

January : 2016 (CBCS)

Note :

Max. marks : 60

- (i) Attempt any five questions.
- (ii) All questions carry equal marks.
- (iii) Assume suitable data if required.
- (iv) Use of steam table is permitted.

Q.1 (a) Discuss working principle of arc welding along with details of equipments required and advantages and disadvantages of the process.

Ans. **Working principle of arc welding :** Heat required for melting and joining of plates, is obtained due to electrical arc. This phenomenon is called *arc welding*. When the power supply is given and optimum gap is maintained between cathode and anode, the negative charged electrons are generated at cathode and it moves towards anode at very high speed, due to this kinetic energy of electrons is converted into heat energy. The amount of heat generated at anode is much higher than the cathode because of very high velocity of electrons.

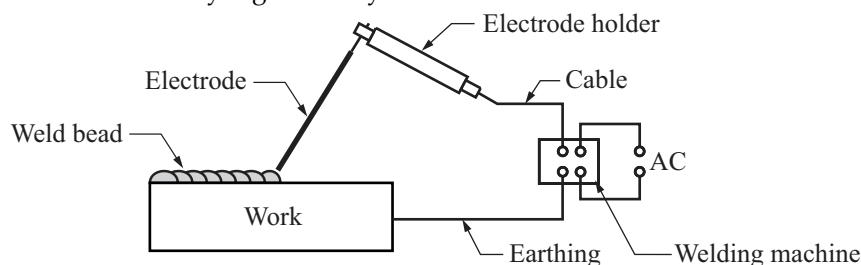


Fig. : Schematic view of arc welding technique

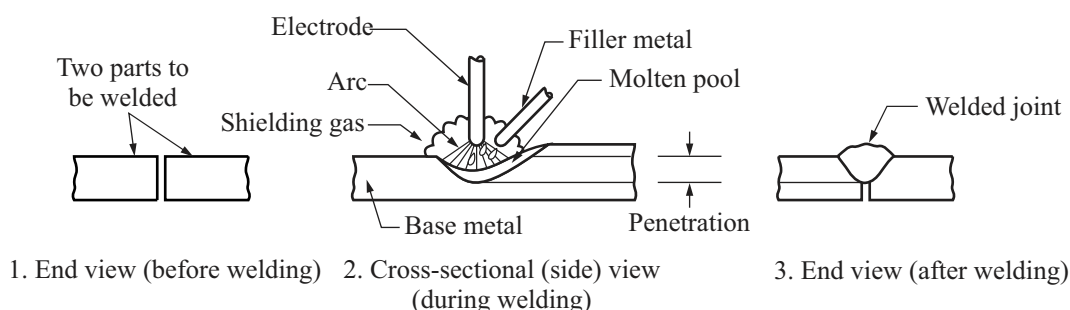


Fig. : Principle of arc welding technique

Application of arc welding : Generally it is used for the fabrication of pressure vessels, penstocks and boilers. Other application includes automobile industries.

The most commonly used equipment for arc welding are as follows :

1. **AC or DC machines :** Both direct current and alternating current are used for electric arc welding, each having its particular application. DC supply is generally obtained from generators driven by electric motors whereas AC supply transformers are used where electricity supply is available.
2. **Electrode and electrode holders :** Commonly used electrodes are of two types i.e. bare electrodes and coated electrodes. Bare electrodes are cheaper but weld produced through these are of poor quality. Coated electrodes are used in modern welding machines as they carry a core of bare metallic wire produced with a coating or covering on the outside surface.

3. **Cables and connector** : Cable carry the current to the desired place and cable connectors are essential for connections.
4. **Earthing clamps** : These are used to close electric circuit.
5. **Chipping hammer** : It is used to remove the slag from welded portions.
6. **Wire brush** : It is used for cleaning the weld after chipping.
7. **Helmet** : The face and the eyes of the operator must be protected from the arc which contains ultra-violet and infra-red rays. For this purpose, helmet or face shield is used.

The advantages of arc welding are :

1. Higher welding speed.
2. Greater deposition rates.
3. Less post welding cleaning.
4. Better weld pool graspability.
5. No loss of working hours brought in by changing terminals.
6. Positional welding offers no issues when contrasted with different procedures.
7. The procedure is effortlessly mechanized.
8. No flux is required.
9. Ultra-low hydrogen process.

The disadvantages of arc welding are :

1. Higher introductory setup cost.
2. Higher upkeep costs because of additional electronic parts.
3. The setting of plant variables requires a high aptitude level.
4. Less productive where high obligation cycle prerequisites are vital.
5. Radiation impacts are more extreme.

Q.1 (b) What are the major components of a lathe machine? Enlist various machine operations that can be carried out on lathe machine.

Ans. Various parts of a lathe :

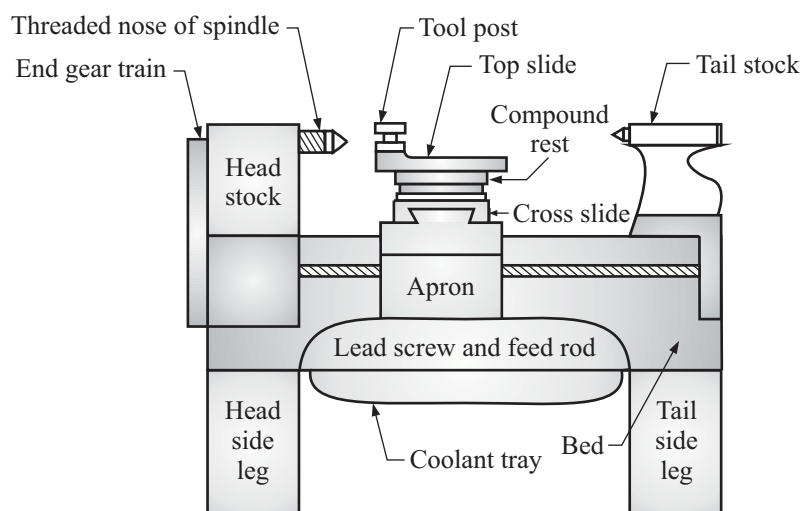


Fig. Schematic diagram of an engine lathe

The machine essentially consists of the following major units :

- | | | |
|------------------------|-------------------|-------------------|
| 1. Bed | 2. Headstock | 3. Tailstock |
| 4. Carriage assembly | 5. Tool post | 6. Feed mechanism |
| 7. Split nut mechanism | 8. Compound rest. | |

1. **Bed** : The bed of the lathe forms the base of the machine. It is supported on two legs at a convenient height. It carries the headstock and the tailstock for supporting the work. It must also absorb vibrations likely to arise during the machining process.
2. **Headstock** : The headstock houses the spindle and the means for supporting and rotating the spindle. It is rigidly fixed on the bed. The spindle is made of steel.
3. **Tailstock** : Tailstock is the counterpart of the headstock fitted at the right hand side of the bed.
4. **Carriage assembly** : The carriage assembly of the lathe comprises of a number of components which support, move and control the tool. The carriage assembly consists of a saddle, cross-slide, compound rest, top slide, tool post and apron.
5. **Tool post** : It is the tool holding device located on the top of the compound rest. In addition to holding the tool, it enables the tool to be adjusted to a convenient working position.
6. **Feed mechanism** : It is used for transferring power from spindle to lead screw for obtaining different automatic feeds of cutting tool.
7. **Split-nut mechanism** : The split-nut or half nut mechanism is used to engage or disengage the carriage with the lead screw for threading.
8. **Compound rest** : It is used for rotating the tool and tool post to perform the taper turning operations.

The various operation that can be performed on lathe machines are as follows :

1. **Facing** : It is an operation for generating flat surfaces in lathes. The feed is given in a direction perpendicular to the axis of revolution.

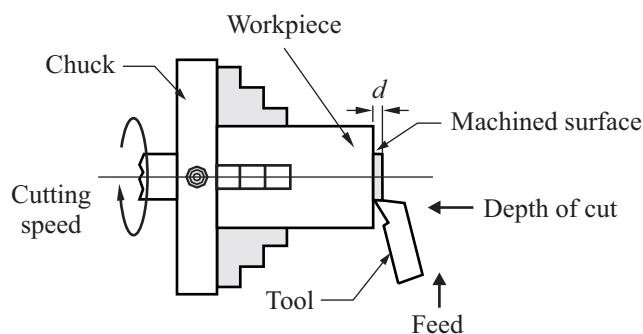


Fig. Facing

2. **Turning** : It is widely used operation in a lathe. The work held in the spindle is rotated while the tool motion is parallel to the axis of rotation there by generating cylindrical surface.

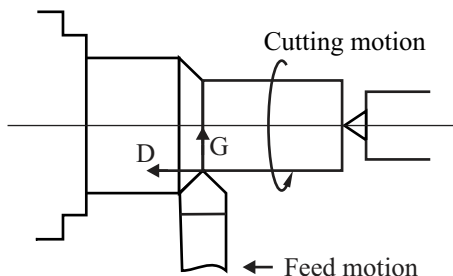


Fig. Turning

3. **Knurling** : It is the operation of plastically displacing metal into a particular pattern for the purpose of creating a hand grip or roughened surface on a workpiece.

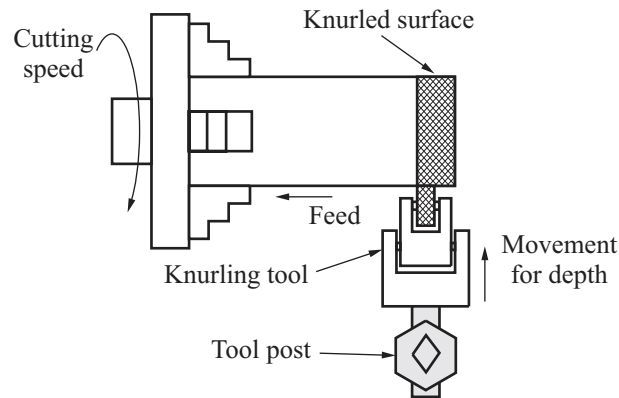


Fig. Knurling

4. **Tapers and taper turning :** A taper is defined as a uniform increase or decrease in diameter of a piece of work measured along its length. In a lathe machine, taper turning means to produce a conical surface by gradual reduction in diameter from a cylindrical job. Taper angle is given by relation.

$$\tan \alpha = \frac{(D-d)}{l}$$

where, D = The diameter of the large end of cylindrical job,

d = The diameter of the small end of cylindrical job, and

l = The length of the taper of cylindrical job, all expressed in inches.

A taper is generally turned in a lathe by feeding the tool at an angle to the axis of rotation of the workpiece. The angle formed by the path of the tool with the axis of the workpiece should correspond to the half taper angle.

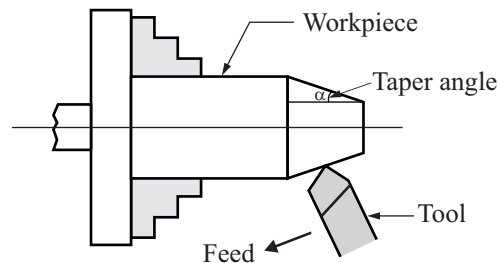


Fig. Taper turning

5. **Thread cutting :** Thread of any pitch, shape and size can be cut on a lathe using single point cutting tool. Thread cutting is operation of producing a helical groove on spindle shape.

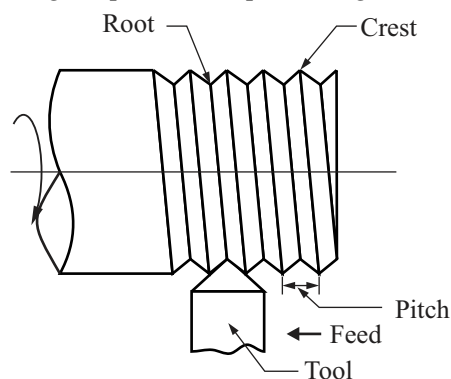


Fig. Thread cutting

6. **Drilling :** It is the operation of making cylindrical holes into the solid material. For producing holes in workpiece on lathe, the workpiece is held in a chuck or on a face plate. The drill is held in the position of tailstock and which is brought nearer to the workpiece by moving the tailstock along the guide ways, thus drill is feed against the rotating workpiece as shown in figure.

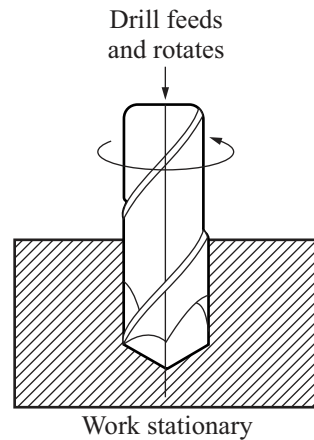


Fig. Drilling

7. **Chamfering :** Chamfering is used to avoid sharp edges, make assembly easier and improve aesthetics.

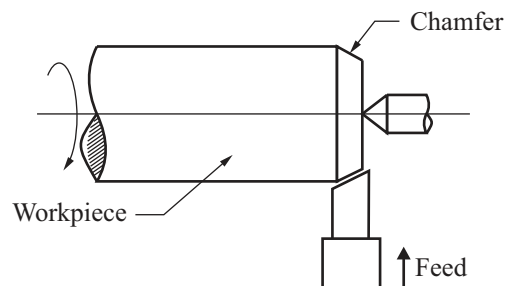


Fig. Chamfering

8. **Grooving :**

- (i) It produces a groove on workpiece.
- (ii) Shape of tool decides the shape of groove.
- (iii) Carried out using grooving tool which is called a form tool.
- (iv) It also called form turning.

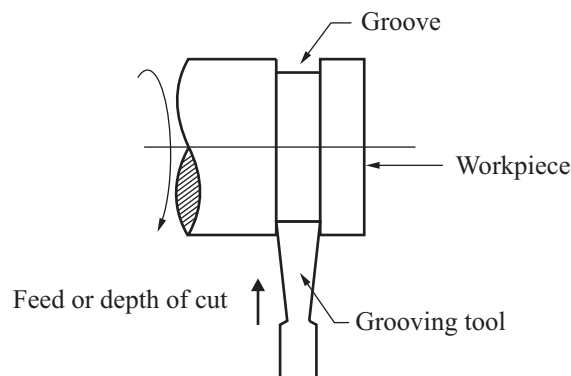


Fig. Grooving

9. **Parting :**

- (i) Cutting workpiece into two parts.
- (ii) Similar to grooving.
- (iii) Parting tool is used.
- (iv) Coolant is used for heat reduction.

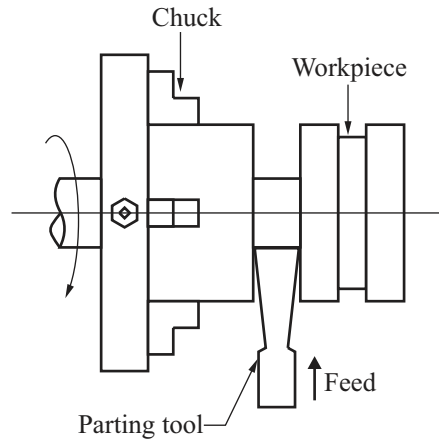


Fig. Parting

Q.2 (a) Discuss various types of flames that may be produced in gas welding along with the cases where each one of them will be suitably used.

Ans. In oxy-acetylene gas welding, flame is the most important means to control the welding joint and the welding process.

There are three basic types of oxy-acetylene flames :

1. Neutral flame (Acetylene and oxygen in equal proportions).

- (a) Inner cone indicates incomplete combustion.
- (b) Outer bluish color indicates complete combustion.
- (c) Maximum temperature of flame is induced at the intersection of inner cone and outer cone.
- (d) During combustion of acetylene large quantity of water is produced, to evaporate this water, large amount of heat is carried away.

Uses :

- (a) It is used for ferrous and non-ferrous metals strictly prohibited for zinc alloys.
For example, brass because zinc is present in brass, it will get evaporated.
- (b) It can be used for high melting point materials.

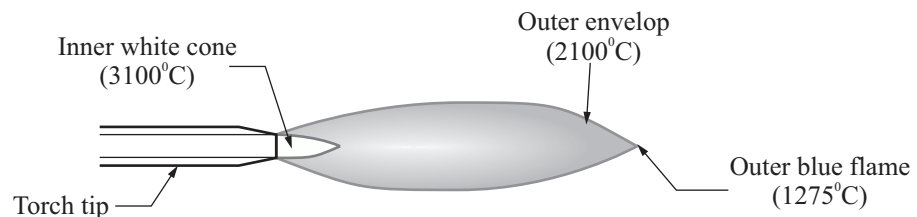


Fig. Neutral flame

2. Carburizing flame or reducing flame (excess of acetylene) :

- (a) Excess supply of acetylene.
- (b) Due to less supply of oxygen, combustion is incomplete.
- (c) Temperature generated in flame is less.

Uses :

- (a) Because of lower average temperature, high melting point metals cannot be joined.
- (b) Because of un-burnt carbon present in flame, this carbon may absorb by the iron during joining of ferrous metals and increase brittleness and reduce toughness. So it should not be used for joining of ferrous materials.
- (c) This is mostly used for high carbon steels.

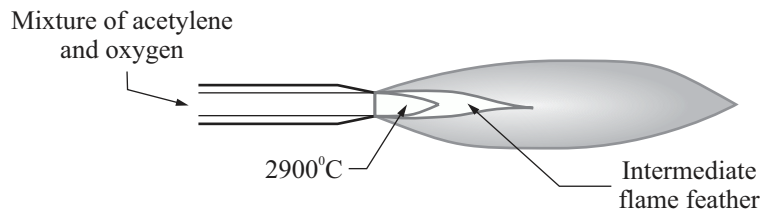


Fig. Carburizing flame

3. Oxidizing flame (excess of oxygen) :

- (a) Here excess amount of oxygen is present.
- (b) Due to presence of excess amount of oxygen complete combustion of acetylene is taking place.
- (c) The temperature of flame is maximum than any other flames.

Uses :

- (a) Because of higher average temperature, it can be used for high melting point materials.
- (b) Oxidizing flame is used to weld metal like copper (Cu). It is not suitable for highly reactive metals like, Al, Mn etc., because of excess supply of oxygen there is a possibility of oxidation.
- (c) It can be used for joining brass workpiece.

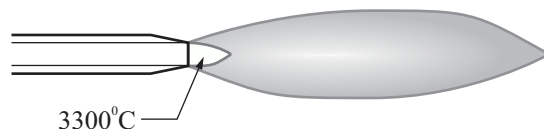


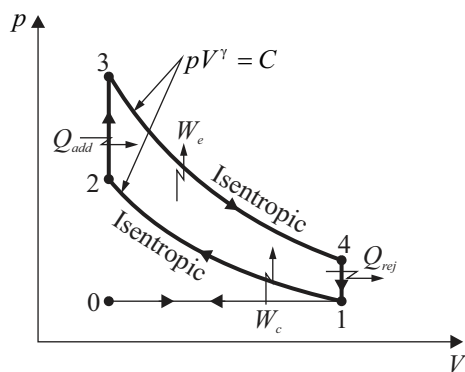
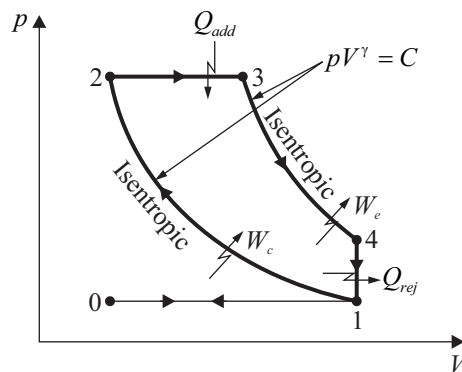
Fig. Oxidizing flame

Q.2 (b) Compare spark ignition and compression ignition internal combustion engines and discuss merits, demerits and applications of each one of them. Also draw cycles on which each one of them work.

Ans. Comparison between spark ignition and compression ignition engine :

S. No.	Parameters	S.I. engine	C.I. engine
1.	Ignition system	Spark ignition, system requires a spark plug in combustion chamber.	Self-ignition due to high temperature caused by high compression of air when fuel injected (no need of spark plug).
2.	Basic cycle	Works on Otto cycle	Works on Diesel cycle
3.	Fuel	Petrol (because of high self-ignition temperature).	Diesel (low self-ignition temperature is desirable).
4.	Compression ratio (C.R.)	6 to 10.5 upper limit of C.R. is fixed by antiknock quality of fuel.	16 to 20 upper limit of C.R. is decided by weight and structure of engine also.
5.	Introduction of fuel	Fuel and air are mixed and introduced in to the cylinder, carburettor is required to mix the air and fuel.	Fuel is directly injected to the cylinder at high pressure at the end of combustion. A high pressure fuel pump is required with an injector (Carburettor is eliminated).

Based on cycle : Spark ignition engine and compression ignition engine is based on Otto cycle and Diesel cycle respectively.

Fig. Otto cycle on p - V diagramFig. Diesel cycle on p - V diagram**Merits of spark ignition engine :**

1. S.I. engines arrangement are lighter than C.I. engines.
2. Vibrations in S.I. engines is lower than C.I. engines.

Demerits of spark ignition engine :

1. Due to lower compression ratio thermal efficiency obtained is lower.
2. Cost of fuel (petrol) is generally higher than Diesel.

Applications of spark ignition engine :

1. Mopeds, scooters and motor cycles.
2. In small pumping sets and mobile electric generating sets.

Merits of compression ignition engine :

1. Thermal efficiency of C.I. engines is higher than S.I. engines because of its higher C.R.
2. C.I. engines have major application than S.I. engines.

Demerits of compression ignition engine :

1. C.I. engines are heavier than S.I. engines for the same power output.
2. The vibration from engine and the unpleasant odour in the exhaust are the main drawbacks.

Applications of compression ignition engine :

1. In ship propulsion, jeeps, buses and trucks.
2. Tractors for agricultural application.

- Q.3** (a) The following data was recorded during a test run made on a single cylinder, four stroke engine having a compression ratio of 6.
- Bore and stroke = 10 cm and 12.5 cm respectively.
- Dead load and spring balance reading = 60 N and 20 N.
- Effective radius of brake drum = 40 cm
- Fuel consumption = 1.2 kg/hr
- Calorific value of fuel = 42500 kJ/kg
- If the engine turns 2000 rev/min and the indicated mean effective pressure is 0.25 MPa, determine its
- (i) Indicated power and brake power
 - (ii) Mechanical and relative efficiencies

Sol. Given :

Compression ratio, $r_k = 6$

Bore, $D = 10$ cm

Stroke, $L = 12.5$ cm

Dead load = 60 N

Spring balance reading = 20 N

Effective radius of brake drum, $r = 40$ cm

Fuel consumption, $m_f = 1.2$ kg/hr

Calorific value of fuel, CV = 42500 kJ/kg

Number of revolution, $N = 2000$ rpm

Indicated mean effective pressure, $p_{mi} = 0.25$ MPa

Number of cylinder, $k = 1$

Indicated power (I.P.) :

$$\text{I.P.} = \frac{p_{mi} \times L \times A \times \frac{N}{2} \times k}{60}$$

$$\text{I.P.} = \frac{0.25 \times 10^6 \times 0.125 \times \frac{\pi}{4} \times 0.10^2 \times 2000 \times 1}{2 \times 60}$$

$$\text{I.P.} = 4.0906 \text{ kW}$$

Ans.

$\Rightarrow F = \text{Dead load} - \text{Spring balance}$

$$F = 60 - 20 = 40 \text{ N}$$

$\Rightarrow \text{Torque, } T = \text{Force} \times \text{Effective radius of brake drum}$

$$T = F \times r$$

$$T = 40 \times 0.4 = 16.0 \text{ Nm}$$

Brake power (B.P.) :

$$\text{B.P.} = \frac{2\pi \times N \times T}{60} = \frac{2\pi \times 2000 \times 16}{60}$$

$$\text{B.P.} = 3.351 \text{ kW}$$

Ans.

Mechanical efficiency (η_{mech}) :

$$\eta_{\text{mech}} = \frac{\text{B.P.}}{\text{I.P.}} = \frac{3.351}{4.0906} \times 100$$

$$\eta_{\text{mech}} = 81.920 \%$$

Ans.

Air standard efficiency ($\eta_{\text{air std.}}$) :

$$\eta_{\text{air std.}} = 1 - \frac{1}{(r_k)^{\gamma-1}} = \left[1 - \frac{1}{(6)^{0.4}} \right] \times 100$$

$$\eta_{\text{air std.}} = 51.16 \%$$

Brake thermal efficiency (η_b) :

$$\eta_b = \frac{\text{B.P.}}{m_f \times \text{CV}}$$

$$\eta_b = \frac{3.351}{1.2 \times 42500} = 0.2365$$

$$\eta_b = 23.65 \%$$

Relative efficiency (η_r) :

$$\eta_r = \frac{\eta_b}{\eta_{\text{air std.}}} = \frac{0.2365}{0.5116} = 0.4622$$

$$\eta_r = 46.22 \%$$

Ans.

Q.3 (b) Derive expression for efficiency of Rankine cycle? How this cycle is different from Carnot cycle?

Ans. Rankine cycle is the ideal cycle for vapour power plants. The ideal Rankine cycle does not have any internal irreversibility.

Thermodynamic analysis of cycle :

Process (4-1) : Constant pressure heat addition in a boiler.

Process (1-2) : Isentropic expansion in a turbine.

Process (2-3) : Constant pressure heat rejection in condenser.

Process (3-4) : Isentropic compression in pump.

Referring T - s diagram figure (b).

h_1 represent enthalpy of steam at turbine inlet in kJ/kg.

h_2 represent enthalpy of steam at condenser inlet in kJ/kg.

h_3 represent enthalpy of steam at pump inlet in kJ/kg.

h_4 represent enthalpy of steam at boiler inlet in kJ/kg.

W_T is work output from turbine in kJ/kg.

W_p is work input to the pump in kJ/kg.

Q_{add} is heat addition to the boiler in kJ/kg.

Q_{rej} is heat rejected from the condenser in kJ/kg.

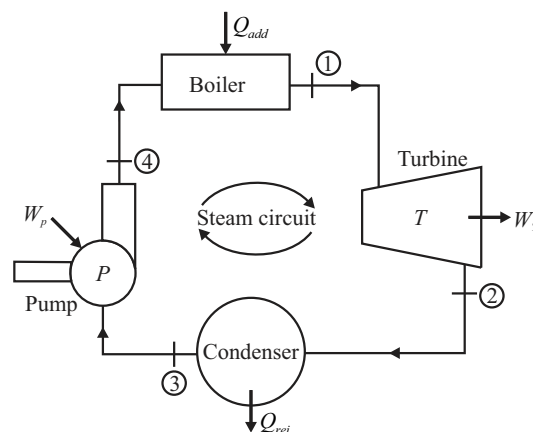


Fig.(a) Block diagram of simple Rankine cycle

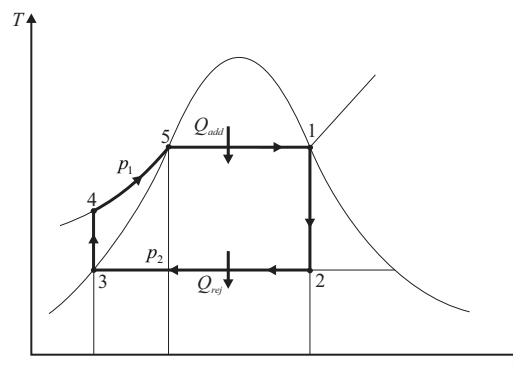


Fig.(b) T - s diagram of simple Rankine cycle

Heat added in the cycle :

The SFEE (steady flow energy equation) for the boiler,

$$h_4 + Q_{add} = h_1$$

\therefore

$$Q_{add} = h_1 - h_4$$

...(i)

Work done by turbine :

The SFEE for the turbine,

$$h_1 = W_T + h_2$$

$$W_T = h_1 - h_2$$

...(ii)

Heat rejected to condenser :

The SFEE for the condenser,

$$h_2 = Q_{rej} + h_3$$

$$\therefore Q_{rej} = h_2 - h_3$$

...(iii)

Work done on pump :

The SFEE for pump,

$$h_3 + W_P = h_4$$

$$\therefore W_P = h_4 - h_3$$

...(iv)

The thermal efficiency of Rankine cycle is given as :

$$\eta = \frac{W_{net}}{Q_{add}} = \frac{W_T - W_P}{Q_{add}}$$

$$\eta = \frac{(h_1 - h_2) - (h_3 - h_4)}{h_1 - h_4}$$

...(v)

The pump handles water which is incompressible, i.e. density or specific volume undergoes little change with an increase in pressure. For reversible adiabatic compression, the use of general property relation :

$$Tds = dh - vdp \quad [\because ds = 0]$$

$$\therefore dh = vdp$$

Since change in specific volume is negligible hence assuming it as constant.

$$\text{So } \Delta h = v\Delta p.$$

$$h_4 - h_3 = v_3 (p_4 - p_3)$$

$$W_P = h_4 - h_3 = v_3 (p_1 - p_2)$$

Usually pump work is very small compared to turbine output and is some time neglected. Then $h_4 - h_3$, and the cycle efficiency approximately becomes

$$\eta \approx \frac{h_1 - h_2}{h_1 - h_4}$$

- Q.4 (a)** A compound spring has two close coiled helical steel springs connected in series; each spring has 12 coils at a mean diameter of 2 cm. Find the diameter of the wire in one of the springs if the diameter in the other spring is 0.25 cm and the stiffness of the composite spring is 1 kg/cm. Estimate the greatest load that can be carried by the composite spring and the corresponding extension for a maximum shearing stress of 1800 kg/cm². Take modulus of rigidity $G = 0.82 \times 10^6$ kg/cm².

Sol. Given :

Number of coils, $n_1 = n_2 = 12$,

Mean coil diameter, $D_1 = D_2 = 2$ cm,

Wire diameter, $d_1 = 0.25$ cm, $d_2 = ?$

Required spring rate, $K = 1$ kg/cm $= 1 \times 9.81 \times 10^2 = 981$ N/m $[\because 1 \text{ kgf} = 9.81 \text{ N}]$

Modulus of rigidity, $G = 0.82 \times 10^6$ kg/cm² $= (0.82 \times 10^6) \times 9.81 \times 10^4 = 80.442 \times 10^9$ N/m²

Extension of the first spring :

$$\delta_1 = \frac{8W_1 D_1^3 n_1}{G d_1^4}$$

Since the springs are in series, they carry the same load.

$$\delta_1 = \frac{8W \times 12 \times 2^3 \times 10^{-6}}{80.442 \times 10^9 \times (0.25)^4 \times 10^{-8}}$$

$$\delta_1 = 0.24 \times 10^{-3} \text{ W m}$$

Extension of the second spring :

$$\delta_2 = \frac{8W \times 2^3 \times 10^{-6} \times 12}{80.442 \times 10^9 \times d_2^4}$$

$$\delta_2 = \frac{9.54 \times 10^{-15} W}{d_2^4} \text{ m}$$

Total extension :

$$\delta = \delta_1 + \delta_2$$

$$\delta = \left[0.24 \times 10^{-3} + \frac{9.54 \times 10^{-15}}{d_2^4} \right] W$$

Now, $\delta = \frac{W}{K}$

$$\therefore \left[0.24 \times 10^{-3} + \frac{9.54 \times 10^{-15}}{d_2^4} \right] W = \frac{W}{981}$$

$$\left[0.24 \times 10^{-3} + \frac{9.54 \times 10^{-15}}{d_2^4} \right] = \frac{1}{981}$$

$$\frac{1}{981} - 0.24 \times 10^{-3} = \frac{9.54 \times 10^{-15}}{d_2^4}$$

$$7.793 \times 10^{-4} = \frac{9.54 \times 10^{-15}}{d_2^4}$$

$$d_2^4 = \frac{9.54 \times 10^{-15}}{7.793 \times 10^{-4}}$$

$$d_2 = \left(\frac{9.54 \times 10^{-15}}{7.793 \times 10^{-4}} \right)^{1/4}$$

$$d_2 = 1.87 \times 10^{-3} \text{ m}$$

Ans.

Maximum shear stress,

$$\tau = \frac{8WD}{\pi d^3}$$

The permissible load for the spring having smaller wire diameter.

$$\tau = 1800 \text{ kg/cm}^2 = 1800 \times 9.81 \times 10^4$$

$$\tau = 176.58 \times 10^6 \text{ N/m}^2$$

$$W = \frac{\tau \times \pi \times d^3}{8 \times D}$$

So,
$$W = \frac{176.58 \times 10^6 \times \pi \times (1.87)^3 \times 10^{-9}}{8 \times 2 \times 10^{-2}}$$

$$W = 22.67 \text{ N}$$

Ans.

Extension,

$$\delta = \frac{W}{K} = \frac{22.67}{981} = 23.10 \times 10^{-3} \text{ m}$$

Ans.

- Q.4 (b) What are the different types of gears used for power transmission? Draw a simple train of gear and establish relation between speed of driver and follower wheel with number of teeth on each of them.

Ans. Different types of gears used in power transmission are :

1. Spur gear
2. Helical gear
3. Bevel gear
4. Spiral bevel gear
5. Hypoid bevel gear

Simple gear train : A series of gear, capable of receiving and transmitting motion from one gear to another is called a *simple gear train*. In simple gear train, each shaft supports one gear.

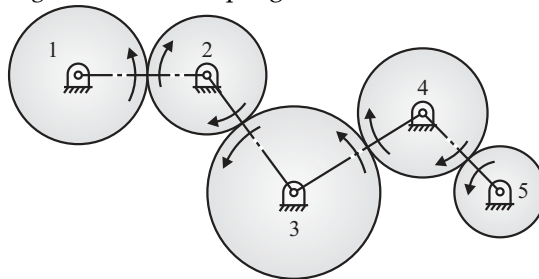


Fig. Simple gear train

In simple gear train :

- (i) Two external gears of a pair always rotate in opposite directions.
- (ii) Two odd numbered gears rotate in one direction and all even numbered gears in the opposite direction. For example 1, 3 and 5 rotate in the counter clock wise direction.
- (iii) Speed ratio, the ratio of the speed of the driving gear to that of the driven gear (follower wheel), is negative when the input and output gears rotates in opposite direction and positive when rotate in same direction. *Reverse of the speed ratio is known as train value of the gear train.*
- (iv) All the gears can be in straight line or arranged in zig-zag manner. A simple gear train can also have bevel gears.

Relation between speed of driver and follower wheel and number of teeth :

Let T_1 be the number of teeth on gear 1,

T_2 be the number of teeth on gear 2,

T_3 be the number of teeth on gear 3,

T_4 be the number of teeth on gear 4,

T_5 be the number of teeth on gear 5,

If gear 1 is driver, then train value is given by,

$$\frac{N_2}{N_1} = \frac{T_1}{T_2} \quad \left[\text{Also } \frac{\omega_2}{\omega_1} = \frac{2\pi N_2}{2\pi N_1} = \frac{N_2}{N_1} \right]$$

$$\frac{N_3}{N_2} = \frac{T_2}{T_3}, \frac{N_4}{N_3} = \frac{T_3}{T_4} \text{ and } \frac{N_5}{N_4} = \frac{T_4}{T_5}$$

Multiplying,

$$\frac{N_2}{N_1} \times \frac{N_3}{N_2} \times \frac{N_4}{N_3} \times \frac{N_5}{N_4} = \frac{T_1}{T_2} \times \frac{T_2}{T_3} \times \frac{T_3}{T_4} \times \frac{T_4}{T_5}$$

$$\text{Train value} = \frac{N_5}{N_1} = \frac{T_1}{T_5} = \frac{\text{Number of teeth on driving gear}}{\text{Number of teeth on driven gear}}$$

$$\text{Speed ratio} = \frac{1}{\text{Train value}} = \frac{N_1}{N_5} = \frac{T_5}{T_1}$$

Thus, it is seen that the intermediate gears have no effect on the speed ratio and, therefore, they are known as idlers.

Q.5 (a) Give Kelvin-Planck and Clausius statements of second law of thermodynamics. Justify that violation of Kelvin-Planck statement leads to violation of Clausius statement and vice versa.

Ans. Kelvin-Planck statement : It is impossible to construct a heat engine or device which operates in a cycle produces no other effects than the production of work and the transfer of heat from a single body.

The efficiency of such an engine would be 100 %

$$\left[\eta = \left(\frac{W_{net}}{Q_{in}} \right) \times 100 = \left(\frac{W_{net}}{W_{net}} \right) \times 100 = \left(\frac{Q_{add}}{Q_{add}} \right) \times 100 = 100\% \right]$$

Such a device violates **Kelvin-Planck** statement even though it satisfies the first law of thermodynamics, i.e. **principle of conservation of energy**.

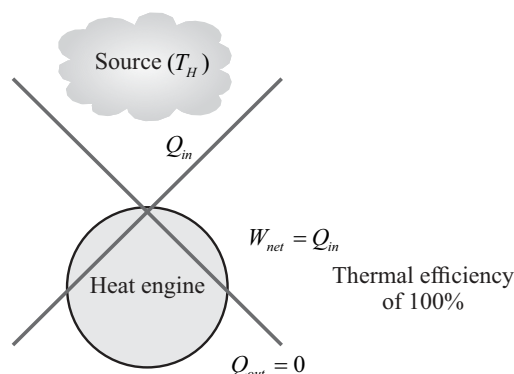


Fig. A heat engine that violates the Kelvin-Planck statement of the second law cannot be built

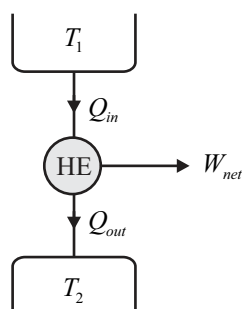


Fig. A heat engine that favors the Kelvin-Planck statement

Clausius Statement :

"It is impossible to construct a device that operates on a cycle whose main result is the transfer of heat from a cooler body to a hotter body without the assistance of external work.

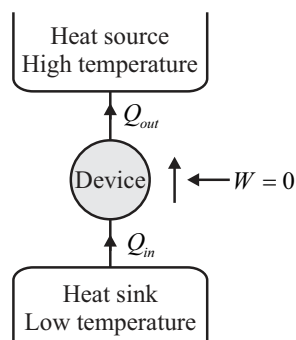


Fig. (a) Impossible

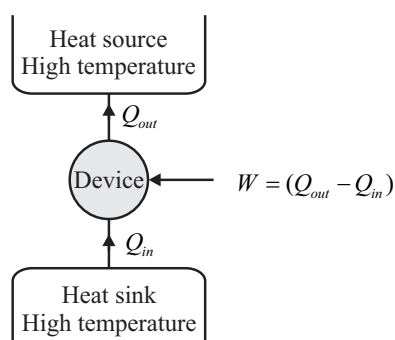


Fig. (b) Possible

According to the above statement, it is clear that heat cannot flow itself from a lower temperature body to a higher temperature body without the assistance of an external work [Figure (a)]. This process is impossible and violates the **Clausius** statement of the second law of thermodynamics.

Alternatively, heat can transfer from a low temperature body to a high temperature body with the help of an external work (W) [Figure (b)]. This process is possible.

Q.5 (b) Differentiate between boiler mountings and accessories. Enlist various mountings and accessories that are used in locomotive boiler and write purpose of each one of them.

Ans. The difference between boiler mounting and boiler accessories are :

S. No.	mounting	Boiler accessories
1.	Boiler mountings are components used for ensuring the safety of boiler operation.	Accessories are the auxiliary items required for proper operation of boiler and improve the efficiency of it.
2.	These are generally mounted on the surface of the boiler.	These are integral parts of the boiler, but not mounted on it.
3.	Control fluid parameters at the inside of the boiler shell.	Control fluid parameters at outside of the boiler.
4.	The mountings are the essential part of a boiler, without which boiler operation is impossible.	These are not essential parts of the boiler, without which boiler can operate though at lower efficiency.
5.	Proper maintenance is required.	Proper maintenance is not required.
6.	The size of boiler mounting are less as compare to boiler accessories.	The size of boiler accessories are large.
7.	Examples : Pressure gauges, water level indicator, safety valves, stop valve, fusible plug, blow off cock, etc.	Examples : Superheater, feed pump, injector, economizer, steam separator, air preheater, etc.

The various mountings and accessories including their purpose or function used in locomotive boiler are :

1. Safety valves

Purpose : To release excess steam of the boiler.

2. Pressure gauge

Purpose : To measure the steam pressure inside the boiler.

3. Water level indicator

Purpose : To indicate the water level inside the boiler.

4. Fusible plug

Purpose : To protect the boiler against overheating.

5. Blow off cock

Purpose : To empty the boiler for repairing, cleaning and remove the mud.

6. Feed check valve

Purpose : To control the excess supply of water to the boiler.

7. Superheater

Purpose : To increase the temperature of steam above its saturation point.

8. Economizer

Purpose : To utilize the waste heat of flue gases for heating the feed water.

9. Air preheater

Purpose : To increase the temperature of air before it enters the furnace.

Q.6 (a) Explain the working principle of Bell Coleman air refrigeration system. Also find coefficient of performance.

Ans. Working principle :

- The Bell Coleman air refrigeration system is based on reverse Joule cycle.
- The components of the Bell Coleman air refrigeration system are shown in figure (a). In this system, air is taken into the compressor from atmosphere and compressed.
- The hot compressed air is cooled in heat exchanger up to the atmospheric temperature (in ideal conditions). The cooled air is then expanded in an expander.
- The temperature of the air coming out from the expander is below the atmospheric temperature due to isentropic expansion.
- The low temperature air coming out from the expander enters into the evaporator and absorbs the heat. The cycle is repeated again.
- The working of air refrigeration cycle is represented on figure (b).

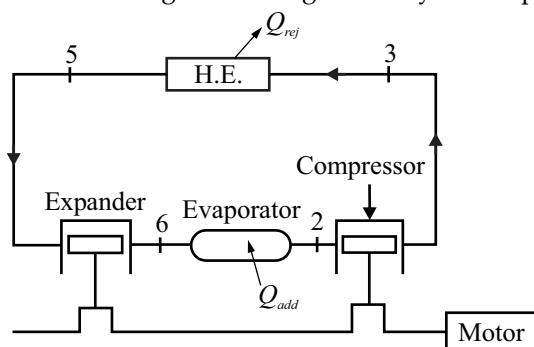


Fig. (a) : Air refrigeration cycle

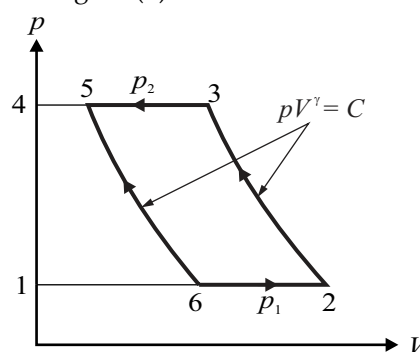


Fig. (b) : p-V diagram

Process (1-2) : It represents the suction of air into the compressor.

Process (2-3) : It represents the isentropic compression of air by the compressor.

Process (3-5) : It represents the discharge of high pressure air from the compressor into the heat exchanger. The reduction in volume of air from V_3 to V_5 is due to the cooling of air in the heat exchanger.

Process (5-6) : It represents the isentropic expansion of air in the expander.

Process (6-2) : It represents the absorption of heat from the evaporator at constant pressure.

Assumptions :

1. The compression and expansion processes are reversible adiabatic processes.
2. There is a perfect inter-cooling in the heat exchanger.
3. There are no pressure losses in the system.

COP of Bell Coleman cycle :

$$\text{COP} = \frac{\text{Net refrigeration effect}}{\text{Net work supplied}}$$

Work done per kg of air for the isentropic compression process 2-3 is given by,

$$W_c = C_p (T_3 - T_2)$$

Work developed per kg of air for the isentropic expansion process 5-6 is given by,

$$W_e = C_p (T_5 - T_6)$$

Net work required :

$$W_{net} = (W_c - W_e) = C_p (T_3 - T_2) - C_p (T_5 - T_6)$$

Net refrigerating effect per kg of air is given by,

$$Q_{add} = C_p(T_2 - T_6)$$

$$COP = \frac{Q_{add}}{W_{net}} = \frac{C_p(T_2 - T_6)}{C_p\{(T_3 - T_2) - (T_5 - T_6)\}}$$

For perfect inter-cooling, the required condition is $T_5 = T_2$

$$COP = \frac{(T_2 - T_6)}{(T_3 - T_2) - (T_2 - T_6)}$$

$$COP = \frac{1}{\frac{(T_3 - T_2)}{(T_2 - T_6)} - 1}$$

$$COP = \frac{1}{\frac{T_3 \left(1 - \frac{T_2}{T_3}\right)}{T_2 \left(1 - \frac{T_6}{T_2}\right)} - 1}$$

For isentropic compression process 2-3 and for expansion process 5-6,

$$\frac{T_3}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}}, \quad \frac{T_5}{T_6} = \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\therefore \frac{T_3}{T_2} = \frac{T_5}{T_6}, \quad \frac{T_6}{T_5} = \frac{T_2}{T_3} \quad [T_5 = T_2]$$

$$COP = \frac{T_2}{T_3 - T_2}$$

Q.6 (b) Draw a stress-strain curve for a ductile material and explain following :

- (i) Proportionality limit
- (ii) Elastic limit
- (iii) Upper and lower yield points
- (iv) Plastic deformation
- (v) Ultimate limit
- (vi) Breaking point stress
- (vii) Proof stress

Ans. Stress-strain curve : Stress-strain curve gives the relation between the stress and strain induced in a material due to externally applied force. This curve is different for ductile material (steel, rubber copper etc.) and brittle material (cast iron, glass etc.).

Stress-strain curve for ductile material :

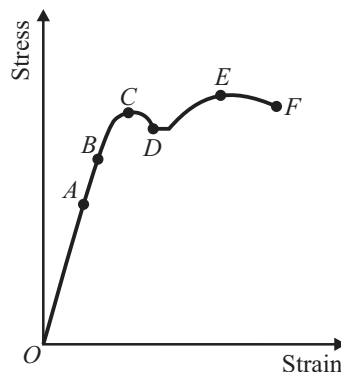


Fig. (a) Stress-strain curve for ductile material (mild steel)

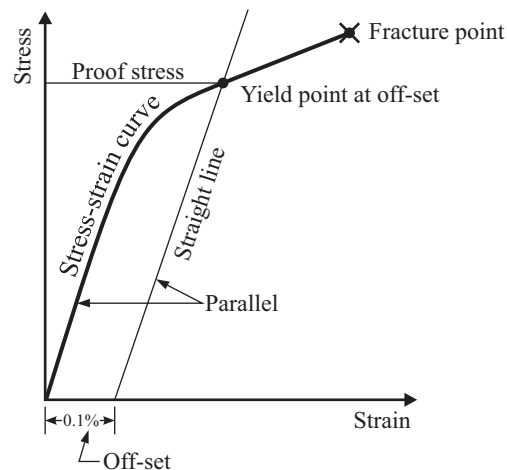


Fig. (b) Stress-strain curve for a brittle material (cast iron)

The important points on the stress-strain curve are as follows :

1. **Proportional limit** : It is also called *proportional stress*. It is the maximum value of the stress up to which stress is directly proportional to strain. In figure (a) point O to A is a straight line and beyond point A the curve slightly deviates from the straight line.
2. **Elastic limit** : It is the maximum value of stress up to which the deformation are elastic or temporary (after unloading, metal regains its original shape and size). Beyond elastic limit i.e. point B the deformation of metal is permanent.
3. **Yield point** : It is the stress at which material yields i.e. deformed plastically without any strain hardening. In this curve the stress corresponding to point C is called *upper yield stress* and for point D it is called *lower yield stress*.
4. **Ultimate stress** : It is the maximum value of stress on this curve without fracture. After this value i.e. point E, the failure of metal begins.
5. **Breaking point stress** : It is also called *failure stress* or *fracture stress*. Breaking stress point F is the fracture or failure point.
6. **Proof stress** : From figure (b) most of ductile materials such as *high strength deformed steel*, *brass*, *duralumin* etc., does not have position of yield point, so that the curve passes smoothly from elastic deformation to plastic deformation. For such materials a proof stress at a specified strain is calculated. It is generally calculated after test by an offset method.

- Q.7 (a) Explain following phenomenon related to plastic deformation of materials.
- (i) Slip (ii) Twinning

Ans. The two modes of plastic deformation are as follows :

1. Slip
 2. Twinning
1. **Slip** : The term "*Slip*" may be defined as a shear deformation, which moves the atoms through many interatomic distance, relative to their initial position. The deformation by slip is shown in figure below.
 - (i) **From figure (a)** : It shows the adjacent planes of a hypothetical crystal. A shearing stress, acting as indicated by the arrows, tends to move the atoms of the upper planes to the right. The movement of atoms or slip occurs only when the shear stress exceeds a critical value.
 - (ii) **From figure (b)** : It shows the atoms move an integral number of atomic distances along slip plane and a step is produced.

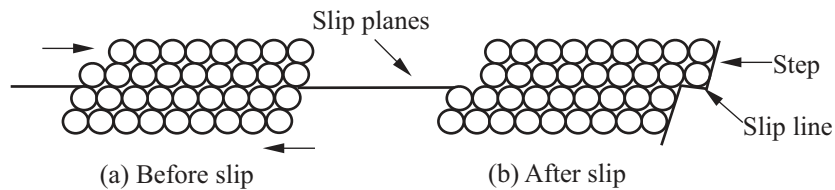


Fig. Slip Deformation

2. **Twining** : The term “*twining*” may be defined as the plastic deformation, which occurs along two planes due to a set of force applied on a given metal piece.

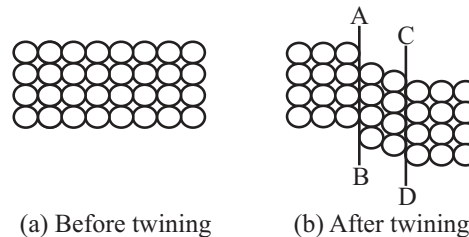


Fig. Twining Deformation

- (i) **From figure (a)** : It shows the condition, which indicates the arrangement of atom before twining.
- (ii) **From figure (b)** : It shows the arrangement of atom after twining along the planes AB and CD.

- Q.7 (b)** Explain the schematic arrangement for carrying out any one of the following tests in detail along with the formulae used for calculations and merits and demerits of test :
- (i) Izod impact test
 - (ii) Rockwell hardness test

Ans. In manufacturing of locomotive wheels, coins and connecting rods etc., the components are subjected to impact loads or shock loads. These loads are applied suddenly. The stress induced in components are many times more than the stress produced by gradual loading. Hence materials should be able to sustain such loads. Therefore, impact tests are performed to assess shock absorbing capability of materials subjected to suddenly applied shock loads.

These capabilities are expressed as :

- (i) Rupture energy
- (ii) Modulus of rupture
- (iii) Notch impact strength

Generally two test are performed to measure the impact strength of a specimen.

1. Charpy test
2. Izod test

1. **Charpy Test** : The charpy test is carried out on a specimen which is $55\text{ mm} \times 10\text{ mm} \times 10\text{ mm}$ in size and has a 2 mm deep notch at its centre making an angle of 45° as shown in figure (a). A heavy hammer strike on the specimen from a standard height. The specimen gets fractured due to the applied load. The ductile material becomes brittle due to the presence of notched specimen. From this test, one can directly measure from the calibrated dial, the energy absorbed for fracturing the specimen in Newton meter.

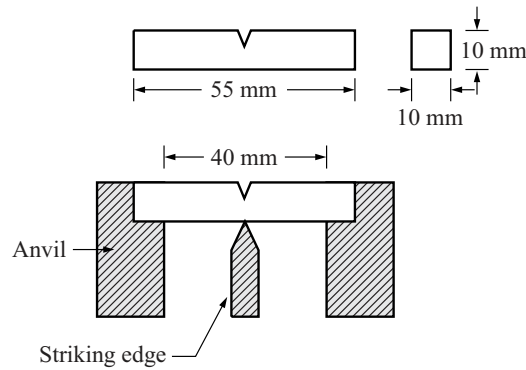


Fig. (a) Charpy test specimen

2. **Izod tests :** A specimen of dimension 11 mm × 11 mm × 75 mm is fixed using vice and the other end is free shown in figure (b). A V-notch of 2 mm depth and angle 45° is produced at a distance of 22 mm from the free end. By striking the edge of the free end using a striking hammer, the energy for fracture is determined.

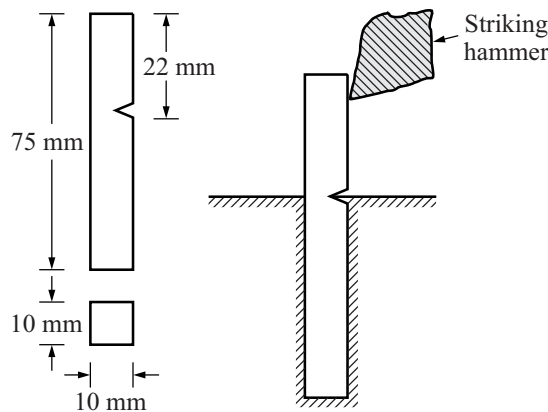


Fig. (b) Izod test specimen

The advantages of impact test are :

1. It can determine the impact strength of the material.
2. After examining the fractured surface, it can identify whether the material is brittle or ductile or a combination of both.
3. The ductile-brittle transition temperature can be determined through measuring the impact test over a range of temperatures.

Rockwell's hardness test : The Rockwell's hardness test is, generally performed when quick and direct reading is desirable. This test is also performed when the material have hardness, beyond the range of Brinell's hardness test. It differs from the Brinell's test in such a way that in this test the loads for making indent are smaller, and thus it makes smaller and shallower indents. It is because of this reason that the Rockwell's hardness test is widely used in the industry.

Process of Rockwell's hardness test :

- The specimen is placed on the machine.
- Hand wheel is providing for rising the specimen up against the steel ball.
- When minor load is applied on indenter till the needle on the dial shows zero reading.
- The machine is connected to dial indicator which shows the reading.
- With the help of crank mechanism (which is not shown in the figure) major load is applied.
- When crank mechanism is acting in the reverse direction the major load is removed and minor load is applied.
- Finally hand wheel is rotated and the specimen is lowered.
- After the above process the hardness of specimen material can be read from the dial indicator.

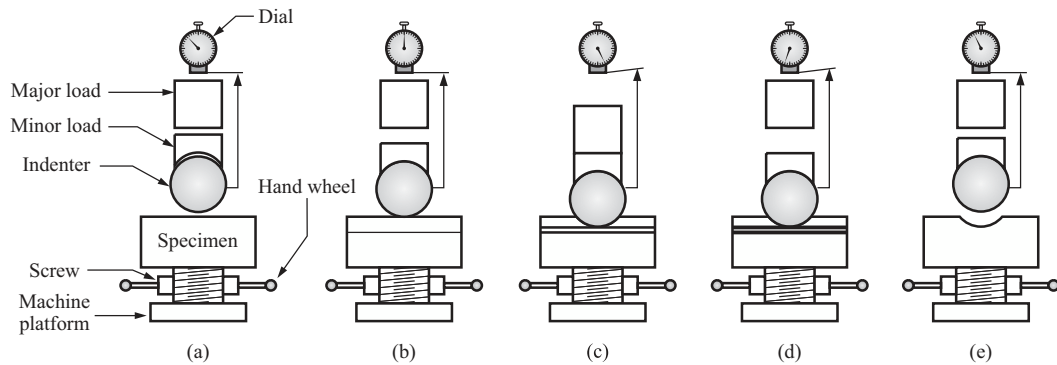


Fig. Rockwell hardness test process

Scaling of Rockwell hardness test material :

- It consists of different scales such as *B* scale and *C* scale.
- The *B* scale is used to measure the hardness of a soft material using a steel ball from *RHO* to *RH100* where *RH* stands for Rockwell hardness.
- The *C* scale is used to measure the hardness greater than *RH100* using a diamond cone indenter for hard materials.

Mathematically, the hardness of the material is,

$$\text{Rockwell hardness, } RH = h - \frac{t}{0.002}$$

where, h = Constant of material in mm

t = Depth of material in mm

The merits of Rockwell hardness test are :

1. This instrument is easy to handle and the readings are noted directly from the reading dial.
2. A small size impression is made before using a larger load and hence, the uneven surface in the specimen is avoided.
3. It is very useful when a large number of samples is used.
4. The process of testing is very fast.

The demerits of Rockwell hardness test are :

1. Error occurs when more than one scale is used to find the hardness of the material in the measurement.
2. The conversion of Rockwell hardness number into Brinell hardness number and Vicker's hardness number is not possible.
3. The accuracy of Rockwell hardness test is less than the Vicker's hardness test, especially when measuring the hardness of materials having small differences.

