Laboratory Manual
Subject Code: ESME-403
Subject Name: Elements of Mechanical Engineering Lab.
UG Programme

Developed By
Dr. Anil Kumar Singla, AsP (ME)

DEPARTMENT OF MECHANICAL ENGINEERING
SANT LONGOWAL INSTITUTE OF ENGINEERING AND TECHNOLOGY
(Deemed to be University)
LONGOWAL-148106, (PUNJAB)

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GENERAL INSTRUCTION

1. All the students are instructed to wear protective uniform, Shoes and identity card before entering into the laboratory.
2. Before starting the exercise, students should have a clear idea about the principal of that exercise.
3. All the students are advised to come with completed record and corrected observation book of pervious experiment.
4. Do not operate any instrument/machine without getting staff member's prior permission.
5. The entire instrument is costly. Hence handle them carefully, to avoid fine for any breakage.
6. Utmost care must be taken to avert any possible injury while on Laboratory work. In case, anything occurs immediately to the staff members.
7. One student from each batch should put his/her signature during receiving the instrument in instrument issue Register.

ESME-403 : Elements of Mechanical Engineering Lab.

List of Experiments

Exp. No.	Title
1.	To verify the Zeroth law of thermodynamics.
2.	To study the COP's of Heat pump and Refrigerator.
3.	Draw stress strain diagram for ductile material using Universal Testing Machine and identify its salient features.
4.	Draw stress strain diagram for brittle material using Universal Testing Machine and identify its salient features.
5.	To perform Charpy-V Notch test to examine the toughness of given material.
6.	To study different types of kinematic links, kinematic pairs and kinematic chains
7.	To study different kind of planner mechanism: four bar mechanism, single slider crank mechanism and double slider mechanism.
8.	To find out the mechanical advantage, velocity ratio and efficiency of first system of pulley.
9.	To find out mechanical advantage, velocity ratio and efficiency of a simple lifting machine.
10.	To study the classification and properties of various engineering materials.

Title of the course : **Elements of Mechanical Engineering Lab**
Subject Code : **ESME - 403**

L	T	P	Credits	Weekly Load
0	0	2	1	2

COURSE OUTCOMES:
After successful completion of course, the students should be able to
CO1: Learn about the basic concepts of thermodynamics.
CO2: Understand various laws of thermodynamics and how it is applied on various engineering devices.
CO3: Understand the behavior of solids under various types of loads.
CO4: Learn about the mechanism of different machines and its applications.
CO5: Get knowledge about properties of engineering materials and its industrial applications.

Aim: - To verify the Zeroth Law of Thermodynamics
Apparatus: - Thermostat; Three bodies. A, B, C; A&B, B&C must be in thermal equilibrium

Theory: - According to Zeroth law of thermodynamics. "If two systems, A and B, are each in thermal equilibrium with a third system, C, then they are in thermal equilibrium with each other."
For Example, the wooden chair and iron chair, initially at different temperatures, when left in the same room, will eventually reach the same temperature as the surrounding air due to the Zeroth Law of Thermodynamics, which states that if two systems are in thermal equilibrium with a third system, they are also in thermal equilibrium with each other.

Procedure: -

1. Take a thermometer and place it in contact with the first body, like wood.
2. Note down the temperature of wood.
3. Put another thermometer with metal body and note down the temperature.
4. Note down the temperature of surrounding after some time, note temperature of both the bodies lies same with surrounding.
5. This shows that all of them are in equilibrium with each other.

Precautions: -
Thermometer must be working properly.

Result: -
Thus, we prove that A, B, C are in equilibrium and zeroth law of thermodynamics is verified.

Aim: To compute COP of Heat Pump and Refrigerator

INTRODUCTION: Refrigeration is the branch of science that deals with the process of reducing and maintaining the temperature of a space or material below the temperature of the surroundings. Heat must be removed from the body being refrigerated and transferred to another body whose temperature is below that of the refrigerated body.

THEORY: A mechanical heat pump is mechanical equipment which is used to supply the heat to the system, where it is installed, and maintain its temperature more than that of surrounding. Mechanical heat pump absorbs heat from surrounding (atmosphere). Work input to a heat pump is supplied by compressor.

Performance of heat pump is given by

$$C.O.P = \frac{Q}{W}$$

Where

Q = Heat removed from the system

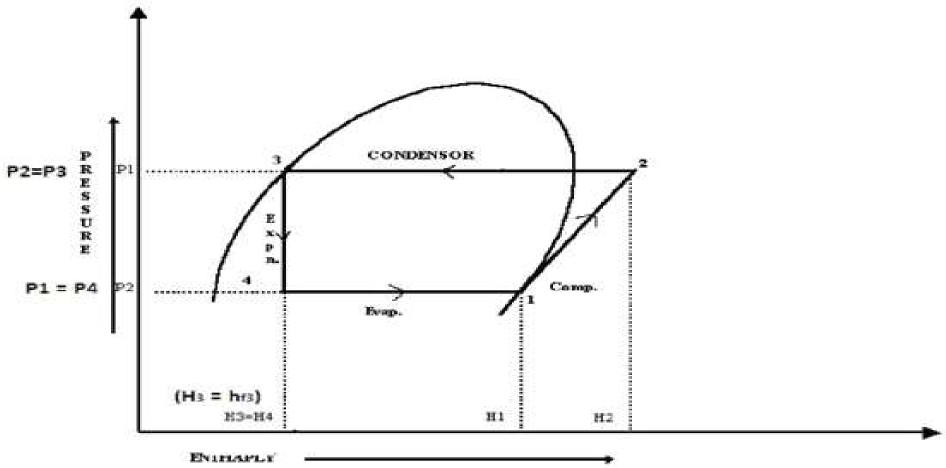
W = Work supplied in compressor

VAPOUR COMPRESSOR CYCLE:

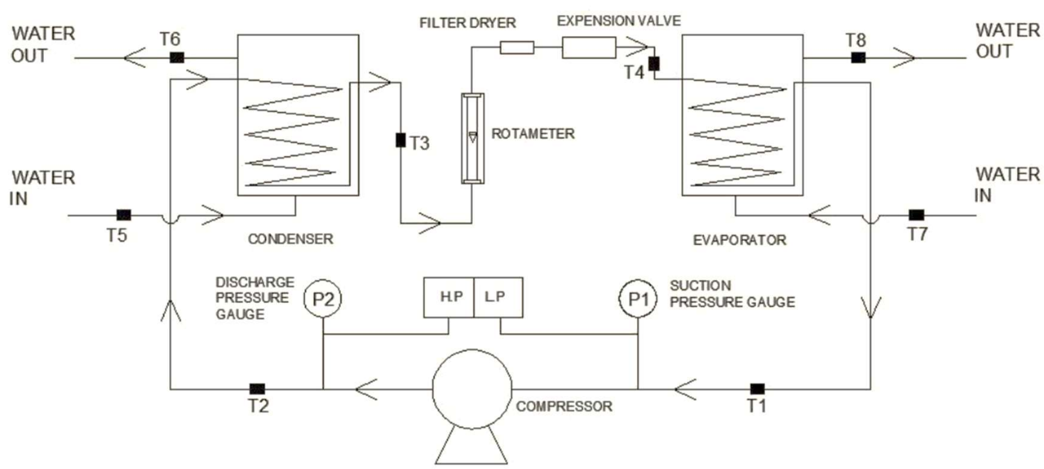
The refrigerant starts at some initial state or condition, passes through a series of processes in a definite sequence and returns to the initial condition. This series of processes is called a cycle.

The Standard Vapour Compressor Cycle (SVCC) consists of the following processes:

- 1-2 Reversible adiabatic compression from the saturated vapour to a super heated Condition (electrical) input.
- 2-3 Reversible heat rejection at constant pressure (de-superheating and condensation of the refrigeration)
- Irreversible is enthalpy expansion from saturated liquid to a low-pressure vapour.
- Reversible heat addition at constant pressure.



STANDARD VAPOUR COMPRESSION CYCLE (SVCC):



SCHEMATIC DIAGRAM OF HEAT PUMP TEST RIG

COMPRESSOR:

The main function of compressor is to raise the pressure and temperature of the refrigerant by the compression of the refrigerant vapour and then pump it into the condenser.

CONDENSER:

Condense the vapour refrigerant into the liquid by condenser and passes it into the receiver tank for recirculation.

CAPILLARY TUBE:

It expands the liquid refrigerant at high pressure to the liquid refrigerant at low pressure so that a measured quantity of liquid refrigerant is passed into the evaporator.

THERMOSTATIC EXPENSION VALVE:

It also expands the liquid refrigerant at high pressure to the liquid refrigerant at low pressure so that a measured quantity of liquid refrigerant is passed into the evaporator.

EVAPORATOR:

Evaporates the liquid refrigerant by absorbing the heat into vapour refrigerant and sends back into the compressor.

DRIER:

A drier is used in between the condenser and expansion device. The main function of the drier is to absorb the moisture from the liquid refrigerant and filter the dust particles.

COEFFICIENT OF PERFORMANCE:

The coefficient of performance of (C.O.P.) of a refrigerating cycle is defined as the ratio between net refrigeration (output) and compressor work (input).

$$C.O.P = \frac{RE}{CW}$$

DESCRIPTION:

The Heat pump test rig is designed for the study of Vapour Compression Refrigeration Cycle. The set up consist of compressor (1/3 Tones) filled with refrigerant **R-134a**. Discharge of the compressor is connected to water cooled condenser (shell & coil condenser with refrigerant inside the tube). The condensed gas after condenser passes through drier and then to the expansion device i.e. Thermostatic expansion valve. A water tank (Evaporator) is provided in which expended gas flows through coils and then returns back to the compressor. Two rotameters are also installed in the water line, one for each condenser and evaporator, to measure water flow rate. Instrumentation is done to measure the temperature & pressure wherever necessary.

PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

- Never run the apparatus if power supply is less than 180 volts and above 230 volts.
- Do not start unit, before putting the water in the condenser and evaporator.

OBSERVATION & CALCULATION:

DATA:

Power factor Cos Φ = 0.8

Density of water ρ_w = 1000 kg/m^3

Specific heat of water Cp = 4.186 kJ/kg ^{o}C

OBSERVATION TABLE:

P1	
P2	
T1 (°C)	
T2 (°C)	
T3 (°C)	
T4 (°C)	
T5 (°C)	
T6 (°C)	
T7 (°C)	
T8 (°C)	
V, Volt	
I, Amp	
F_C , LPH	
F_E , LPH	

CALCULATION FOR COLD WATER (IN EVAPORATOR)

$$m = \frac{F_E \times \rho}{1000 \times 3600}\text{, Kg/sec}$$

$$RE_{Act} = m \times C_P \times (T_7 - T_8)\text{, KJ/sec}$$

$$CW_{Act} = \frac{V \times I \times \cos\phi}{1000}\text{ KJ/sec}$$

$$(C.O.P)_{Act} = \frac{RE_{Act}}{CW_{Act}}$$

CALCULATION FOR HOT WATER (IN CONDENSER)

$$m = \frac{F_C \times \rho}{1000 \times 3600}\text{, Kg/sec}$$

$$RE_{Act} = m \times C_P \times (T_5 - T_6)\text{, KJ/sec}$$

$$CW_{Act} = \frac{V \times I \times \cos\phi}{1000}\text{ KJ/sec}$$

$$(C.O.P)_{Act} = \frac{RE_{Act}}{CW_{Act}}$$

NOMENCLATURE:

Nom	Column of Heading	Units
ρ_w	Density of water,	kg/m^3.
Cos Φ	Power factor	0.8
C_p	Specific heat of water	kJ/ kg ^{o}C
I	Ammeter reading	Amps
m	Mass of water	kg/sec
P_1	Pressure at compressor suction	kg/cm^2
P_2	Pressure at compressor discharge	kg/cm^2
T_1	Temperature at compressor suction	°C
T_2	Temperature at compressor discharge°C	°C
T_3	Temperature at condenser outlet °C	°C
T_4	Temperature at evaporator inlet °C	°C
T_5	Temperature of water inlet for condenser	°C
T_6	Temperature of water outlet for condenser	°C
T_7	Temperature of water inlet for Evaporator	°C
T_8	Temperature of water outlet for Evaporator	°C
V	Voltmeter reading	volts
F_C	Flow rate of water through Condenser	LPH
F_E	Flow rate of water through evaporator	LPH
RE_{Act}	Refrigeration Effect (output)	KJ/sec
CW_{Act}	Compressor work (input)	KJ/sec
$C.O.P._{Act}$	Actual Coefficient of performance	

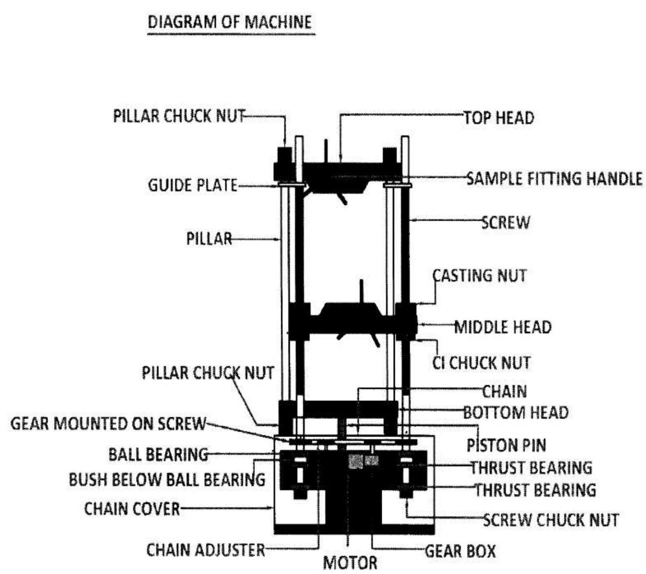
Aim: **-** Draw stress strain diagram for ductile material using Universal Testing Machine and identify its salient points.

Equipments required: **-** Universal Testing Machine with all attachment i.e. shear test attachment, bending attachment, tension grips, compression test attachment etc.

THEORY: **-** The Universal Testing Machine consists of two units.

1. Loading unit
2. Control panel

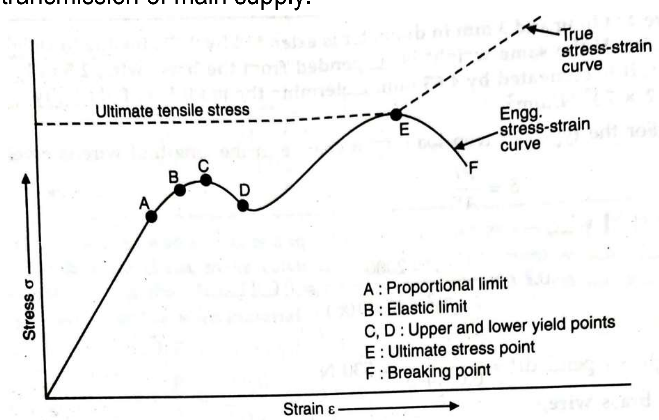
Universal Testing Machine (UTM)



Computerized Universal Testing Machine
Capacity: 600 KN.
Model: - AEC 1112-60T , Sr.No.. - 2K19J26
Mfd. By: M/s Ashian engineers Company India, Ashian, 831, Westend Mall , District Center, Janakpuri, New Delhi- 110058

LOADING UNIT: - It consists of main hydraulic cylinder with robust base inside. The piston which moves up and down. The chain driven by electric motor which is fitted on left hand side. The screw column maintained in the base can be rotated using above arrangement of chain. Each column passes through the main nut which is fitted in the lower cross head. The lower table connected to main piston through a ball & the ball seat is joined to ensure axial loading. There is a connection between lower table and upper head assembly that moves up and down with main piston. The measurement of this assembly is carried out by number of bearings which slides over the columns. The test specimen is fixed in the job is known as 'Jack Job'. To fix up the specimen tightly, the movement of jack job is achieved helically by handle.

CONTROL PANEL: - It consists of oil tank having a hydraulic oil level sight glass for checking the oil level. The pump is displacement type piston pump having free plungers those ensure for continuation of high pressure. The pump is fixed to the tank from bottom. The suction & delivery valve are fitted to the pump near tank Electric motor driven the pump is mounted on four studs which is fitted on the right side of the tank. There is an arrangement for loosing or tightening of the valve. The four valves on control panel control the oil stroke in the hydraulic system. The loading system works as described below. The return valve is close, oil delivered by the pump through the flow control valves to the cylinder & the piston goes up. Pressure starts developing & either the specimen breaks or the load having maximum value is controlled with the base dynameters consisting in a cylinder in which the piston reciprocates. The switches have upper and lower push at the control panel for the downward & upward movement of the movable head. The on & off switch provided on the control panel & the pilot lamp shows the transmission of main supply.



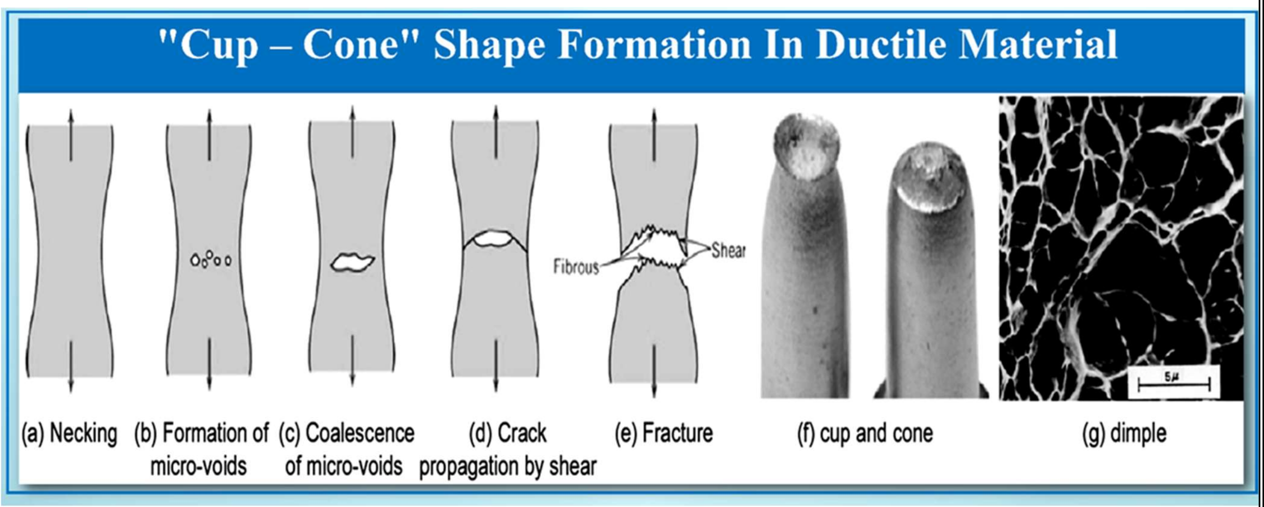
Proportional limit: Stress is a linear function of strain and the material obeys Hook's law. This proportionality extends upto point A and this point is called proportional limit or limit of proportionality. 0-A is a straight line portion of the curve and its slope represents the value of modulus of elasticity.

Elastic limit: Beyond proportional limit, stress and strain depart from straight line relationship. The material however, remains elastic upto state point B. The word elastic implies that the stress developed in the material is such that there is no residual or permanent deformation when the load is removed. Upto to this point, the deformation is reversible or recoverable. Stress at B is called the elastic limit stress; this represents the maximum unit stress to which a material can be subjected and is still able to return to its original form upon removal of load.

Yield point: Beyond elastic limit, the material shows considerable strain even there is no increase in load or stress. This strain is not fully recoverable, i.e., there is though no tendency of the atoms to return to their original positions. The behaviour of the material is inelastic and the onset of plastic deformation is called yielding of the material- Yielding pertains to the region C-D and there is drop in load at the point D. The point C is called the upper yield point and point D is the lower yield point. The difference between the upper and lower yield point is small and the quoted yield stress is usually the lower value.

Ultimate strength or tensile strength: After yielding has taken place, the material becomes strain hardened strength of the specimen increases) and an increase in load is required to take the material to its maximum stress at point E. Strain in this portion is about 100 times than that of the portion from 0 to D. Point E represents the maximum ordinate of the curve and the stress at this point is known either as ultimate stress or the tensile stress of the material.

Breaking strength: In the portion EF, there is falling off the load (stress) from the maximum until fracture takes place at F. The point F is referred to as the fracture or breaking point and the corresponding stress is called the breaking stress.



<u>METHOD OF TESTING</u>: - Initial Adjustment: - Before testing adjust the pendulum with respect to capacity of the test i.e. 8 Tones; 10 Tones; 20 Tones; 40 Tones etc. For ex: - A specimen of 6 tones capacity gives more accurate result of 10 Tones capacity range instead of 20 Tones capacity range. These ranges of capacity are adjusted on the dial with the help of range selector knob. The control weights of the pendulum are adjusted correctly. The ink should be inserted in pen holder of recording paper around the drum & the testing process is started depending upon the types of test as mentioned below.

<u>TENSION TEST</u>: - Select the proper job and complete upper and lower check adjustment. Apply some Greece to the tapered surface of specimen or groove. Then operate the upper cross head grip operation handle & grip the upper end of test specimen fully in to the groove. Keep the lower left valve in fully close position. Open the right valve & close it after lower table is slightly lifted. Adjust the lower points to zero with the help of adjusting knob. This is necessary to remove the dead weight of the lower table. Then lock the jobs in this position by operating job working handle. Then open the left control valve. The printer on dial gauge at which the specimen breaks slightly return back & corresponding load is known as breaking load & maximum load is known as the ultimate load.

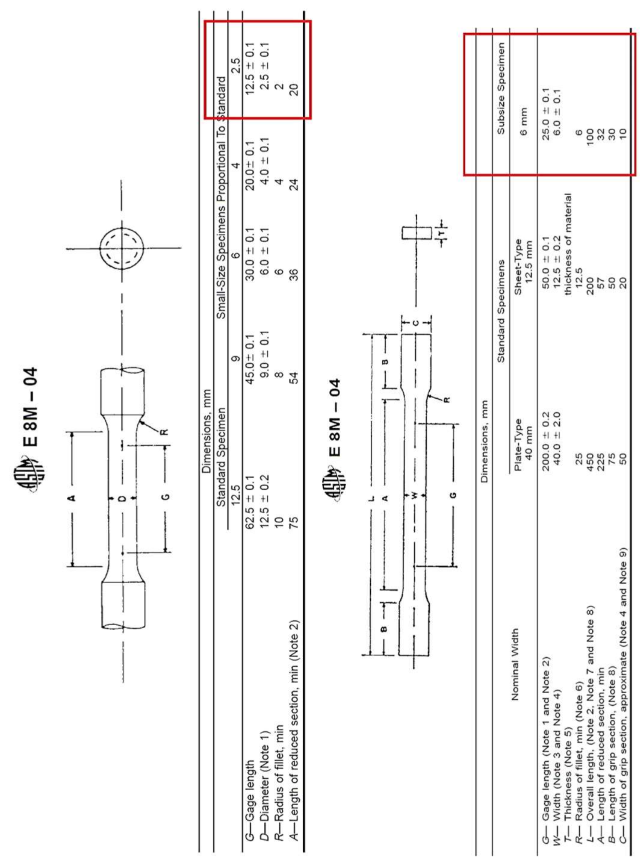
<u>STUDY OF EXTENSOMETER</u>: - This instrument is an attachment to Universal / Tensile Testing Machines. This measures the elongation of a test place on load for the set gauge length. The least count of measurement being 0.01 mm and maximum elongation measurement up to 5 mm. This elongation measurement helps in finding out the proof stress at the required percentage elongation.

<u>WORKING OF THE INSTRUMENT</u>: - The required gauge length (between 30 to 200) is set by adjusting the upper knife edges, scale is provided for this purpose. Hold the specimen in the upper and lower jaws of Tensile / Universal Testing Machine. Position the extensometer on the specimen. Position upper clamp to press upper knife edges on the specimen. The extensometer will be now fixed to the specimen by spring pressure. Set zero on both the dial gauges by zero adjust screws. Start loading the specimen and take the reading of load on the machine at required elongation or the elongation at required load. Force setter accuracies mean of both the dial gauge readings should be taken as elongation. It is very important to note & follow the practice of removing the extensometer from the specimen before the specimen breaks otherwise the instrument will be totally damaged. As a safety, while testing the instrument may be kept hanging from a fixed support by a slightly loose thread.

<u>TECHNICAL DATA</u>: -

Measuring Range: 0 – 3 mm Least Count: 0. 01 mm Gauge Length adjustable from: 30 - 120 mm Specimen Size: 1 to 20 mm Round or Flats up to 20 x 20 mm

<u>SPECIMEN DIAGRAM</u>



Dimensions, mm	Standard Specimen	Small-Size Specimens Proportional To Standard			
	12.5	9	6	4	2.5
G—Gage length	62.5 ± 0.1	45.0± 0.1	30.0 ± 0.1	20.0± 0.1	12.5 ± 0.1
D—Diameter (Note 1)	12.5 ± 0.2	9.0 ± 0.1	6.0 ± 0.1	4.0 ± 0.1	2.5 ± 0.1
R—Radius of fillet, min	10	8	6	4	2
A—Length of reduced section, min (Note 2)	75	54	36	24	20

Dimensions, mm	Standard Specimens		Subsize Specimen
Nominal Width	Plate-Type 40 mm	Sheet-Type 12.5 mm	6 mm
G— Gage length (Note 1 and Note 2)	200.0 ± 0.2	50.0 ± 0.1	25.0 ± 0.1
W— Width (Note 3 and Note 4)	40.0 ± 2.0	12.5 ± 0.2	6.0 ± 0.1
T— Thickness (Note 5)		thickness of material	
R— Radius of fillet, min (Note 6)	25	12.5	6
L— Overall length, (Note 2, Note 7 and Note 8)	450	200	100
A— Length of reduced section, min	225	57	32
B— Length of grip section, (Note 8)	75	50	30
C— Width of grip section, approximate (Note 4 and Note 9)	50	20	10

Observation Table

Lower Yield Point Strength	
Upper Yield Point Strength	

% Elongation	
%age reduction in Area	
Ultimate Tensile Strength	
Breaking Point Strength	

	Sant Longowal Institute of Engineering and Technology, Longowal	**ESME-403**
	Experiment No. 4	**Elements of Mechanical Engineering Lab**

Aim: - Draw stress strain diagram for brittle material using Universal Testing Machine and identify its salient points.

Equipments required: - Universal Testing Machine with all attachment i.e. shear test attachment, bending attachment, tension grips, compression test attachment etc.

THEORY: - The Universal Testing Machine consists of two units.

1. Loading unit
2. Control panel

LOADING UNIT: - It consists of main hydraulic cylinder with robust base inside. The piston which moves up and down. The chain driven by electric motor which is fitted on left hand side. The screw column maintained in the base can be rotated using above arrangement of chain. Each column passes through the main nut which is fitted in the lower cross head. The lower table connected to main piston through a ball & the ball seat is joined to ensure axial loading. There is a connection between lower table and upper head assembly that moves up and down with main piston. The measurement of this assembly is carried out by number of bearings which slides over the columns. The test specimen is fixed in the job is known as 'Jack Job'. To fix up the specimen tightly, the movement of jack job is achieved helically by handle.

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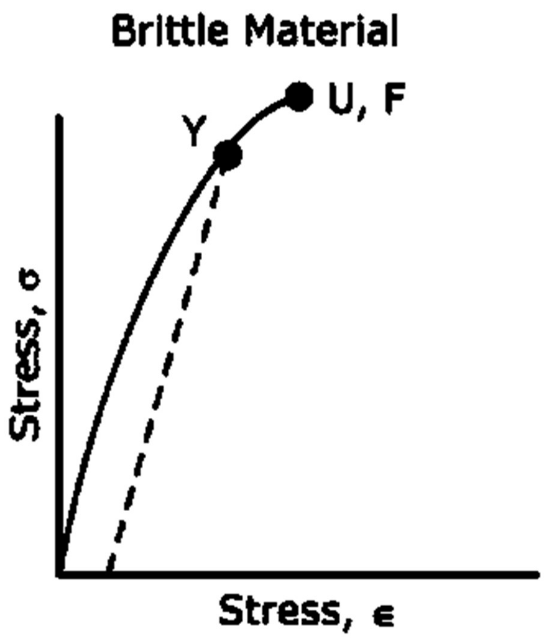
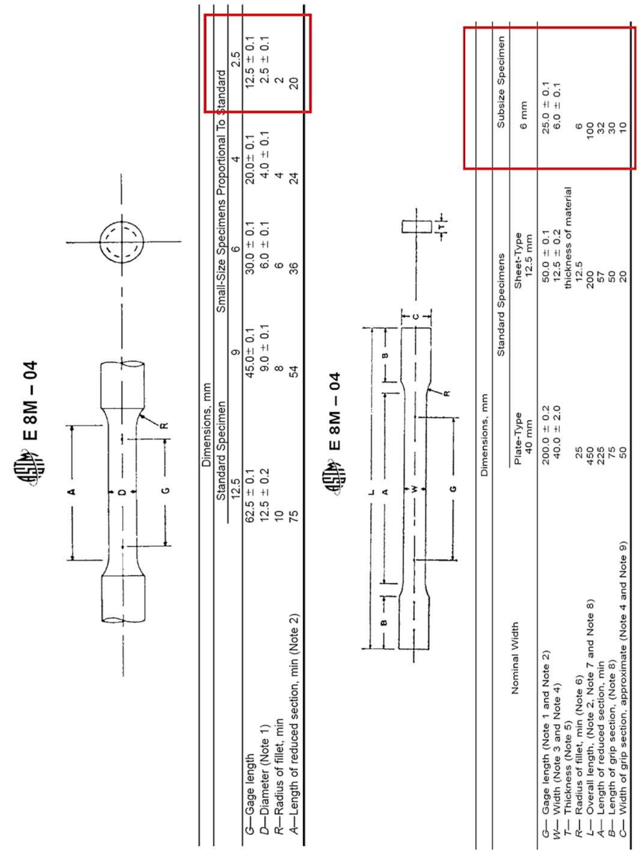
WORKING OF THE INSTRUMENT: - The required gauge length (between 30 to 200) is set by adjusting the upper knife edges, scale is provided for this purpose. Hold the specimen in the upper and lower jaws of Tensile / Universal Testing Machine. Position the extensometer on the specimen. Position upper clamp to press upper knife edges on the specimen. The extensometer will be now fixed to the specimen by spring pressure. Set zero on both the dial gauges by zero adjust screws. Start loading the specimen and take the reading of load on the machine at required elongation or the elongation at required load. Force setter accuracies mean of both the dial gauge readings should be taken as elongation. It is very important to note & follow the practice of removing the extensometer from the specimen before the specimen breaks otherwise the instrument will be totally damaged. As a safety, while testing the instrument may be kept hanging from a fixed support by a slightly loose thread.



SPECIMEN DIAGRAM



Observation Table

% Elongation	
%age reduction in Area	
Ultimate Tensile Strength	
Breaking Point Strength	

Aim: - To perform Charpy-V Notch test to examine the toughness of given material.

Equipments required: - 1) Charpy impact testing machine.
2) Test specimens.

THEORY: -

Several engineering materials have to withstand impact or suddenly applied load while in use impact strength, in general are less as compared to the strength achieved by the slowly applied load. An impact test signifies toughness of material that is ability of material to observe energy during plastic deformation.

To determine the notched beam impact strength of three type of notches are used i.e. V-notch, U-notch, Key-hole notch. These notches are shown in fig. the test field should be machine all over and 55 long and of square cross section with 100 mm sides. The notch is made up at the centre of the test specimen. The plane of symmetry of the notch should be perpendicular to the longitudinal axis of the test piece. The distance of the plane of symmetry of the notch from the end of the test shall be 27.5 ± 0.42 mm and the angle between the plane of the symmetry of the notch and longitudinal axis of the test piece shall be 90 ± 2o.

The notch should be prepared carefully by any machining method like milling, shaping, but no grooves should be visible to the naked eye. The test piece should lie squarely against the supports with the plane of symmetry of the notch within 0.5 mm of the plane mid-way between them as shown. It should be struck by hammer in the plane of symmetry of the notch on the side opposite to the notch. The speed of striking should be 5 m/s. The centre of the percussion should be at the point of the hammer. The accuracy of the graduation on the scale should be ± 0.5 % of maximum capacity of the machine. in our case, the maximum capacity of the machine is 30 kgf (300 Joules).

PROCEDURE: -

1) Lift the hammer to an appropriate knife -edge position and the note the energy stored in the hammer. For the standard test. It should be 30 kgf (300 Joules).
2) Locate the test piece on the machine support as showed.
3) Release the hammer. The hammer will break the specimen and shoot up to the other side of the machine.
4) Note the residual energy indicated on the scale by hammer.
5) The impact strength of the test piece is the difference of the initial energy stored in the hammer and the residual energy.
6) Calculate the impact module given by the ratio of rupture to the volume of the test piece below the notch.

OBSERVATIONS: -

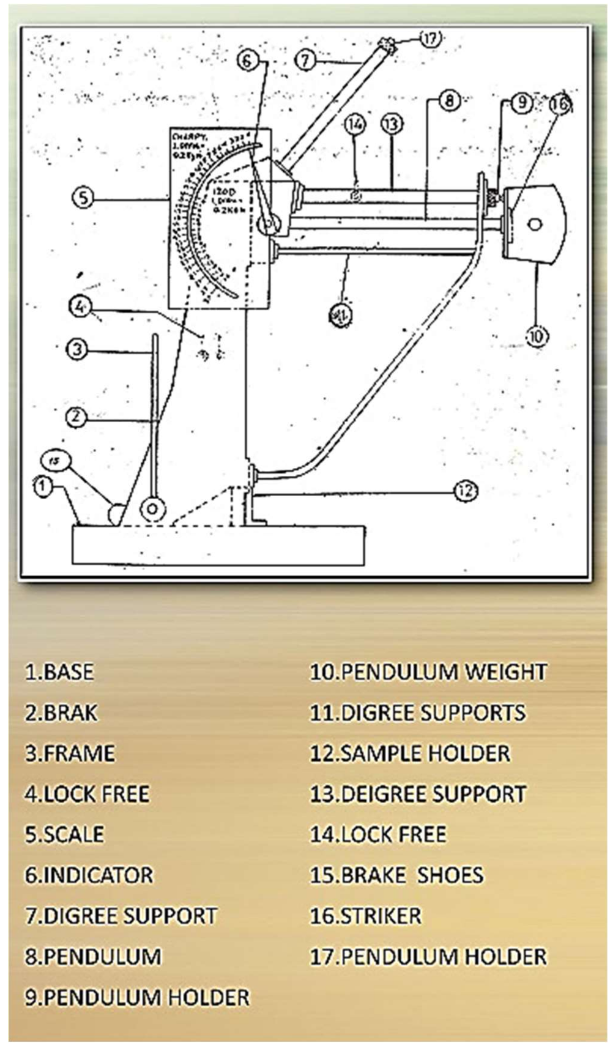
Material of the test piece =
Type of the notch =
Dimensions of the test piece =
Room temperature =
Velocity of striking =

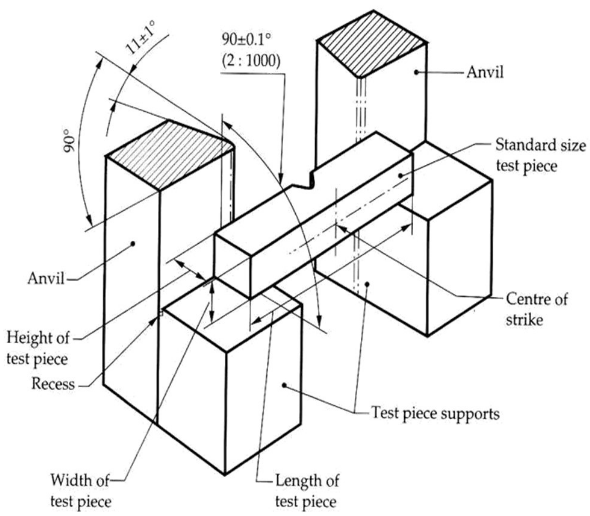
Test No.	Initial energy (Joules)	Residual energy (Joules)	Energy absorbed (Joules)
1.			
2.			

Mean value of impact strength= _______Joules.

PRECAUTIONS: -

1) The notch should be properly machined.
2) The test specimen should be correctly placed on the supports.
3) Machine bearing and moving parts should be lubricated





SOURCE OF ERRORS: -

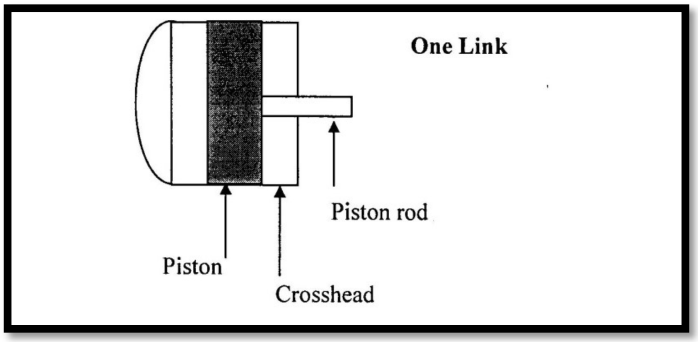
1) Velocity of striking.
2) Friction in bearing.
3) Air resistance to hammer.
4) Temperature changes during test.
5) Errors in machining of notch.
6) Variations in material compositions.

Aim: - To study different types of kinematic links, kinematic pairs and kinematic chains.

Equipments required: - Models of different links and pairs.

Theory: -

Kinematic Link: -Each part of a machine, which moves relative to some other part, is known as **kinematic link or element (or simple link).** A link may consist of several parts, which are rigidly fastened together, so that they do not move relative to one another. For example, in a reciprocating steam engine, piston, piston rod and crosshead constitute one link.



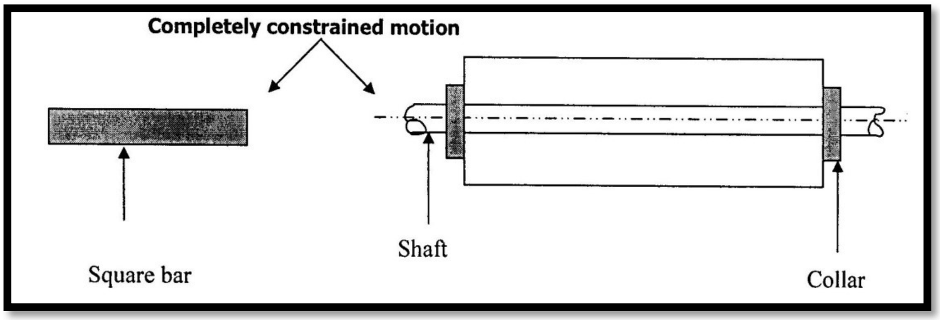
Types of Links: -

1. **Rigid Link: -** A rigid link is one which does not undergo any deformation while transmitting motion.
2. **Flexible Link: -** A flexible link is one which is partly deformed in a manner not affect the transmission of motion for e.g. belts, ropes, chains and wires.
3. **Fluid Link: -** A fluid link is one which is formed by having a fluid in a container and the motion is transmitted through the fluid by pressure or compression only, as in the case of hydraulic presses, jacks and brakes.

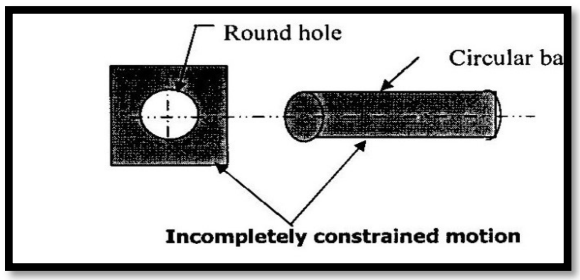
Kinematic Pair: - The two links or elements of a machine, when in contact with each other, are said to form a pair. If the relative motion between them is completely or successfully constrained (i.e. in a definite direction), the pair is known as *kinematic pair.*

The different types of constrained motion are as follows;

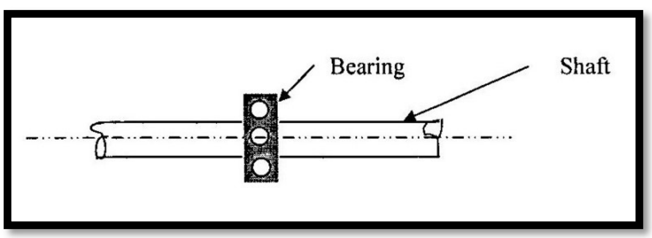
1. **Completely constrained motion: -** When the motion between a pair is limited to a definite direction irrespective of direction of force applied, then the motion is said to be completely constrained motion. The motion of a square bar in square hole and the motion of shaft with collar at each end in circular hole are also examples of completely constrained motion.



2. **Incompletely constrained motion: -** When the motion between a pair can take place in more than one direction, then the motion is called as incompletely constrained motion. A circular bar or shaft in a circular hole is the example of incompletely constrained motion because a circular bar or shaft either can rotate or slide in a circular hole.



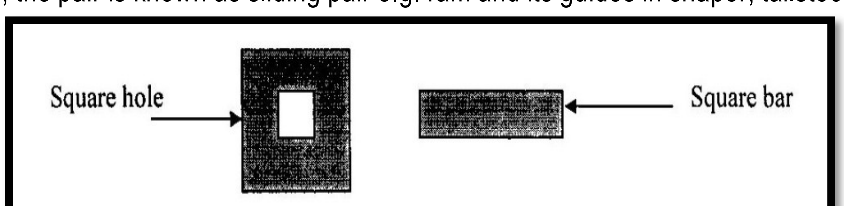
3. **Successfully constrained motion: -** When the motion between the elements forming a pair is such that the constrained motion is not completely by itself, but by some other means, then the motion is said to be successfully constrained motion. A shaft fastened in bearing can rotate only with help of bearing is the example of S.C.M.



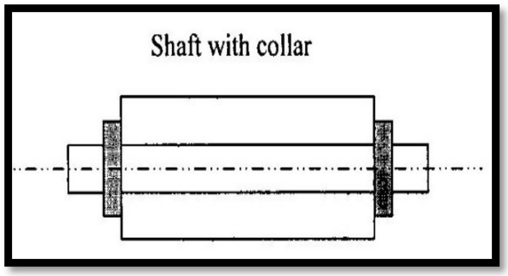
Classification of kinematic pairs: - The kinematic pairs may be classified according to the following considerations.

According to the type of relative motion between elements: -

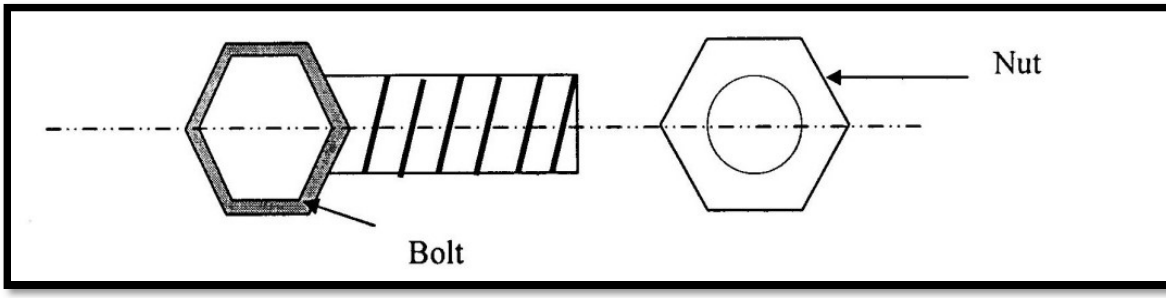
- **Sliding Pair :-** When two elements of a pair are connected in such a way that one can only slide relative to the other, the pair is known as sliding pair e.g. ram and its guides in shaper, tailstock on the lath bed.



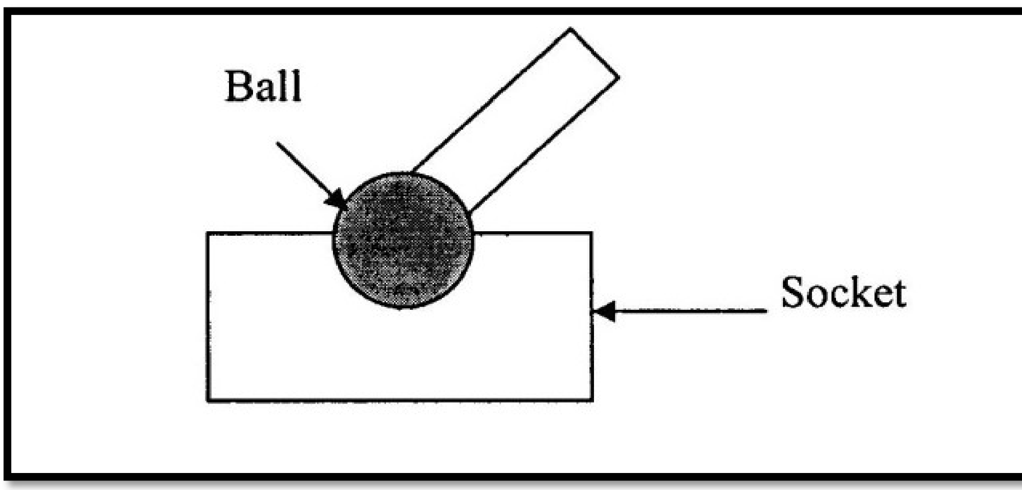
- **Turning Pair: -** When two elements of a pair are connected in such a way that one link is constrained to have only a turning motion relative to the other element. Shaft with collar is the example of turning pair.



- **Rolling Pair: -** When two elements of pair are connected in such a way that one of them is constrained to roll over the other. A road roller rolling over the ground is the example of the rolling pair.
- **Screw Pair: -** The pair in which one link turns about the other link by means of threads or screws such that the relative motion being a combination of turning and sliding is known as screw pair. Nut and bolt is the example of the screw pair.



- **Spherical Pair: -** When two elements of a pair are connected in such a way that one element turns or swivels about other fixed element are called spherical pair, ball and socket joint is the example of spherical pair.



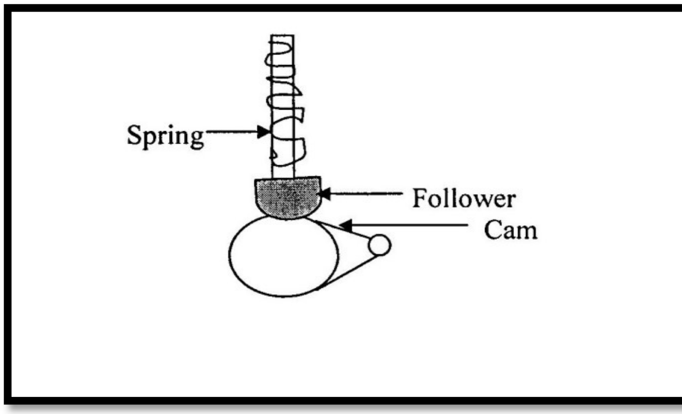
According to the types of contact between elements: -

- **Lower Pair: -** When two links or elements while having sliding or turning relative motion have surface contacts between them they constitute what is known as lower pair. For example a shaft revolving in a bearing, piston reciprocating in a cylinder etc.
- **Higher Pair: -** When two elements of a pair have line or point contact when relative motion takes place and motion between two elements is partially turning and partially sliding is called higher pair, e.g. ball and roller bearing, cam and follower.

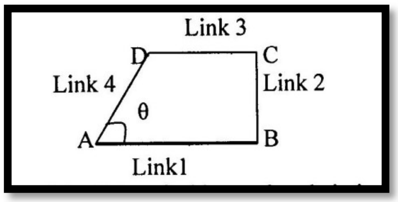
According to the type of closure: -

- **Self closed Pair: -** When two elements of a pair are connected together mechanically in such a way that only required kind of relative motion occurs, is called self closed pair. The lower pairs are self closed pair.

- **Force closed Pair: -** When two elements are not connected mechanically but are kept in contact by action of external forces pair is called force-closed pair. The cam and follower is an example of force closed pair, as it is kept in contact by the forces exerted by spring and gravity.



Kinematic chain: - When the kinematics pairs are coupled in such a way that last link is joined to the first link to transmit the definite motion, it is called a kinematic chain.



Aim: - To study different kind of planner mechanism: four bar mechanism, single slider crank mechanism and double slider mechanism.

Equipment's required: - Models of different mechanisms.

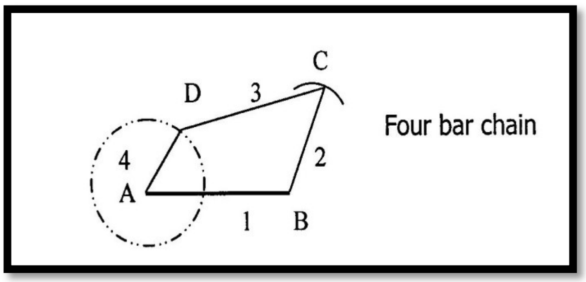
Theory: -

Mechanism: - When one of the links of a kinematics chain is fixed, the chain is known as mechanism. It may be used for transmitting or transforming motion e.g. engine indicators, typewriter etc.

- **Simple mechanism: -** A mechanism with four links is known as simple mechanism.
- **Compound mechanism: -** A mechanism with more than four links is known as compound mechanism.

Types of mechanism:

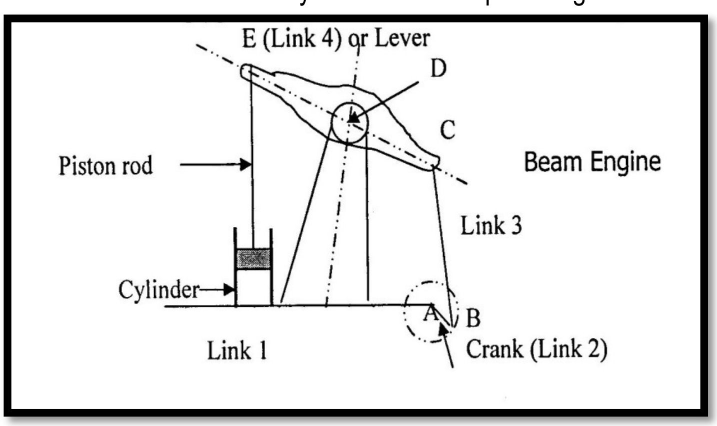
1. **Four Bar/Quadric Cycle Chain: -** Kinematic chain is a combination of four or more kinematic pairs, such that the relative motion between the links or elements is completely constrained. The simplest and the basic kinematic chain is a four bar chain or quadric cycle chain as shown in the figure.



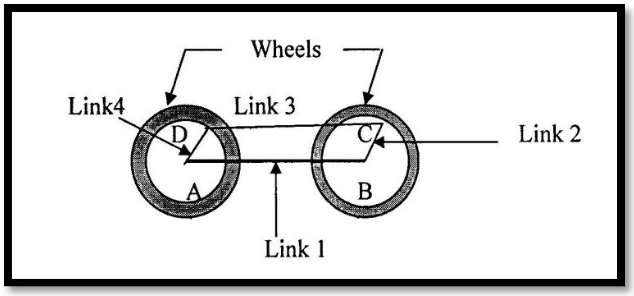
- **Inversion: -** The method of obtaining different mechanisms by fixing different links in a kinematic chain is known as inversion of the mechanism.

Inversion of Four bar Chain: -

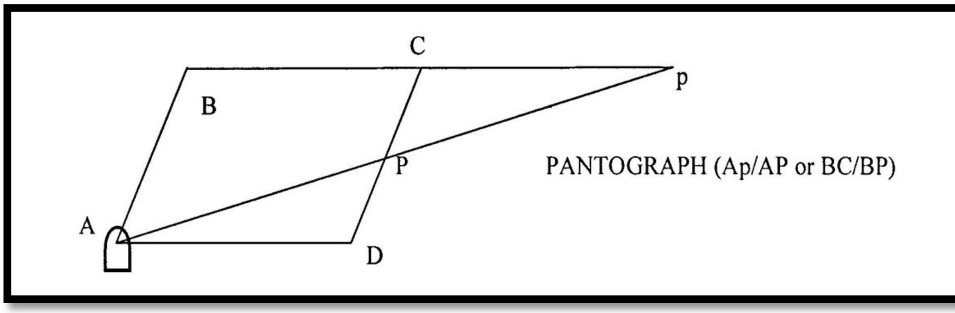
- **Beam Engine: -** A beam engine, also known as crank and lever mechanism consist of four links. The purpose of this mechanism is to convert rotary motion into reciprocating motion.



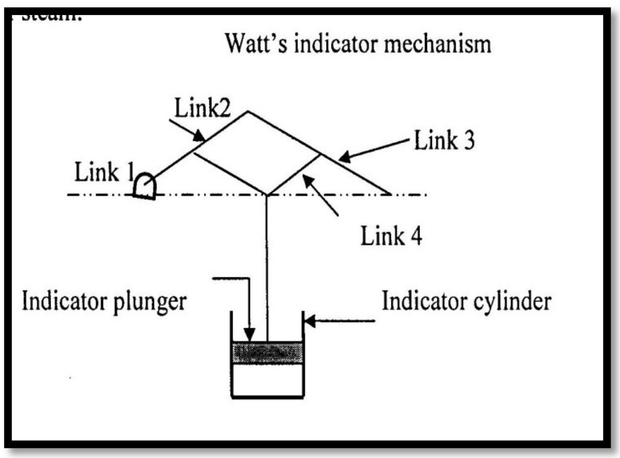
- **Coupling rod of locomotive: -** The mechanism of a coupling rod of locomotive (double crank mechanism) which consist of four links, is shown in figure.



- **<u>Pantograph: -</u>** It is a device which is used to reproduce a displacement, exactly, in an enlarged or reduced scale. It is used in drawing offices for duplicating the drawings.



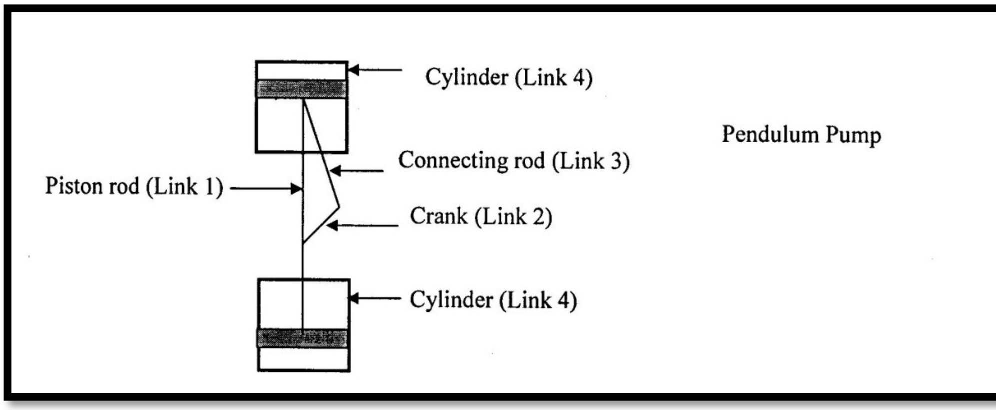
- **<u>Watt's Indicator: -</u>** A Watt's indicator mechanism also known as Watt's straight line mechanism or double lever mechanism which consists of four links. It is used to indicate the pressure of gas or steam.



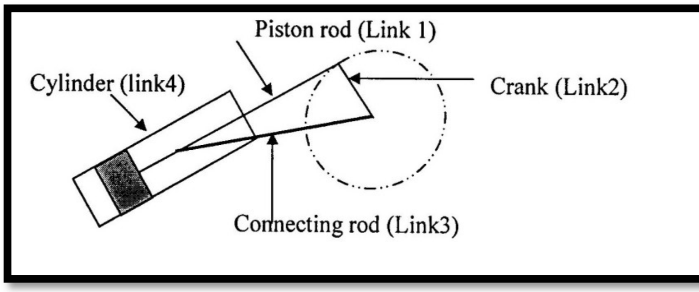
2. **<u>Single Slider Crank Chain:-</u>** A single slider crank is a modification of the basic four bar chain. It consists of one sliding pair and three turning pairs, e.g. reciprocating steam engine mechanism. This type of mechanism converts rotary motion into reciprocating and vice-versa.

<u>Inversions of Single Slider Crank Chain-</u>

- **<u>Pendulum pump or bull engine:</u> -** It is used to supply feed water to boilers. It consist two pistons attached to same link. In this case when crank rotates then connecting rod oscillates and piston reciprocates.

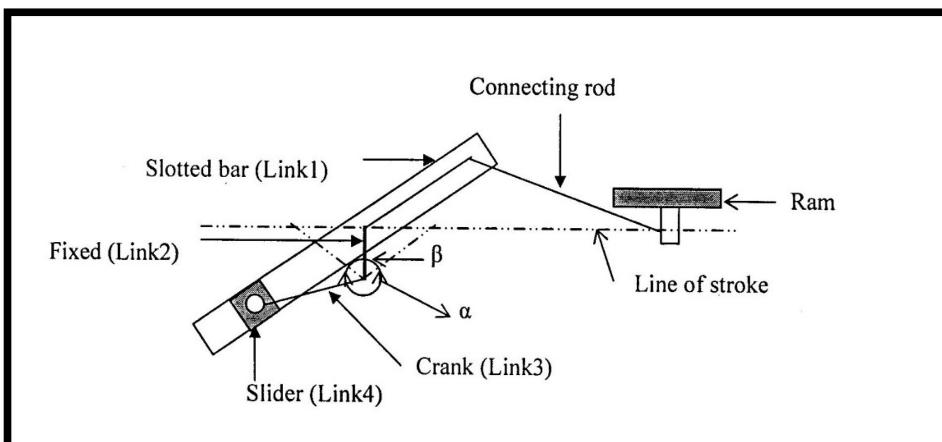


- **Oscillating cylinder engine: -** It is used to convert reciprocating motion into rotary motion. In this mechanism the turning pair is fixed. When the crank rotates then the piston reciprocates and cylinder oscillates.



- **Whitworth quick return mechanism: -** This mechanism is mostly used in shaper and slotting machine. The turning pair is fixed and crank rotates at a uniform angular speed, then slider slides along the slotted bar which oscillates at a pivoted point. In this mechanism the connecting rod carries the ram. This ram takes more time during cutting stroke than return stroke which comes back fast.

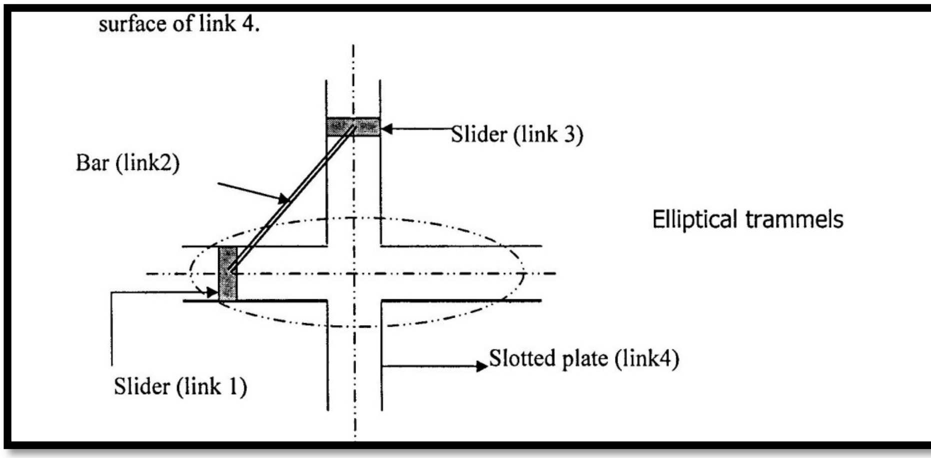
Time of cutting stroke/ Time of return stroke= α/β=α/360°- α or 360°-β/β



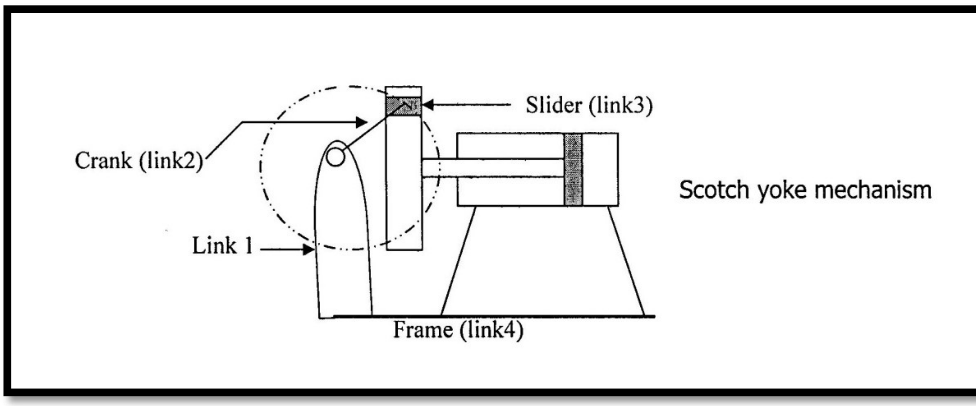
3. **Double Slider Crank Chain: -** A kinematic chain which consists of two turning pairs and two sliding pairs is known as double slider crank chain. In this mechanism the link 2 and link 1 form one turning pair and link 2 and link 3 form the second turning pair. The link 3 and link 4 form one sliding pair and link 1 and link4 form the second sliding pair.

Inversions of Double Slider Crank Chain:

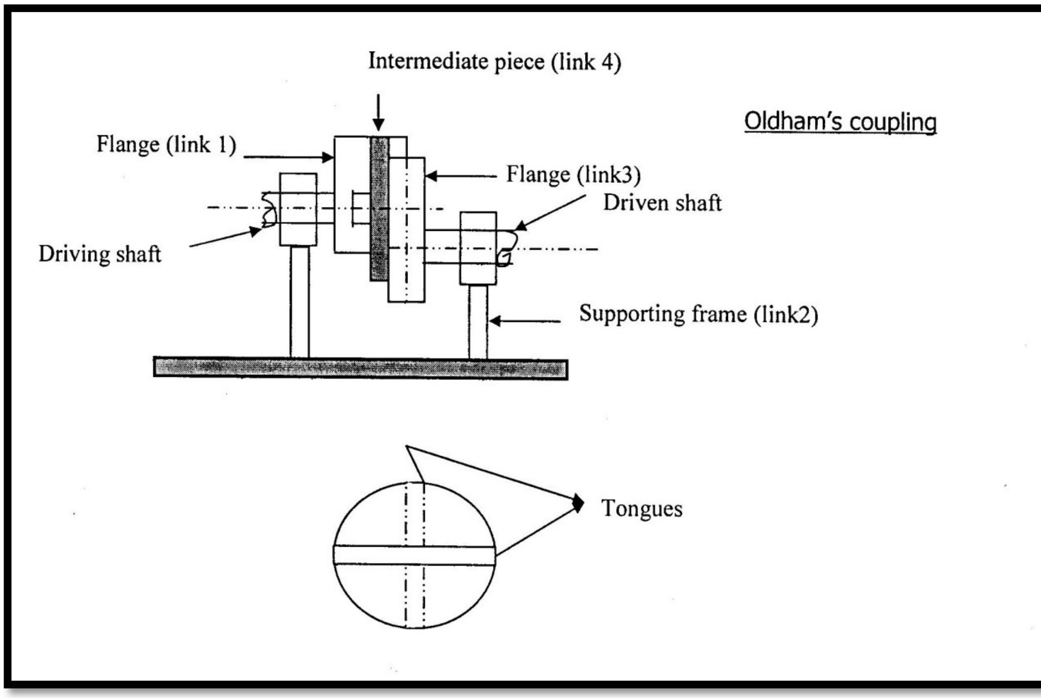
- **Elliptical trammels: -** It is an instrument used for drawing ellipses. This inversion is obtained by fixing the slotted plate (link 4). The fixed plate or link 4 has two straight grooves cut in it at right angles to each other. The link 1 and link3 are known as sliders and form sliding pairs with link 4. The link 2 is a bar which forms turning pair with links 1 and 3. When the links 1 and 3 slide along their respective grooves, any point on the link 2 such as traces out an ellipse on the surface of link 4.



- **<u>Scotch yoke mechanism:</u> -** This mechanism is used for converting rotary motion into a reciprocating motion. The inversion is obtained by fixing either the linkl or link3, link 1 is fixed. In this mechanism, when the link 2 (which corresponds to crank) rotates about its centre, the link 4 (frame) reciprocates. The fixed link 1 guides the frame.



- **<u>Oldham's coupling:</u> -** An Oldham's coupling is used for connecting two parallel shafts whose axes are at a small distance apart. The shafts are coupled in such a way that if one shaft rotated, the other shaft also rotates at the same speed. This inversion is obtained by fixing the link2. The shafts to be connected have two flanges (link I and link3) rigidly fastened at their ends by forging. The link 1 and link3 form turning pairs with link2. These flanges have diametrical slots out in their inner faces. The intermediate piece (link4) which is a circular disc; have two tongues on each face at right angles to each other. The tongues on the link4 closely fit into the slots in the two flanges (link 1 and link3). The link 4 can slide or reciprocate in the slots in the flanges.


Intermediate piece (link 4)
Oldham's coupling
Flange (link 1)
Flange (link3)
Driven shaft
Driving shaft
Supporting frame (link2)
Tongues

Aim: - To determine the mechanical advantage (M.A.), velocity ratio (V.R.) and efficiency (A) of a simple lifting machine.

Apparatus: - Wheel and axle arrangement, weights, string along with hanger.

Theory: -

Machine: - A machine is a device by means of which the available energy can be converted into useful work.

Simple Lifting Machine: - Simple lifting machines are used for lifting loads. The effort is applied at one point of the machine and load is lifted at other point of the machine.

Input of Machine: - It is defined as work done on the machine by the effort (P).

Input — Effort x distance moved by the effort (y)

$$\text{Input} = P \times y$$

Output of Machine: - It is defined as work done by machine in lifting the load (W).

$$\text{Output} = \text{Load} \times \text{Distance through which load is lifted. (x)}$$

$$\text{Output} – W \times X$$

Velocity Ratio (V.R.): - It is defined as the ratio of the distance moved by the effort to the distance moved by the load.

$$\text{Velocity Ratio (V.R.)} = y/x$$

Mechanical Advantage (M.A.): - It is defined as the ratio of the load lifted to the applied effort.

$$\text{Mechanical advantage (M.A.)} = W/P$$

Efficiency of Machine (η): It is defined as the ratio of the output of the machine of the input of the machine.

$$\text{Efficiency } \eta = \text{0utput/ input} = W*x/P*y = MA/VR$$

Procedure: -

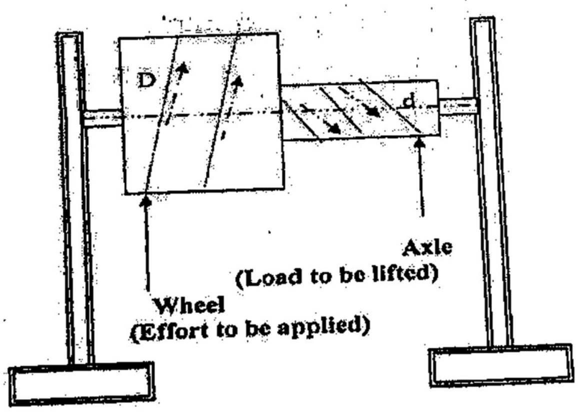
1. Adjust the wheel and axle management on the stand.
2. A string is wound round on the axle which carries the load to be lifted and another string is wound round the wheel to which the effort is applied in opposite direction.
3. Put the weights on the hangers attached with springs.
4. Apply an effort by placing the weight on hanger to lift the load.
5. Measure the effort and load and the distance moved by the effort and load respectively.

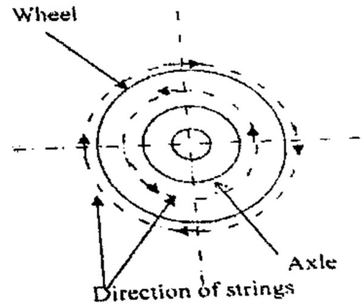
Precautions:

1. The string should be wound round opposite in direction on wheel and axle.
2. Weights should be placed gently on hangers.
3. Diameter of wheel and axle should be measured correctly.

DIAGRAM:

SIMPLE LIFTING MACHINE





<u>Observations: -</u>

Sr. No.	Effort applied (P)	Load lifted (W)	V. R.= D/d	M.A.= W/P	Efficiency= M.A. / V. R.
1.					
2.					
3.					

<u>Aim</u>: - To find out mechanical advantage, velocity ratio and efficiency of a Pulley system

<u>Apparatus</u>: - First system of pulleys apparatus weights, meter-scale, cotton thread, etc.

<u>Theory</u>: - In this system, the pulleys are so arranged that there are as many strings as there are pulleys. The end of each string is fastened to a rigid ceiling, while the other end passing round the bottom periphery of the pulley, and is fastened to the next higher pulley. The load is attached to the bottom-most pulley; whereas the effort is applied to the far end of the string passing round the last pulley. Generally, four pulleys are arranged in this system of pulleys. one pulley is used just to change the direction of the effort which is fixed while other three in succession are movable pulleys. The pulleys are assumed to be frictionless and very light also, therefore their weight is negligible.

In this first system of pulleys the VR-Distance moved by the effort/Distance moved by the load or V.R = 2^n

When load to be lifted than tension in string passing round the pulleys no.4 is W/2

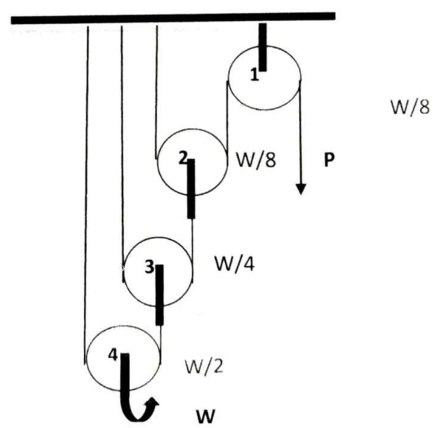
Tension in string passing round the pulley no. 3 is W/4

Tension in string passing round the pulley no. 2 is W/8

For the equilibrium of pulley no. 1, P= W/8 or W=8P or W = 2^3 P or W= 2^n P where n is the number of movable pulleys

MA. = W/P which is also equal to 2" (when friction is zero)

Efficiency (n) = M.A./V.R.



<u>Observations</u>: -

Sr. No.	Load Lifted + (wt. of pan)	Effort Applied + (wt. of pan)	V.R.	M.A.	Efficiency (η)
1.					
2.					
3.					

Wt. of pan may be assumed equal on both sides.

Results:

1. M.A. (mean)
2. V.R. (mean)
3. Efficiency

Aim: - To study the classification and properties of various engineering materials.

Theory:

Different mechanical properties of metals: -

Classification of engineering materials: -

The engineering materials are mainly classified as:

1. Metals and their alloys, such as iron, steel, copper, aluminum, etc.
2. Non-metals, such as glass, rubber, plastic, etc.

The metals may be further classified as: (a) Ferrous metals, and (b) Non-ferrous metals.

The *__ferrous metals__ are those which have the iron as their main constituent, such as cast iron, wrought iron and steel.

The *__non-ferrous metals__ are those which have a metal other than iron as their main constituent, such as copper, aluminum, brass, tin, zinc, etc.

Physical Properties of metals: -

The physical properties of the metals include luster, color, size and shape, density, electric and thermal conductivity, and melting point. The following table shows the important physical properties of some pure metals.

Metal	*Density* (kg/m³)	*Melting point* (°C)	*Thermal conductivity* (W/m°C)	*Coefficient of linear expansion at 20°C* (μm/m/°C)
Aluminium	2700	660	220	23.0
Brass	8450	950	130	16.7
Bronze	8730	1040	67	17.3
Cast iron	7250	1300	54.5	9.0
Copper	8900	1083	393.5	16.7
Lead	11 400	327	33.5	29.1
Monel metal	8600	1350	25.2	14.0
Nickel	8900	1453	63.2	12.8
Silver	10 500	960	420	18.9
Steel	7850	1510	50.2	11.1
Tin	7400	232	67	21.4
Tungsten	19 300	3410	201	4.5
Zinc	7200	419	113	33.0
Cobalt	8850	1490	69.2	12.4
Molybdenum	10 200	2650	13	4.8
Vanadium	6000	1750	—	7.75

Mechanical Properties of metals: -

The mechanical properties of the metals are those which are associated with the ability of the material to resist mechanical forces and load. These mechanical properties of the metal include strength, stiffness, elasticity, plasticity, ductility, brittleness, malleability, toughness, resilience, creep and hardness. We shall now discuss these properties as follows:

1. Strength: Strength is the ability of a material to withstand an applied load without deformation or failure. It is commonly divided into several categories:

- **Tensile Strength:** The maximum stress a material can endure under tension before it breaks.
- **Compressive Strength:** The maximum stress a material can endure under compression before it fails.
- **Yield Strength:** The stress at which a material transitions from elastic deformation to plastic deformation.
- **Shear Strength:** The maximum stress a material can endure before it shears along a plane.

2. Hardness: Hardness measures a material's resistance to indentation, scratching, or abrasion. Various hardness testing methods, such as the Brinell, Rockwell, and Vickers tests, provide quantitative values for comparison.

3. Ductility: Ductility is the ability of a material to undergo significant plastic deformation without fracturing. Ductile materials can be drawn into wires or formed into various shapes without breaking.

4. Brittleness: Brittleness is the opposite of ductility. Brittle materials exhibit little plastic deformation before fracture, often with minimal warning. Examples include cast iron and certain ceramics.

5. Elasticity: Elasticity refers to a material's ability to return to its original shape after deformation. The relationship between stress and strain in the elastic region is described by Hooke's Law.

6. Stiffness: Stiffness, also known as rigidity, is a measure of how a material resists deformation under an applied load. It is related to the material's Young's Modulus (modulus of elasticity).

7. Creep: Creep is the slow, time-dependent deformation of a material under constant stress at elevated temperatures. It can lead to permanent deformation over extended periods.

8. Fatigue Resistance: Fatigue is the failure of a material under repeated or cyclic loading, even if the applied stress is below the material's ultimate strength. Fatigue resistance is crucial in applications subjected to dynamic or cyclic loads, like aircraft components and bridges.

9. Fracture Toughness: Fracture toughness is a measure of a material's ability to withstand crack propagation. Materials with high fracture toughness can resist the growth of existing cracks and are more resistant to catastrophic failure.

10. Toughness: Toughness combines strength and ductility, indicating a material's ability to absorb energy before fracturing. Tough materials can absorb impact energy without breaking.

11. Malleability: Malleability is the ability of a material to undergo plastic deformation under compression, resulting in thin sheets or foils.

12. Resilience: Resilience is the ability of a material to absorb energy without undergoing permanent deformation. It is often measured by the material's ability to absorb energy up to its elastic limit.

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