effect of the graphite is reduced, so that malleable cast iron has a higher strength, greater ductility and shock resistance.

By addition of cerium or magnesium under controlled conditions to the molten metal before pouring into the moulds, the graphite forms spherical particles on the castings. This spheroidal graphite cast iron is found to have superior strength than malleable cast iron and with suitable annealing, which precipitates further graphite from the pearlite matrix, the ductility is as good.

III TO DETERMINE THE SIZE OF THE GRAIN

The properties of any alloy are affected not only by the character of phases present, but also by the size of grains that are present in the structure. Larger the size of the grains, greater will be the hardenablity of the steel. Smaller the size of the grains greater is the strength.

The grain size in steel depends upon the nature and quality of raw material, method of manufacture, chemical composition, metallic and non metallic inclusions, mechanical working like rolling, forging etc. The elements like molybdenum and vanadium have a very pronounced effect in controlling the grain size in steel.

According to ASTM, the grain size N is given by $m = 8x2^N$,
where ‘m’ is the number of grains per mm^2

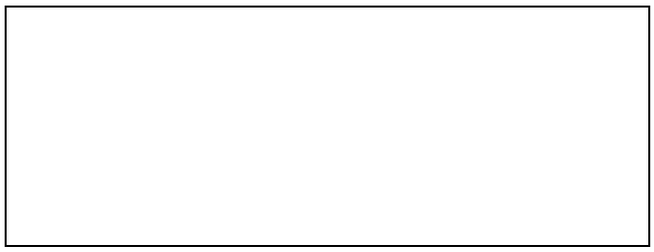
The grain size serves as an indication of the characteristics of the particular specification of steel to its response towards heat treatment, machinablity and other processing operations. Grain size is considered as important as chemical specification with regard to the results obtained from the commercial hear treatment of steel.

The grain size is measured by comparison, under microscope with a magnification of X100, with standard charts shown in the figure.

Steels with grain size number 1 to 5 are coarse grained and number 6,7 and 8 are fine-grained steels.

RESULTS:

1. MATERIAL
2. ETCHANT
3. MAGNIFICATION
4. MICROSTRUCTURE OBSERVED



STRCUTURAL DESCRIPTIONS AND COMPOSITION:
(ex. Structure -Pearlite, ferrite, etc.
Steel - eutectoid, hypereutectoid, hypereutectoid etc.
% C - < 0.8, =0.8 or > 0.8 etc)

5. GRAIN SIZE NUMBER

HEAT TREATMENT OF STEEL

AIM: To heat treat the given specimen and to determine its hardness.

APPARUTUS: Electric furnace, hardness testing machine.

THEORY: heat treatment may be defined as the operation or combination of operations involving heating and cooling of a metal or alloy in the solid state for the purpose of obtaining certain desirable conditions or properties. The usefulness of steel is largely due to the ease with which its properties may be altered by properly controlling the manner in which it is heated and cooled. Only by heat treatment, it is possible to impart high mechanical properties to steel required for the normal operation of modern machinery and tools.
Various heat treatment operations are:

1. Annealing 2.Normalizing 3. Hardening 4. Tempering 5. Carburizing

1. ANNEALING:

Annealing is one of the most widely used operation in the heat treatment of steel.. The purpose annealing is

i) To reduce the hardness.
ii) To improve machinability.
iii) To increase or restore ductility and toughness.
iv) To relive internal stresses.
v) To refine grain size.

There are various types of annealing:

a) Full annealing b) Incomplete annealing c) Process annealing
d) Stress relief annealing e) Spheroid zing annealing
f) Isothermal annealing g) Homogenizing (diffusion) annealing

FULL ANNEALING

It consists of heating a hypo eutectoid steel 30-50^0 above the higher critical point Ac_3 (line GS in fig), holding it at this temperature and then slowly cooling. (at the rate of 30-200^0 per hour depending upon the composition)
Slow cooling can be achieved by allowing the steel in the furnace itself or by covering with non- conducting materials. Slow cooling is required in annealing to enable the austenite to decompose so as to form a pearlite + ferrite structure in hypo eutectoid steel, pearlite structure in eutectoid steel and a pearlite + cementite structure in hypereutectoid steel.

Annealing reduces the tensile strength, yield point and hardness or rolled (or forged) steel while elongation and reduction of area are increased.

When cast steel is annealed, its strength is also increased because a fine grained structure is obtained. Full annealing considerably improves the machinability and formability of steel.

INCOMPLETE ANNEALING

It consists of heating steel to a temperature somewhat above the lower critical point AC_1 (line PSK), holding it at this temperature for some time and then slowly cooling it. Incomplete annealing is used to relive internal stresses and to improve the machinability of steel. It is associated with only partial recrystalisation, excess ferrite of hypoeuctoid steel or excess cementite of hypereutectoid steel does not pass over into the solid solution and is not recrystalised. Incomplete annealing is chiefly applied to eutectoid and hypereutectoid steels in which heating about the point AC_1 causes practically complete recrystalisation

PROCESS ANNEALING

It is done by heating the steel to a temperature below or close to the lower critical temperature, followed by any desired rate of cooling. Its principal purposed are to soften the steel partially and to obtain release of internal stresses. In this treatment, grain refinement by face transformation is not accomplished as it is in full annealing process, annealing is extensively used in treatment of sheet and wire. For this purpose, the steel is heated to temperature between 549 and 649^0 C.

SPHERIODIZING ANNEALING

It is extensively used for high carbon steels to transform lamellar pearlite into granular type (refer fig of microstructure). This process is performed by heating the steel slightly above the critical point AC_1 (730-770^0 C) with subsequent holding at this temperature followed by slow cooling at a rate of 25-30^0C/hour to 600^0 C.

ISOTHERMAL ANNEALING

It is the operation where steel is heated as per full annealing and then cooled comparatively rapidly (in air or by blast in the furnace) to a temperature below point Ar_1 . The steel is held isothermally at this temperature during certain period of time to provide for complete austenite decomposition. Comparatively rapid cooling follows this. The main advantage of isothermal annealing is that it reduces the time required for heat treatment of steel.

HOMOGENIZING OR DIFFUSION ANNEALING

It is done on steel ingots and heavy castings for eliminating chemical in homogeneity, by diffusion. The steel is heated to about 1100^0 C, cooled slowly to about 800^0 C and then cooled in still air to room temperature.

NORMALIZING

It is a process consisting of heating the steel to temperature from 40-50^0 C above point AC_3 (Acm), holding at this temperature for a short time, and subsequent cooling in air. Normalizing is used to eliminate coarse grain structure obtained in previous working (rolling, forging, stamping etc,,), to increase the strength of medium carbon steels to a certain extent in comparison with annealed steel, to improve the machinability of low carbon steel, to improve the structure in welds, to reduce internal stresses, to eliminate the ceementatite network in hypereutectoid steels.

Normalized carbon steel consist of pearlite and ferrite in hypo eutectoid steels and of pearlite and cementatite hyper eutectoid steels. Normalizing is frequently applied as a final heat treatment for items, which are to operate at relatively high stresses. It is extensively used for improving the properties of steel castings, to increase yield point, tensile strength and impact strength than annealed castings.

HARDENING

It is a heat treating process in which steel is heated to a temperature above a critical point held at this temperature, and then quenched in water, oil or molten salt baths.

Hypo eutectoid steels are heated from 30-50^0 C above point Ac_3 while hyper eutectoid steels are heated above point Ac_1.In the first case, ferrite and pearlite, and in the second, pearlite and cementite are transformed into austenite upon heating. A considerable part of the cementite is retained.

Cooling at a rate higher than the critical value should enable the austenite to be super cooled to the marten site point. Hardened steel is in stressed condition and is very brittle so that it cannot be employed for practical purposed. After hardening, the steel must be tempered to reduce the brittleness to relieve the internal stresses caused by hardening, and to obtain predetermine mechanical properties. It increases the hardness and wear resistance, retaining sufficient toughness at the same time.

Selecting the hardening temperature depends upon its chemical composition and principally upon its carbon content.

Hypo eutectoid steels, containing pearlite and excess ferrite are hardened by heating to a temperature slightly (30-50^0 C) above point AC_3.

Hypereutectoid steels are heated in hardening to a temperature of AC_1+(30-50^0 C). Fig shows the microstructure of hypereutectoid steels before hardening, after normal hardening and after hardening with over heating.

TEMPERING

It leads to the decomposition of martensite into a ferrite cementite mixture and strongly affects all properties of steel. At low tempering temperatures (200-350^0 C), the hardness changes only to a small extent and the true tensile strength and bending strength are increased. A further increase in the tempering temperature reduces the hardness, true tensile strength, proportional limit and yield point while the relative elongation and reduction of area are increased. Tempering at 250-400^0 C reduces the impact strength of steel, which can be known as temper brittleness.

Tempering is the principal method for relieving residual stresses in hardened steel. The higher the tempering temperature, the more completely the internal stresses, caused by quenching, will be relieved. After tmpering a cylindrical specimen at 550^0 C, the maximum axial stresses were reduced from 60 to 8 kg per sq.mm.
Tempering temperatures are classified in accordance with the heating conditions.
Low-temperature tempering is performed in the range from 150-250^0 C and its purpose is to reduce to internal stresses and to increase toughness without any appreciable loss in hardness. This type of tempering is used for measuring and cutting tools of carbon and alloy steels, as well as parts that have been surface hardened, case carburized and so forth. The following holding times at tempering temperature may be recommended for carbon and alloy tool steels.

Diameter (thickness) of the tool, mm.	Holding time, Hrs.
Up to 20	1.0
21-40	1.5
41-60	2.0
Over 60	2.5

Medium temperature tempering at 350-450^0 C is employed for coil and laminated springs provided highest attainable elastic limit in conjunction with ample toughness.
High temperature tempering is performed in the range 500-650^0 C. It almost completely eliminates internal stresses and provides the most favorable ratio of strength to toughness for structural steels.

CARBURIZING

It is the process of saturating the surface layer of steel with carbon. The main purpose of carburizing is to obtain a hard and wear resistant surface on machine parts by enrichment of the surface layer with carbon to a concentration from 0.75 to 1.2% and subsequent quenching. Steels which has been carburized and quenched (case hardened) has a higher fatigue limit.

In practice steel is carburized in the range from 900-950^0 C, where carbon is diffused in gamma iron. Carburizing normally take several hours. More time (10-20 hrs) is seldom required. The carbon concentration in the surface layer does not usually exceed 0.8 to 1.2% for a holding time of several hours. Carbon content at the surface depends on the temperature of the process, holding time the steel composition, and the activity of the surrounding medium, which supplies carbon atoms to the surface.

RESULTS:

1. Material of the specimen -
2. Heat treatment details:
    - i) Heat treatment operation -
    - ii) Temperature -
    - iii) Soaking period -
    - iv) Quenching medium - (cooling in furnace, still air water, oil)
    - v) Cooling rate -
    - vi) Hardness before treatment - (RHB, RHC)
    - vii) Hardness after treatment - (RHB, RHC)

DESCRIPTION OF SOME IMPORTANT TERMS

- Alloys of iron-carbon system include steel and cast.
- Alloys with carbon content up to 2% are called steels.
- Alloys of carbon content exceeding 2% are called cast iron.
- **Critical temperatures:** When steel is heated (or cooled), transformations, associated with structural changes, occur at definite temperatures (depending on the composition of steel). These temperatures are called 'critical temperatures' or 'critical points'.
- Melting point of a cast iron is 1539 ^{0}C .
- α and γ irons are the two allotropic forms of iron.
- α iron has body centered atomic arrangement and is called ferrite (solid solution of carbon in α iron). This is magnetic.
- γ iron has face centered atomic arrangement and is called austenite (solid solution of carbon in γ iron). This is non magnetic.
- In addition to solid solutions (ferrite and austenite), iron and carbon Forms a chemical compound called iron-carbide (Fe_3C) and is called Cementite. (cementite has 6.67% carbon).
- Hypoeutectic cast iron-cast iron of any composition between 2.0 to 4.3%C.
- Eutectic cast iron- Cast iron with 4.3%C.
- Hypereutectic cast iron- cast iron of any composition between 4.3 to 6.67% C.
- Eutectoid steels – Steels at 0.8%C consisting of 100% pearlite.
- Hypo eutectoid steels – Steels less than 0.8%C.
- Hyper eutectoid steels – Steels above 0.8%C.
- Pearlite is the eutectoid mixture of ferrite and cementite.
- Lediburite – Eutectic mixture of austenite and cementite.

TRANSFORMATION IN STEEL:

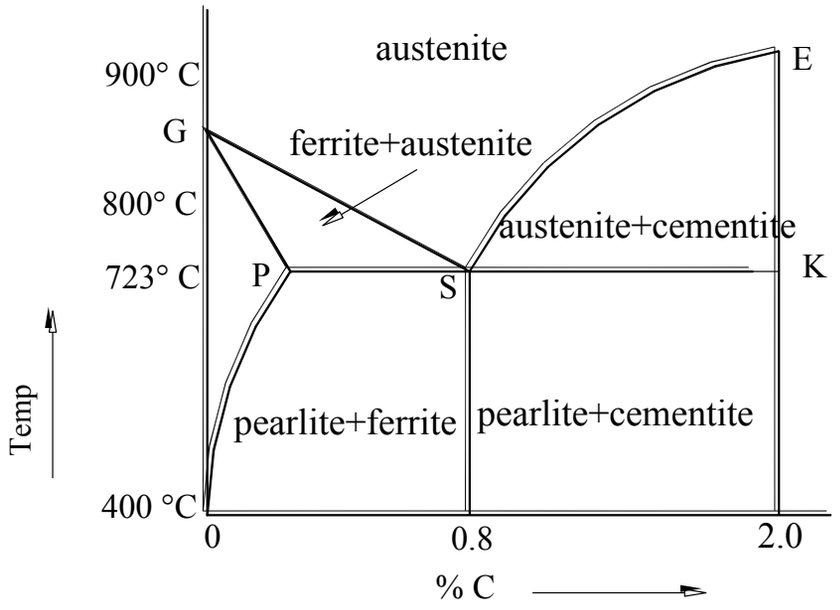


FIG: Iron - Carbon Equlibrium Diagram
(Transformations in steel)

Line GS – indicates the beginning of austenite decomposition and the precipitation of ferrite from the austenite. The critical points along the line GS are designated as AC_3 in heating and as Ar_3 in cooling.
Line SE – indicates the temperatures at which austenite begin to decompose with precipitation of excess carbon as cementite. Temperatures along SE are designated as AC_m points.
Point S – corresponding to 0.8%C, shows the minimum temperature 723^0C at which austenite may exist in a state of equilibrium. At point S, austenite decomposes with simultaneous precipitation of ferrite and cementite, which forms eutectoid mixture of ferrite and cementite known as pearlite.
Line PSK – The decomposition of austenite with formation of pearlite corresponds to the line PSK (723^0C) for all iron carbon alloys. The critical temperatures (723^0C) at which pearlite is formed (transformation of austenite into pearlite) in cooling is designated as Ar_1, and critical temperature at which austenite is formed (transformation of pearlite into austenite) in heating is designated as AC_1.