CONVERSION FACTORS

DIMENSION	METRIC	METRIC/ENGLISH
Acceleration	1 m/s^2 = 100 cm/s^2	1 m/s^2 = 3.2808 ft/s^2 1 fts^2 = 0.3048* m/s^2
Area	1 m^2 = 10^4 cm^2 = 10^6 mm^2 = 10^{-6} km^2	1m^2 = 1550 in^2 = 10.764 ft^2 1 ft^2 = 144 in^2 = 0.09290304* m^2
Density	1 g/cm^3 = 1 kg/L = 1000 kg/m^3	1 g/cm^3 = 62.428 ibm/ft^3 = 0.036127 ibm/in^3 1 ibm/in^3 = 1728 Ibm/ft^3 1 kg/m^3 = 0.062428 ibm/ft^3
Energy, heat work, and specific energy	1 kJ = 1000 J = 1000 N m = 1kPa m^3 1 kJ/kg = 1000 m^2/s^2 1 kWh = 3600 kJ	1 kJ = 0.94782 Btu 1 Btu = 1.055056 kJ = 5.40395 psia ft^3 = 778.169 ibf ft 1 Btu/Ibm = 25,037 ft^2/s^2 = 2.326* kJ/kg 1 kWh = 3412.14 Btu
Force	1 N = kg m/s^2 = 10^5 dyne 1 kgf = 9.80665 N	1 N = 0.22481 ibf 1 Ibf = 32.174 ibm ft/s^2 = 4.44822 N 1 ibf = 1 slug ft/s^2

DIMENSION	METRIC	METRIC/ENGLISH
Length	1 m = 100 cm = 1000 mm = 10^6 μm 1 km = 1000 m	1 m = 39.370 in = 3.2808 ft = 1.0926 yd 1 ft = 12 in = 0.3048*m 1 mile = 5280 ft = 1.6093 km 1 in = 2.54* cm
Mass	1 kg = 1000 g 1 metric ton = 1000 kg	1 kg = 2.2046226 ibm 1 ibm = 0.45359237* kg 1 ounce = 28.3495 g 1 slug = 32.174 ibm = 14.5939 kg 1 short ton = 2000 ibm = 907.1847 kg
Power	1 W = 1 J/s 1 kW = 1000 W = 1 kJ/s 1 hp$^{\updownarrow}$ = 745.7 W	1 kW = 3412.14 Btu/h = 1.341 hp = 737.56 ibf ft/s 1 hp = 550 ibf ft/s = 0.7068 Btu/s = 42.41 Btu/min = 2544.5 Btu/h = 0.74570 kW 1 Btu/h = 1.055056 kJ/h
Pressure or stress, and pressure expressed as a head	1 pa = 1 N/m^2 1 kPa = 10^3 Pa = 10^{-3} MPa 1 atm = 101.325 kPa = 1.01325 bar = 760 mm Hg at 0°C = 1.03323 kgf/cm^2 1 mm Hg = 0.1333 kPa	1 Pa = 1.4504 × 10^{-4} psi = 0.020886 ibf/ft^2 1 psi = 144 ibf/ft^2 = 6.894757 kPa 1 atm = 14.696 psi = 29.92 inches Hg at 30°F 1 inch hg = 13.60 inches H_2O = 3.387 kPa

DIMENSION	METRIC	METRIC/ENGLISH
Specific heat	1 kJ/kg °C = 1 kJ/kg K = 1 J/g °C	1 Btu/ibm °F = 4.1868 kJ/kg °C 1 Btu/ibmol R = 4,1868 kJ/kmol K 1 kJ/kg °C = 0.23885 Btu/ibm °F = 0.23885 Btu/ibm R
Specific volume	1 m^3/kg = 1000 L/kg = 1000 Cm^3/g	1 m^3/kg = 16.02 ft^3/ibm 1 ft^3/ibm = 0.062428 m^3/kg
Temperature	T(K) = T(°C) + 273.15 Δ T(K) =	T (R) = T(°F) + 459.67 = 1.8T(K) T(°F) = 1.8 T(°C) + 32 ΔT(°F) = ΔT(R) = 1.8* ΔT(K)
Velocity	1 ms = 3.60 km/h	1 m/s = 3.2808 ft/s = 2.237 mi/h 1 mi/h = 1.46667 ft/s 1 mi/h = 1.6093 km/h
Viscosity, dynamic	1 kg/m s = 1 N s/m^2 = 1 Pa s = 10 poise	1 kg/m s = 2419.1 ibm/ft h = 0.020886 ibf s/ft^2 = 0.87197 ibm/ft s
Volume	1 m^3 = 1000 L = 10^6 cm^3/cc	1 m^3 = 7/1-24 × 10^4 in^3 = 35.315 ft^3 = 26417 gal (U.S.) 1 U.S. gallon = 231 in 3 = 3.7854 L 1 fl ounce = 29.5735 cm^3 = 0.0295735 L 1 U.S. gallon = 128 fl ounces

*Exact conversion factor between metric and English units.

Mechanical horsepower. The electrical horsepower is taken to be exactly 746 W.

PHYSICAL CONSTANT	METRIC	ENGLISH
Standard acceleration of gravity	$g = 9.80665\ m/s^2$	$g = 32.174\ ft/s^2$
Standard atmospheric pressure	P_{atm} = 1 atm = 101.325 kPa = 1.01325 bar =760 mm Hg (0°C) = 10.3323 m H_2O (4°C)	P_{atm} = 1 atm = 14.696 psia = 2116.2 ibf/ft^2 = 29.9213 inches Hg (32°F) = 406.78 inches H_2O (39.2°F)

ENERGY RESOURCES

MODULE 1

HIGHLIGHTS

- Energy Resources
- Forms of Energy
- Non Renewable and Renewable Sources of Energy
- Petroleum Based Fuels
- Combustion of Fuel
- Hydro Power
- Nuclear Power
- Solar Energy
- Harvesting Solar Energy is done in 3 Major Forms
- Solar Ponds
- Wind Energy
- Bio Fuels
- Steam and Formation of Steam
- Differences between dry steam and superheated steam
- Properties of Steam
- Boilers
- Fire Tube and Water Tube Boilers
- Lanchashire Boiler (Fire Tube Boiler)
- Babcock and Wilcox Boiler
- Boiler Mounting and Accessories

Energy Resources

Solar Energy

Wind Energy

Biomass Energy

1.0 Energy Resources

Mechanical engineering is a discipline of engineering which uses the knowledge of physics and material science to a large extent. Mechanical engineers are expected to understand and apply basic concepts from physics and chemistry. The study of energy is essential since the gamut of engineering encompasses mainly energy. The unit of energy in SI system are KJ for practical applications. Another unit of energy which is derived from power is kilo watt hour(kWh). It is the amount of energy which is used in 1 hour when the power is 1 kilowatt.

Power is a measure of the rate at which work is done. The unit of power in SI system is 1 J/s =1 W

735.5 J/s = 735.5 W

Energy is defined as the capacity to do work. Energy is a key input parameter in the development of the nation. The law of conservation of energy states that Energy can neither be created nor be destroyed.

Hence all energy conversions follow this principle.

1.1 Forms of Energy

Energy is available in nature in various forms as per the law of conservation of energy. The total energy of a system is preserved. Energy can be converted from one form to another form.

1. Mechanical energy
2. Electrical energy
3. Chemical energy
4. Heat energy
5. Nuclear energy

1.1.2 Sources of Energy

There are several sources of energy in nature which have been used since several years and are called as 'conventional 'source of energy. The conventional sources of energy include fossil fuel, peat, wood, lignite, coal, petrol, diesel, natural gas etc. The fossil fuels are formed from vegetation matter which are decayed and present in the earth's crust. Due to carbonisation these are transformed into petrochemicals. The fossil fuels are depleting day by day and estimates show that the fossil fuels may get exhausted within a few decades.

The Sources of energy are

1. Fossil fuels
2. Hydro energy
3. Solar energy
4. Wind energy
5. Tidal energy

The conventional source of energy are formed by nature from millions of years and cannot be renewed and hence all conventional source of energy are non-renewable. Fossil fuels are exhaustible energy sources. When fossil fuel burns its chemical energy turns into heat and light. Today we are using the fuels abundantly due to increasing demands.

All non-conventional energy resources like solar, wind, tidal, geothermal energy are available free in nature and can be renewed from time to time. Hence we conclude that all non-conventional energy are renewable.

1.2 Non renewable and Renewable Sources of Energy

1. **Non renewable energy**:- The source which are formed in the earth crust over millions of years and which get depleted with their use are known as non-renewable sources of energy (conventional energy sources)

   Examples: Coal, Petroleum products, Nuclear fuels

2. **Renewable energy**:- The sources which will not deplete with their use are known as renewable energy sources (non conventional energy sources)

   Examples: Solar energy, wind energy, tidal energy

1.2.1 Advantages and Disadvantages of Non Renewable Energy Sources

Advantages of Non Renewable Energy Sources

1. These are traditional sources for which technology of conversion is developed.
2. Initial cost is low
3. Wide commercial applications

Disadvantages of Non Renewable Energy Sources

1. They are exhaustible source of energy
2. Causes pollution and leads to environmental impact
3. These are not available directly at free of cost.

1.2.2 Advantages and Disadvantages of Renewable Energy Sources

Advantages of Renewable Energy Sources

1. They are non-depletable.
2. Available at free of cost.
3. Don't cause pollution and eco-friendly
4. Energy transportation cost is low.

Disadvantages of Renewable Energy Sources

1. The availability is non-continuous
2. Complete commercialisation is not available
3. Initial cost of the set up to extract energy source is high.

Renewable	Non renewable
1. The energy source does not deplete with time.	1. Depletes with time.
2. Eco-friendly	2. Causes pollution
3. They are available free of cost.	3. They are not available free of cost.

1.2.3 Classification of Fuels

Fuels are classified into three types. There are Solid Fuels, Liquid Fuels and Gaseous Fuels.

Solid Fuels

Solid fuels include wood, coal, charcoal, peat and lignite etc.,

Coal: It is abundantly available in the earth's crust. It is a carbonaceous product formed from vegetation matter, which under went transformation due to high temperature and pressure in the earth's crust.

Peat is partially carbonised dead vegetation matter. It is inferior to coal in its properties.

Lignite: It is the lowest rank coal with 25-30% carbon and used for power generation. Neyveli Lignite Corporation in Tamil Nadu produces Lignite in abundance. Its calorific value is about 16 MJ/Kg.

Bituminous coal is a getter grade coal with 45.86%. Carbon and calorific value of 32 MJ/Kg.

Carbon and calorific value of 32 MJ/Kg.

Authracite: It is the best grade of coal with 85-98%.

Carbon with calorific value of 34 MJ/Kg

Coke: It is carbonised form of coal by baking or heating high carbon content coal. It contains 90% carbon and calorific value of 30 MJ/Kg.

Liquid Fuels

Petro chemical products from oil wells include crude oil and other fuels. Crude oil is further refined into petrol, diesel and kerosene by fractional distillation.

Petrol or Gasoline: It is a blend of paraffins and has a calorific value of 47.4 MJ/Kg. It has good volatility and ignition characteristics.

Diesel: It is a hydrocarbon fuel. Its calorific value is 45 MJ/Kg. Diesel oil is less expensive compared to petrol. However emissions from diesel engines produce toxic exhaust gases which are hazardous.

Alcohol: Methanol and Ethanol are used as substitutes for petrol and diesel engines.

Gaseous Fuels

These gaseous fuels includes Natural Gas,

Natural Gas: It is available naturally in oil wells and contains 60-95%. Methane. Its calorific value is 50 MJ/m^3.

It is stored at high pressure of 20-25 bar and is then called as **Compressed Natural Gas(CNG)** or **Liquified Natural Gas(LNG).**

Blast Furnace Gas: The by-product of burning pig iron is called Blast Furnace Gas. It has low calorific value of 3.6 MJ/M^3.

1.3 Petroleum Based Fuels

Fuel is a material which can produce thermal energy by the process of combustion. There are several fossil fuels of hydrocarbon which are used to produce heat.

Coal is a primary source of fuel which is abundantly available in nature though it gets depleted and is exhaustible. The carbonisation of vegetation matter over many years under high pressure and temperature of earth's crust created some fuels such as peat, coal, wood, etc. The complex chemical reactions between micro organisms, ocean water and vegetation matter created the hydrocarbon fuels such as diesel, methane, petrol, natural gas etc. In the refining of petroleum we get coke .Petroleum coke is directly used as fuel. Coal and coke are petroleum fuels.

The liquid fuels which are petroleum based are petrol, diesel and kerosene.

The petroleum based gaseous fuels include natural gas, liquified petroleum gas (LPG), Compressed natural gas (CNG)

Properties of Fuels

Most of the carbon and hydrocarbon fuels generate thermal energy when they undergo combustion. These fuels possess heating value or calorific value which is a very important property of any fuel.

Calorific value (CV) or Heating Value: It indicates the heating efficiency of a fuel. The performance of a fuel is expressed in terms of its calorific value. It is a thermal energy released on combustion of a fuel of unit mass of a fuel. It is expressed in KJ/kg. The calorific value of petrol is 43,500 KJ/kg and of diesel is 42,800 KJ/kg.

1.4 Combustion of Fuel

Combustible elements in a fuel are carbon, hydrogen, sulphur and the reactions are as follows:

$C + O_2 \rightarrow CO_2$ and $S + O_2 \rightarrow SO_2$ For good combustion correct air fuel ratio and turbulence are required. The combustion products are carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen oxide, lead and particulate matter.

1.5 Hydro Power

The rain water stored in the dam is released in a controlled way to generate mechanical power. The potential energy of water stored at a height is utilised for this purpose. The head of water stored in the dam is passed through long pipes called pen stocks. The water while flowing through these pipes gains high velocity and hits the blades of the water turbine thereby causing rotation of the runner wheel of the turbine. This mechanical energy is converted to electrical energy by coupling the turbine to the generator. Thus electrical energy is produced.

Elements of a hydroelectric power plant: The essential elements of a hydroelectric power plant are as follows

1. **Reservoir:** It is a place for storage of water.
2. **Pen Stock:** These are huge long pipes which run from the reservoir to the turbine. These pipes are inclined at an angle ensuring high velocity water.
3. **Turbine:** A hydraulic turbine converts the energy of water into mechanical energy of the rotating shaft.
4. **Power House:** The power house consists of turbine, generators and various accessories for operating the machines and produces electricity.

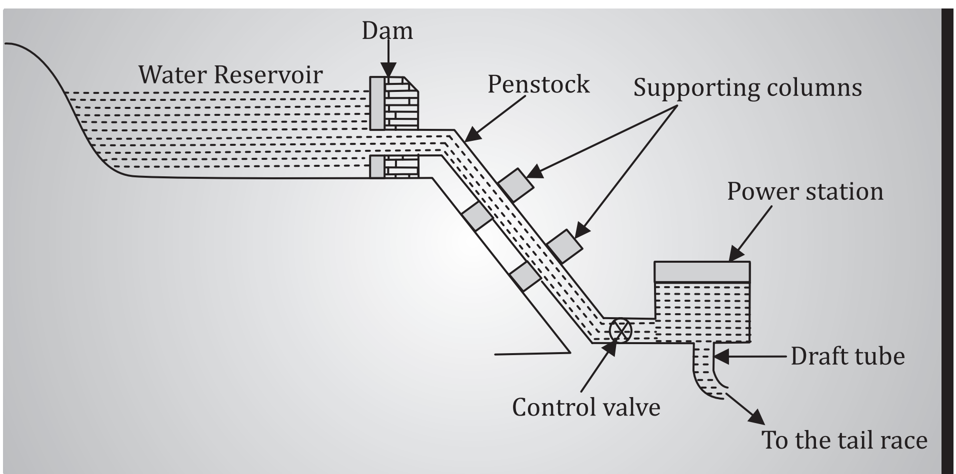


Fig. 1.1: Hydel power plant

Merits of Hydro Power

1. Large scale power generation is possible.
2. Environmental friendly source of energy
3. Energy is available free of cost

Demerits of Hydro Power

1. Construction of dam is expensive
2. The surrounding areas may be flooded.
3. In summer there might be scarcity of water.

Hydro Power comes from a reservoir from the water stored in the dam. Hydro power is a renewable non-depleting source of energy.

1.6 Nuclear Power

The nuclear power is generated by the process of fission and fusion.

A typical nuclear plant consists of:

Fuel: which could be uranium or thorium isotope.

Moderator: A moderator reduces the speed of neutrons within a small number of collisions. Materials like heavy water, carbon, beryllium etc are used as moderators.

Control Rods: These are key elements that control the nuclear chain reaction. They are made of cadmium or boron. They have huge neutron absorption capacity.

Coolant: Coolant ensures the removal of heat. The coolant can be either liquid or gas. Heavy water is used as a coolant.

Shield: shielding is necessary to prevent passage of radiation to the outside of the reactor.

Reactor Vessel: it is a strong walled container housing the reactor core. It contains the moderator, reflector, control rod and thermal shield.

Reflector: It is used to prevent the loss of neutrons by reflecting them back to the reactor.

Nuclear energy is the chemical energy released during the splitting or fusing of atomic nuclei. The amount of heat liberated due to nuclear fusion or fission may be utilised for the generation of steam. This steam may then be used in a steam turbine to generate electrical energy. Heavier unstable atoms such as uranium, thorium and their isotopes produce enormous energy through nuclear reaction process. There are mainly two kinds of nuclear power plants namely boiling water reactor and pressurised water reactor.

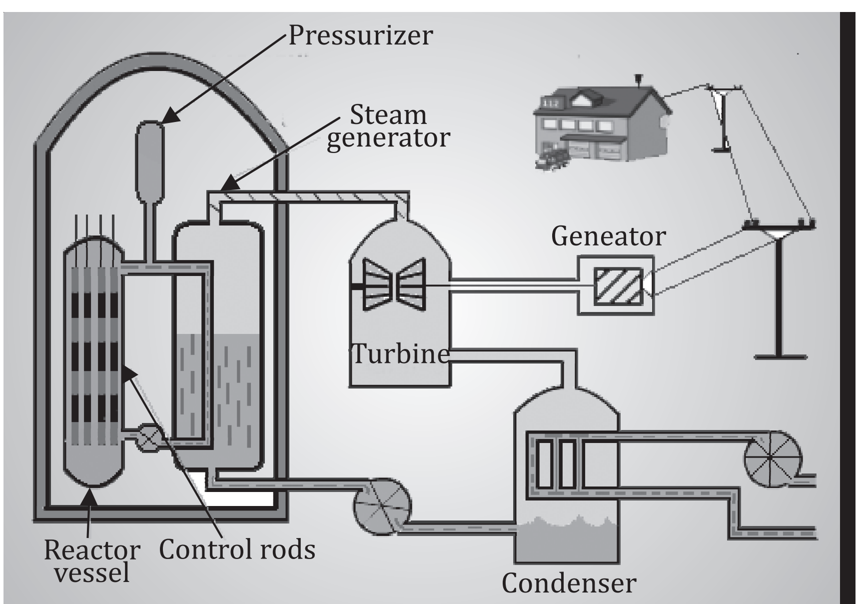


Fig. 1.2: Nuclear Energy

Merits of Nuclear Power

1. Enormous amount of heat is produced through small quantity of fuel.
2. Small storage area is sufficient
3. Increase in reliability of operation
4. Functioning of the plant is not affected by weather conditions
5. They are well suited to meet large power demands at high load factors.

Demerits of Nuclear Power

1. Disposal of radioactive material causes severe hazards
2. Storage of nuclear material involves high risk
3. Causes environmental pollution.
4. Initial cost of the power plant is high
5. Not suited for varying conditions.

1.7 Solar Energy

Solar energy is the greatest potential energy source for the future. Enormous heat energy is derived from the sun. Solar energy can be utilized directly or indirectly. There are different means of solar energy utilization which is termed as solar energy harvesting.

Solar Radiation: It is the energy received from the sun's solar radiation. It is the total frequency spectrum of electromagnetic radiation produced by the sun.

Definition Solar Constant

The amount of incoming solar radiation per unit area is called Solar constant.

The value of solar constant is 1.366 Kilowatts/m^2.

1.8 Harvesting Solar Energy is Done in Three Major Forms

1. **Helio Thermal Process:** The solar energy radiation falling on the earth is converted to heat energy by using a collector. This process is called helio thermal process. A flat plate collector (FPC) is used for this purpose.

2. **Helio Electrical Process:** The process of conversion of solar energy into electrical energy is called photo voltaic process.

3. **Helio Chemical Process:** In this process bio mass like plant matter absorbs solar radiation and biochemical reaction takes place called as photosynthesis. During this process bio-energy such as glucose, cellulose etc., are generated and gets stored inside the bio-matter.

1.8.1 Helio Thermal Process

Flat plate collector: Solar energy can be converted to heat by using a flat plate collector.

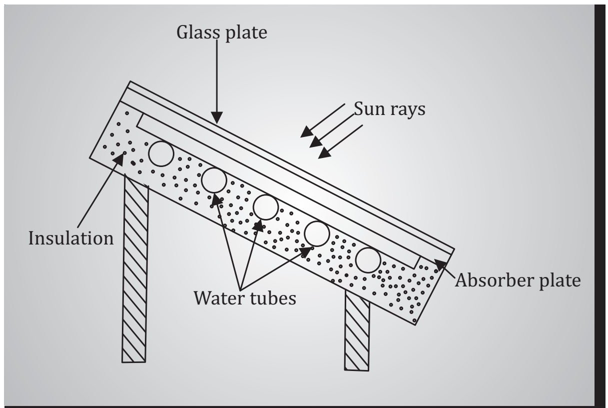


Fig. 1.3: Solar flat plate collector

Black body absorbs radiation

Principle of Operation

A Flat plate collector consists of a glass plate, an absorber plate and water tubes provided with insulation. The black absorber plate absorbs maximum sunlight falling on it. The heat generated is transported to the copper tubes through which water flows. Insulation is done to minimize heat losses.

1.8.2 Helio Electric Process

This involves conversion of solar energy into electrical energy. An example of this is the **solar photo voltaic cell** commonly called as solar PV cells.

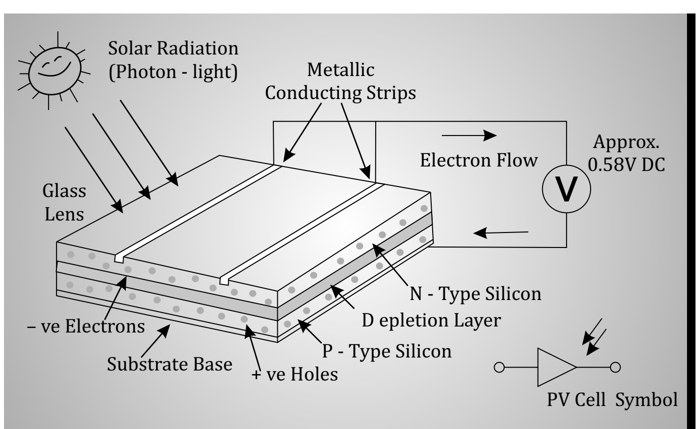


Fig. 1.4(a): Photo Voltaic Cell

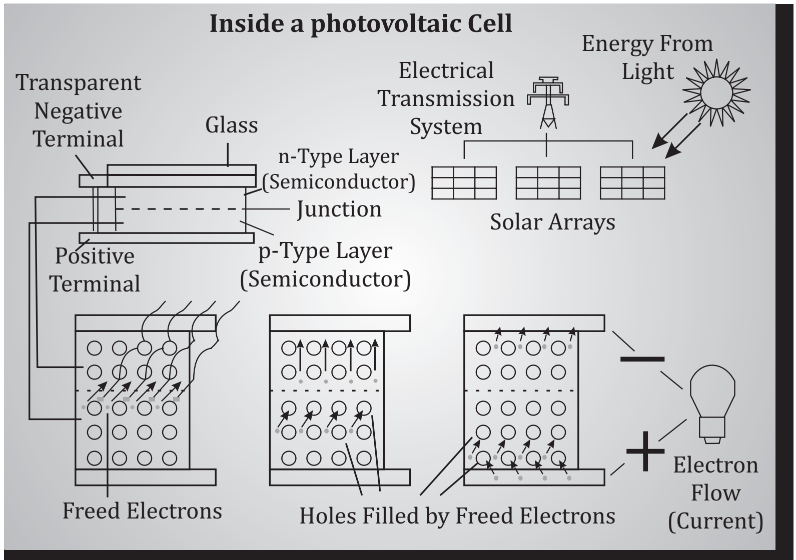
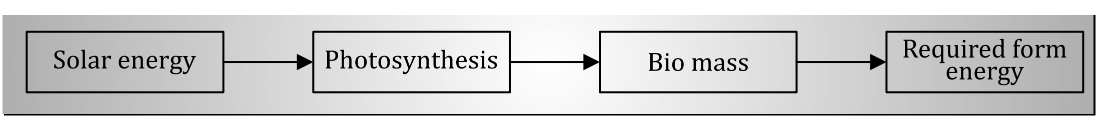


Fig. 1.4(b): Photo Voltaic Cell

The actual conversion of solar energy directly into electrical energy in a semi conductor takes place in a silicon PV cell. Silicon has 4 valence electrons in its outer most shell. By the addition of arsenic or phosphorous one more electron can be added. This excess electron is negatively charged and is called n type silicon. Addition of boron leads to less number of electrons and a hole is created which is positively charged and is called p type silicon. The solar PV cell is composed of p and n type semiconductors. When a p-n junction of a semi conductor is exposed to sunlight its p region becomes positively charged and the n region becomes negatively charged. If an external load is applied, this charge difference will drive a current or emf through it. This principle is used in developing a solar PV cell.

1.8.3 Helio Chemical Process

Light or photons falling on the plants leads to a chemical process called photosynthesis.



1.9 Solar Ponds

These are natural or artificial bodies of water for collecting or absorbing solar radiation energy.

Principle of Operation: Fluids such as water and air rise when heated. This natural principle is used to store thermal energy in a solar pond. The pond has three main water layers called surface zone, gradient zone and storage zone. The salt content of the pond increases from top to bottom.

Application of solar ponds: Solar ponds are used for the following applications

1. Heating and cooling of buildings
2. Production of power
3. Industrial processes
4. Crop drying

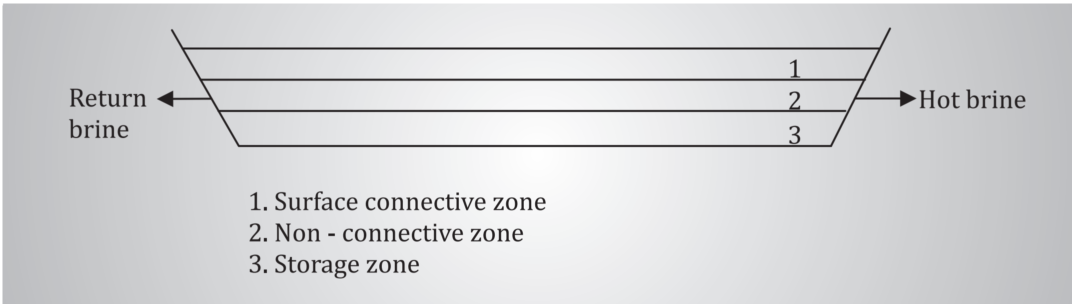


Fig. 1.5: Solar Pond

1.10 WIND ENERGY

Wind is a result of air density with temperature and pressure variation due to the earth's rotation. There are certain regions where high velocity winds blow based on the topography of the land. An important parameter is the velocity.

Principle of wind energy generation; The wind mill consists of a structure on which bearings are mounted. It also contains a rotor at its front end and rotating blades. When the wind blows across the blades they start rotating and develop speed or rpm. This speed or mechanical energy is sent to the generator where mechanical energy is converted into electrical energy.

Wind energy is defined as the kinetic energy associated with the moment of large mass of air. When the wind blows a force causes the rotor of a windmill to rotate like a propeller to generate speed which is a form of mechanical energy. This turning shaft rotates thereby mechanical energy is converted to electrical energy by a rotator.

Note

Maximum efficiency produced by wind = 53%

Know This: Power in Wind

KE of Wind $= 1/2\ \rho V^2$ *(V = Velocity of wind,* ρ *= Density)*

Power in Wind = KE × Velocity $= 1/2\ V^2 \times V$

Power in Wind $= 1/2\ \rho V^3$

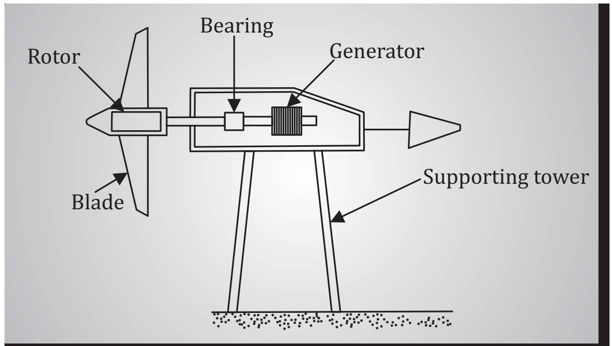


Fig. 1.6: Schematic representation of a wind mill

Merits of Wind Energy

1. Wind energy is a non depletable source of energy
2. It doesn't cause any pollution hence it is environment friendly.
3. It is a cheap source of power
4. Can be used in rural areas

Demerits of Wind Energy

1. It requires high altitude to generate power.
2. It is a fluctuating source of energy as it depends on the velocity of wind

1.11 Biofuels

Biofuels are projected as a replacement to petroleum fuels. However they can be partially used with petrol or diesel which is termed blending. In India Biodiesel is under production and is blended 10 to 20% in KSRTC buses in Karnataka. It reduces carbon emission by 50-80%. Ethanol and Methanol are a kind of biodiesel which are being used widely. Biodiesel emissions are low and hence are eco-friendly.

Advantages of biofuels over petroleum fuels

1. Non depletable
2. Green house emissions are reduced
3. Low level of pollution

Biofuels have increased in popularity due to rise in oil price. Vegetable oils react with alcohols such as methanol and ethanol in the presence of catalyst to produce biodiesel. These are proving to be a substitute for petrol and diesel. Example of biofuels are bioethanol, biodiesel, producer gas and biogas. Biofuel can be used as a fuel for transportation, cooking and in small scale industries.

Emission of Biofuels

Biodiesel plays a vital role in reducing emissions of many air pollutants. The emission of carbon monoxide (CO), sulphur oxides (SO_x)and nitrogen oxides (NO_x)is lesser than those of petroleum fuels and thus they are ecofriendly. Calorific value of biofuels will be considerable lesser than that of petroleum fuels.

Merits of Emission of biofuels

1. It is a renewable energy source.
2. It is a substitute for fossil fuels.

Demerits of Emission of biofuels

1. Requires more land area.
2. Collection and transportation is expensive.

1.12 Steam & Formation of Steam

Water in its vapour form is steam. It is widely used in process industries like chemical industries, sugar factories, pharmaceutical industries etc and also for power generation in steam power plants.

Consider 1 kg of water at 0 °C taken in a cylinder fitted with a freely moving frictionless piston. A weight is placed on the piston to ensure constant pressure. This constant is represented by point A in the T-h diagram. When this water is heated at constant pressure, its temperature rises till the boiling point is reached. When the boiling point of water is reached, there is a slight increase in volume .The temperature at which water boils is called Saturation temperature. This condition is denoted by the point B on the graph and Ts is the saturation temperature. The heating of water from 0 °C to Ts °C is represented by the line AB on the graph.

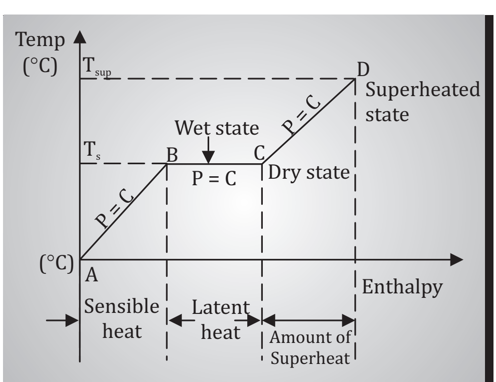


Fig. 1.7: Formation of steam/ Temperature Enthalpy Diagram

T_{sup} = Superheated Temperature

T_s = Saturation Temperature

The amount of heat required to raise the temperature of 1 kg of water from 0 °C to the saturation temperature Ts °C at constant pressure is known as **sensible heat** denoted by h_f. The sensible heat is also called as enthalpy of the liquid. Further addition of the heat leads to evaporation of water while the temperature remains at Ts. The water gets converted to steam. This is represented by the point C on the graph. This constant temperature, heat addition is represented by BC on the graph.

The amount of heat required to evaporate 1 kg of water at saturation temperature Ts to 1 kg of dry steam at given constant pressure is called **Latent heat of evaporation** or enthalpy of evaporation h_{fg}.

On heating the steam further above saturation temperature we obtain super heated temperature. This process is called super heat represented by the line CD.

The amount of heat required to increase the temperature of dry steam from its saturation temperature to any desired higher temperature at constant pressure is called the **amount of super heat.**

Types of steam

There are basically three kinds of steam

(i) Wet steam (ii) Dry steam (iii) Superheated steam

Dryness fraction: Wet steam can have different proportions of water molecules and dry steam. Hence the quality of wet steam is specified by the dryness fraction which indicates the amount of dry steam present in the given quantity of wet steam and is denoted as x. the dryness fraction of a steam is defined as the ratio of mass of actual dry steam present in a known quantity of wet steam to the total mass of the wet steam.

$$\text{Dryness fraction, } x = \frac{\text{Mass of dry steam present in wet steam}}{\text{Total mass of wet steam}}$$

$$\therefore \quad x = \frac{mg}{mf + mg}$$

mg = mass of dry steam present in wet steam

mf = mass of superheated water molecules in sample quantity of wet steam.

1. **Wet Steam:** It is a mixture of liquid and vapour particles. It will be at saturation temperature.
2. **Dry Steam:** The steam which doesn't contain water particles is called dry steam. It will be at saturation temperature Ts.
3. **Superheated Steam:** The steam which is heated beyond its dry saturated state is known as superheated steam. It will be at super heated temperature T_{sup}.

1.13 Differences between Dry Steam and Superheated Steam

Sl. No.	Dry Steam	Superheated Steam
1	Heat content is less	Heat content is more
2	Obtained at T_s	Obtained at T_{sup}
3	Cannot be used for power generation	Can be used for power generation
4	Cost of production is less	Cost of production is more
5	Condensation problems	No condensation problem

1.14 Properties of Steam

Steam is used as a working substance in the operation of steam turbines and steam engines. The following are the important properties of steam which will be needed for the calculation of various properties of steam. The basic thermodynamic properties are pressure, temperature, volume, enthalpy, internal energy and entropy. These properties are estimated at different conditions and various power parameters which are used in specific applications.

1. **Enthalpy of Steam:** It is defined as the sum of internal energy and the product of pressure and volume. It is the heat content of the steam denoted by h.

$$h = u + pV$$

   where u is initial energy, h is the enthalpy, P is the pressure and V is the volume.

2. **Internal Energy:** Actual energy stored in the steam is called as internal energy. It is the difference between the enthalpy of steam and the external work of evaporation and is denoted by u.

$$u = h - pV$$

3. **Specific volume:** It is the volume occupied by unit mass of a substance expressed in m^3/kg. It is the reciprocal of density.

1.15 Boilers

Boiler is a closed metallic vessel in which steam is generated by heating water beyond its boiling point .The steam generated in the boiler will have high pressure and temperature.

This steam is passed through a nozzle which increases the velocity. This high velocity steam passes through a turbine which converts kinetic energy of steam into rotational energy. This rotational energy when coupled to a generator produces electricity. Thus steam energy is converted to electrical energy.

1.15.1 Classification of Boilers

Boilers are classified depending on the content of tube, position of furnace as follows:

(i) Depending on the content of tube (a) Water tube (b) Fire tube	(ii) Depending upon the position of the furnace (a) Externally fired (b) Internally fired
(iii) Depending on the position of tubes (a) Horizontal (b) Vertical (c) Inclined	(iv) Depending on the use (a) Stationary (b) Mobile
(v) Depending on the number of tubes: (a) Single tube (b) Multitube	(vi) Depending on the circulation of water (a) Natural circulation (b) Forced circulation

1.16 Fire Tube and Water Tube Boilers

Fire Tube Boilers

The hot flue gases produced by combustion of fuels is fed through the tubes around which the water circulates.

Example: Cochran boiler, Cornish boiler and Lancashire boiler.

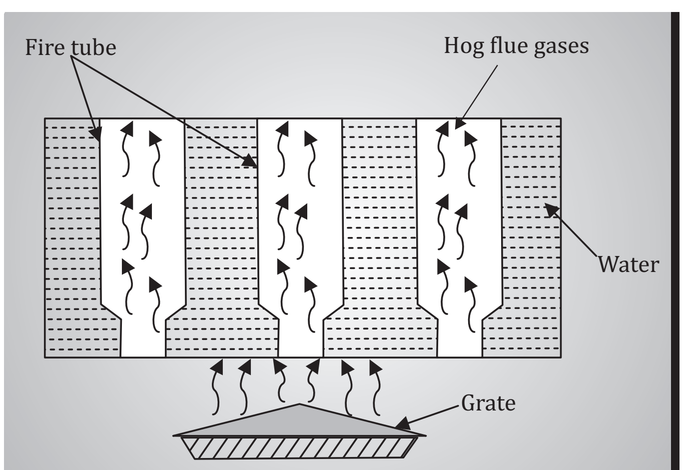


Fig. 1.8: Fire tube boiler

Water Tube Boilers

Water circulates inside the tubes while the hot gases produced by the combustion of fuels passes around them externally. Steam generation is faster in these kind of boilers.

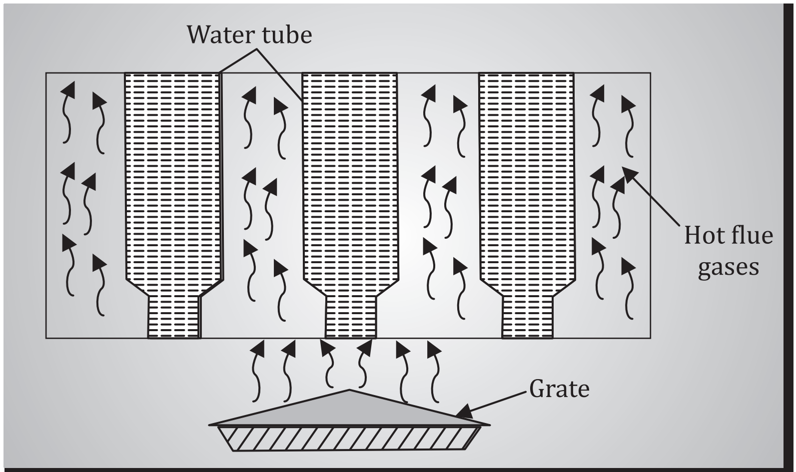


Fig. 1.9: Water tube boiler

Example: Babcock and Wilcox boiler, sterling boiler.

Advantages of Water Tube Boilers over Fire Tube Boilers

1. Steam can be raised quickly.
2. Steam can be produced at higher pressure
3. Steam produced by water tube boilers can be used for power generation.
4. It is suitable for any type of fuel.
5. They occupy less space
6. Damage due to bursting of water tubes is less serious compared to bursting of fire tubes.

Disadvantages of Water Tube Boilers over Fire Tube Boilers

1. Initial cost is high.
2. They require more maintenance.
3. Water tube boilers are not suitable for mobile application
4. Pure feed water is essential and hence is not suitable for ordinary water.

1.16.1 Comparison of Water Tube and Fire Tube Boilers

Sl. No.	Fire Tube Boiler	Water Tube Boiler
1	Hot flue gases will be flowing through the tubes and water surrounds them	Water will be flowing through the tube and hot gases will surround the tube.
2	Generation of steam is slow	Generation of steam is faster
3	They are used to generate steam up to 20 bar pressure	Used to generate steam beyond 20 bar pressure
4	They are internally fired boilers	They are externally fired boilers
5.	They are used in process industries	They are used in power plants to generate power

1.17 Lancashire Boiler (Fire Tube Boiler)

Lancashire boiler is an internally fired natural circulation fire tube boiler. This boiler raises steam up to a pressure of 15 bar and maximum evaporative capacity of 8500 kg of steam/hr. This boiler is very widely used in sugar mills and chemical industries.

Construction: This boiler consists of a horizontal cylindrical shell placed on brickwork setting. Two large flue tubes of diameter 0.4 times than that of the boiler shell runs through its length. Two furnace grates are provided at the front entrance. An ash pit is placed under the grate .The cylindrical shell is located over a brickwork and is filled with water. The flue tubes extend from one end to another end of the cylindrical shell and located below the water level indicator. It also consists of fire grate, safety valve, blow off valve and bottom channel.

Path of the flue gases: The hot gases from the furnace grate passes to the back end of the tubes and move in downward direction. They move by the bottom flue to the front of the boiler. Flue gases are divided into two streams and pass into the side flues. Finally the flue gases move to the chimney through rear exit passage

Working: With the help of the flow passages of the gases, the bottom shell is first heated and then its sides. The heat is transferred to the water through surfaces of the two flue tubes and bottom part and sides of the main shell. Thus steam is formed due to this heat transfer and occupies the steam space .The steam accumulated in the steam space is taken out through the steam stop valve and is allowed to pass over a steam turbine to generate power.

Merits of Lancashire Boiler

1. Simple in design and construction.
2. Maintenance is easy
3. Heating surface area is more
4. Overall efficiency of boiler is high

Demerits of Lancashire Boiler

1. Occupies more space
2. Formation of steam is slow
3. Suitable for steam up to 20 bar only.

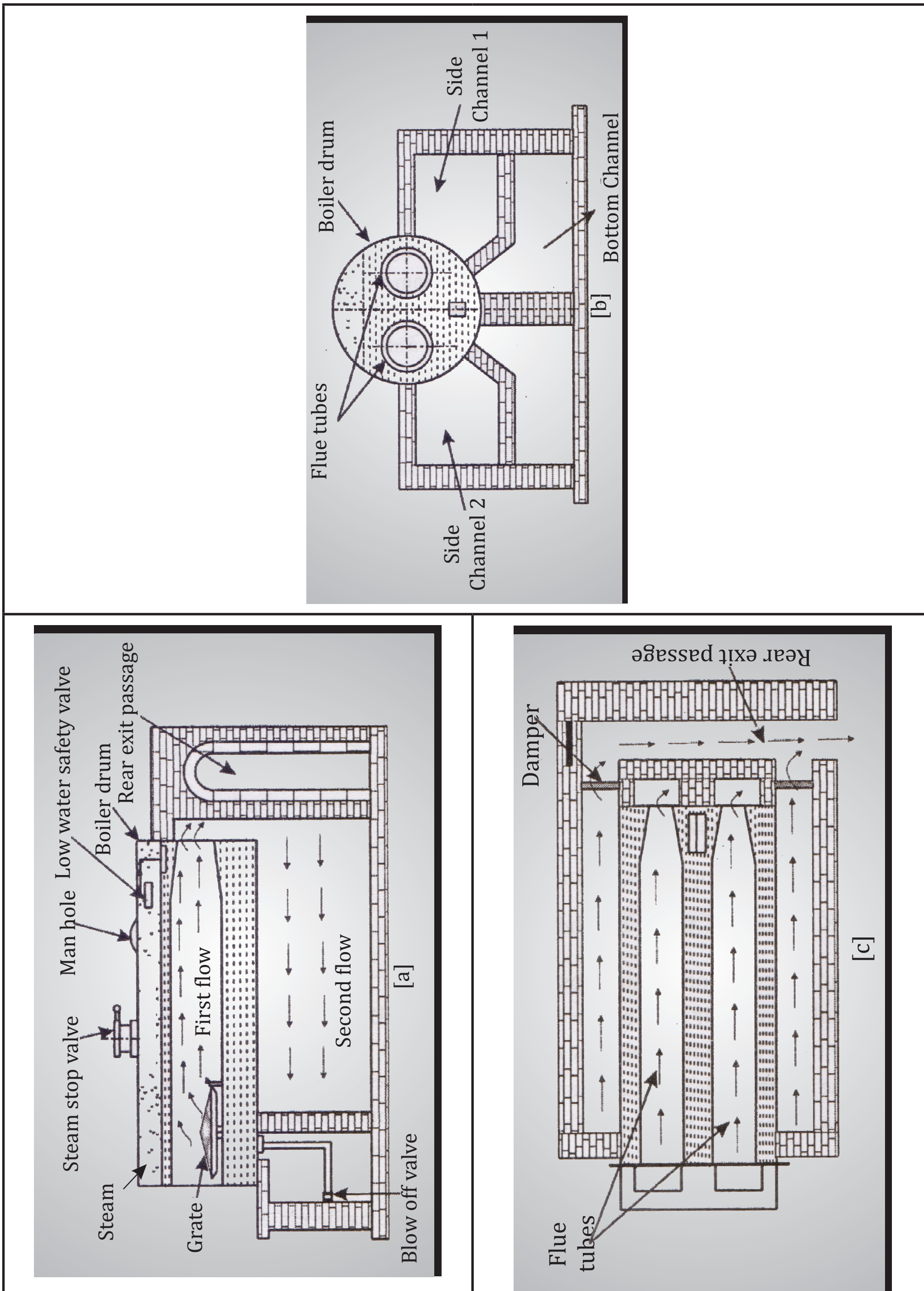


Fig. 1.10: Lancashire Boiler [a] front view [b] side view [c] top view

1.18 Babcock and Wilcox Boiler

It is one of the most common types of water tube boilers. It is a horizontal natural circulation water tube boiler. In this boiler water passes through the tubes and hot gases flow over these tubes. The tubes are placed at an angle of 15° to the horizontal. The tubes are 75-100mm in diameter and about 600 mm length. The water is introduced into the boiler drum through the feed valve.

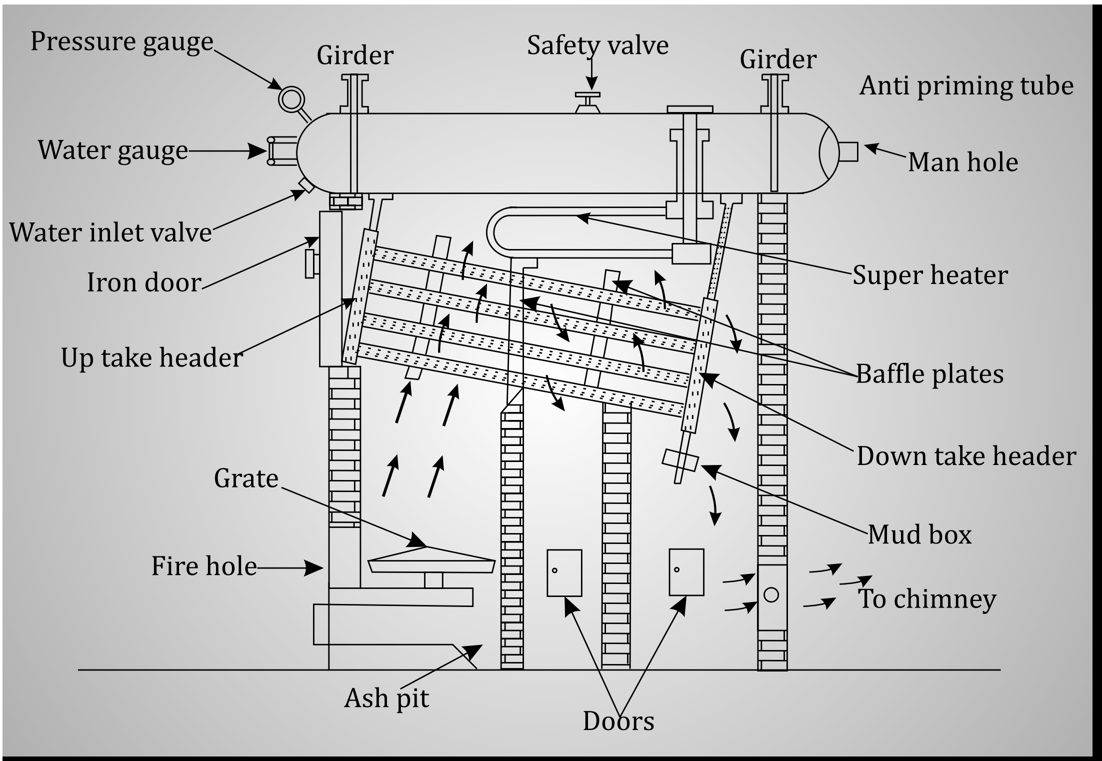


Fig. 1.11 Babcock and Wilcox boiler

The water descends at the rear end into the downtake header and passes into the inclined water tubes. The hot gases from the furnace grate are collected by the baffle plates. As the hot gases pass they come in contact with directly with the water tubes. Now the water in these tubes gets evaporated. The water and steam mixture now ascends through the uptake header and reaches the boiler drum. The steam gets separated from the surface of the water in the boiler drum. The steam from the steam space is then fed into the superheater where the steam is superheated. Steam from the superheater is passed to the steam stop valve. From the steam stop valve, the superheated steam is passed over a steam turbine to generate power.

Merits of Babcock and Wilcox Boiler

1. Evaporation capacity is high
2. Defective tubes can be replaced easily
3. Efficiency is high when compared to fire tube boiler
4. Can be used in power plants for power generation

Demerits of Babcock and Wilcox Boiler

1. Initial cost is high
2. Water should be treated to avoid condensation problems
3. Not suitable for mobile applications.

1.19 Boiler Mountings and Accessories

Boiler Mountings

The devices which are necessary for safe and efficient operation of the boiler are called as boiler mountings. They are directly mounted on the boiler.

List of Boiler Mountings

1. **Safety valve:** The function of safety valve is to maintain the safe pressure inside the boiler. It acts like the safety valve of a pressure cooker. It is fitted on top of the boiler.
2. **Water level indicator:** Indicates the level of water in the boiler drum. It is fitted in the front end of the boiler.
3. **Feed check valve:** It feeds the water into the boiler so as to maintain constant required level of water in the boiler drum. It is fitted in the feed water pipeline.
4. **Fusible plug:** Lower level of water in the boiler drum leads to overheating and explosion. To avoid this fusible plug is used which acts similar to the fuse in electric circuits. It is usually fitted over the combustion chamber.
5. **Blow off cock or Blow off valve:** The function of blow off valve is to remove the sediments collected at the bottom of the boiler. It is used for cleaning the boiler periodically. It is fitted in the lower portion of the boiler.
6. **Steam stop valve:** The function of steam stop valve is to control the passage of steam from the boiler .It is fitted on the top portion of the boiler.

Boiler Accessories

The device which is used for improving the overall efficiency of the boiler is called as boiler accessories. These are the auxiliary parts of the boiler.

List of boiler accessories

1. **Economiser:** The function of economiser is to heat and feed the water using exhaust gases. It is fitted near to the chimney. It improves the efficiency of the boiler.
2. **Air-preheater:** The function of air preheater is to transfer heat from the flue gas to the air fed to the furnace for combustion. It is located between economiser and chimney.
3. **Superheater:** The function of superheater is to increase the temperature of steam above saturation temperature at constant pressure. Superheat utilizes the heat of the combustion products. It is located in the path of the flue gases which are hot.
4. **Steam separator:** The steam separator separates the water particles from the steam before allowing it to the turbine. It is located very close to the turbine.

Review Questions

1. What are the different sources of energy available for power generation?
2. Define Energy, Power, Renewable and non-renewable energy resources.
3. Differentiate between renewable and non –renewable sources of energy.
4. How are coals classified?
5. Name the different kinds of fossil fuels.
6. What are conventional and non conventional source of energy?. Explain with examples.
7. With a neat sketch explain the working of a hydroelectric power plant.
8. What are the advantages of hydroelectric power plant?
9. What are the essential parts of a hydroelectric power plant?
10. What are the various hydraulic turbines?
11. Classify Turbines.
12. What is the principle of a Nuclear reactor?
13. Describe a nuclear reactor with sketch.
14. Describe a nuclear power plant and explain its working.
15. Define nuclear fission and fusion.
16. What are the advantages and disadvantages of nuclear energy?
17. Explain the formation of steam with T-h diagram.
18. Explain the following
    (a) Dry Steam
    (b) Wet Steam
    (c) Saturated Steam
    (d) Superheated Steam
    (e) Dryness fraction
    (f) Degree of Superheated
    (g) Latent heat
    (h) Sensible heat

19. Differentiate between Dry and Wet Steam.
20. What are advantages of Superheated Steam.
21. Explain the working of a Flat plate solar collector.
22. Describe the principle of a flat plate collector.
23. What are advantages and disadvantages of solar energy?
24. Explain with sketch the principle of wind energy generation.
25. Explain the merits and demerits of wind energy.
26. Describe the different types of wind turbines.
27. What is solar harvesting?
28. List various sources of energy with an example.
29. Explain the principle of fire tube and water tube boiler.
30. Differentiate between the following
    (a) Internally fired and externally fired boilers
    (b) Fire tube and water tube boilers
31. What is steam separator?
32. Describe with a sketch the working of Lancashire boiler.
33. With a diagram explain the working of Babcock & Wilcox boiler.
34. What are the merits and demerits of fire tube and water tube boiler.
35. Name some boiler mountings and accessories.
36. Describe the function of (i) Economiser (ii) Air-preheater (iii) Super heater.
37. What are the functions of feed pump, steam trap, safety valve and stop valve?.
38. Differentiate between boiler mountings and accessories.

Multiple Choice Questions

1. Boiler is a mechanical equipment in which
    (a) Steam is heated
    (b) Wet steam generated from ice
    (c) Steam supplied at constant pressure
    (d) Starting with water, steam generated and supplied at constant pressure.
2. Function of fusible plug in a boiler is
    (a) To fuse a hole in fire tube
    (b) To plug the leak in boiler
    (c) To melt and save boiler
    (d) To cool overheated boiler
3. Presure garge and water level indicators are mounted
    (a) Rear of the boiler
    (b) Front top of the boiler
    (c) Front bottom of boiler
    (d) Behind top of boiler

4. Boiler accessories are derives which
   (a) Improve safety of boiler
   (b) Are essential for boiler working
   (c) Improve efficiency
   (d) Makes maintenance easy
5. Amount of water particles present in Super heated steam is
   (a) 100%
   (b) 0%
   (c) 50%
   (d) 90%
6. Calorific value is highest for
   (a) Coal
   (b) Diesel
   (c) Alcohol
   (d) Gaseous fuels
7. Coke is made from
   (a) Coal
   (b) Petrol
   (c) Wood
   (d) Hydrogen
8. Emission levels with respect to Biofuels is
   (a) Lower
   (b) Higher
   (c) Same
   (d) None of above
9. Solar pond is:
   (a) Natural pond with pure water
   (b) Back waters of Sea
   (c) Pond with large depth
   (d) Pond with salt filled upto a depth
10. Solar constant means:
   (a) Solar heat radiated by sun
   (b) Solar radiation at earth's surface
   (c) Solar radiation at earth's atmosphere received per unit are perpendicular to solar rays.
   (d) Total uifrared radiation from sun.
11. Value of solar constant is:
   (a) 1000 Watt/Cm^2
   (b) 1367 watts/$metre^2$
   (c) 1353 Watts/$metre^2$
   (d) 2000 watts/$metre^2$
12. Process of conversion of solar developed in helio electric process is
   (a) Photo chemical
   (b) Photo electric
   (c) Photo voltaic
   (d) Photo synthesis
13. High Temperature is developed in helio thermal process by
   (a) Parabolic collector
   (b) Flat plate collector
   (c) Solar cell
   (d) Semiconductor

❀❀❀❀

Notes

TURBINES AND IC ENGINES AND PUMPS STEAM TURBINES

MODULE 2

HIGHLIGHTS

- Introduction
- Energy Conversion in a Turbine
- Steam Turbines
- Classification of Steam Turbines
- Impulse Turbine
- Delaval's Turbine (Impulse Turbine)
- Gas Turbines
- Water Turbines
- Impulse Water Turbine (Pelton Turbine)
- Francis Turbine
- Kaplan Turbine
- Internal Combustion Engines (IC Engines)
- Four Stroke Petrol Engine
- Four Stroke Diesel Engine
- Two Stroke Engines

2.1 Introduction

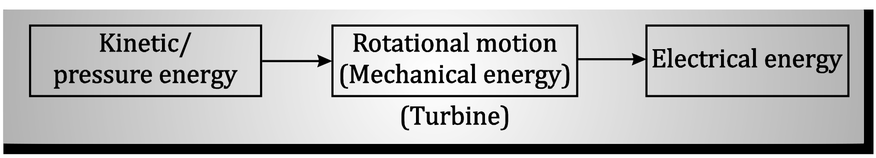
A device which converts the available form of energy into the required form of energy is known as a prime mover. Turbine is a rotating device which converts kinetic energy of a fluid into mechanical energy. Internal Combustion engine is a heat engine which converts heat energy into mechanical work. Hence turbines and IC engines are called prime movers.

Definition: Prime Mover

Any device which utilizes the various sources of energy available in nature and converts it into useful mechanical work, is a prime mover.

2.2 Energy Conversion in a Turbine

Turbine is a prime mover of rotating type having curved blades on its periphery .It converts kinetic energy into rotational energy and then to electrical energy. In general, energy conversion in a turbine is represented by a block diagram as shown



There are different kinds of turbines depending on the working fluid.

They are classified into three different types.

1. **Steam Turbines:** Here the working fluid, which is steam is fed into the turbines to generate mechanical energy.
2. **Gas Turbines:** The working fluid here could be air or any inert gas and this is used as working fluid to generate mechanical energy in the form of rotation or speed.
3. **Water Turbines:** Water is used as the working fluid in the generation of mechanical energy.

2.3 Steam Turbines

Steam turbines is one of the most widely used prime mover for driving generator to produce electrical power. The thermal energy of steam is converted into kinetic energy by expansion and then to mechanical power by steam turbine.

Principle of Operation

The principle of operation of steam turbine is based on Newton's second law of motion which states that the rate of change of momentum is directly proportional to the applied force. The steam turbine is a prime mover which converts heat energy of steam into mechanical energy. The conversion process takes place in two steps, (i) Steam energy is converted into kinetic energy through nozzles (ii)The kinetic energy is converted into mechanical energy with the help of moving blades. When the turbine is coupled to a generator ,the mechanical energy is converted into electrical energy. Steam turbines are used for power generation in steam power plants. The steam power plants adopt the Rankine cycle for power generation.

Principal parts of the steam turbine: The main parts of the steam turbine are Blades. Rotor, casing and shaft.

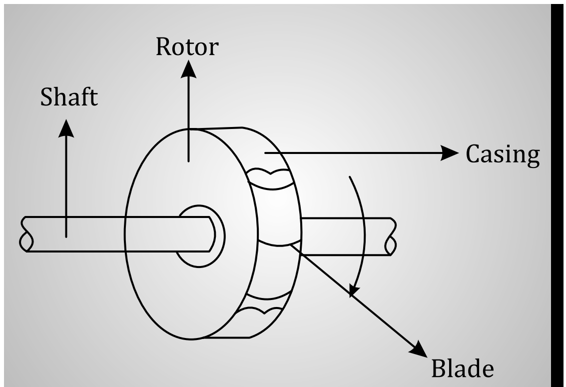


Fig. 2.1 Parts of a Steam Turbine

Blades : The blades of a turbine are curved vanes over which the steam is allowed to flow over the nozzle. There are fixed and moving blades in a steam turbine. The fixed blades are used to increase the velocity of flow while the moving blades convert kinetic energy of steam into mechanical work.

Rotor : It is a rotating element over which the blades are fixed.

Casing : It is the outside cover of a steam turbine which houses the rotor.

Shaft : The blades of the turbine are fixed to a rotating shaft from which power is made available.

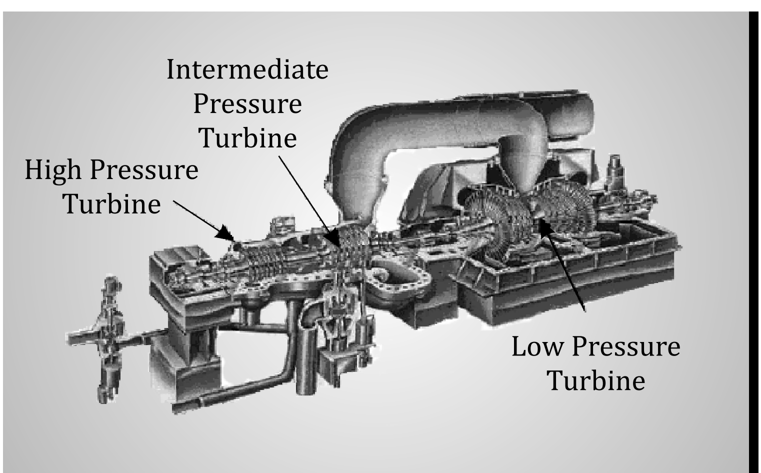


Fig. 2.2 Three Stage Steam Turbine

2.4 CLASSIFICATION OF STEAM TURBINES

Steam turbines are broadly classified as **Impulse** steam turbine and **Reaction** steam turbine.

Expansion of steam in a nozzle: An understanding of the nozzle principle is very essential before studying the working principle of steam turbines.

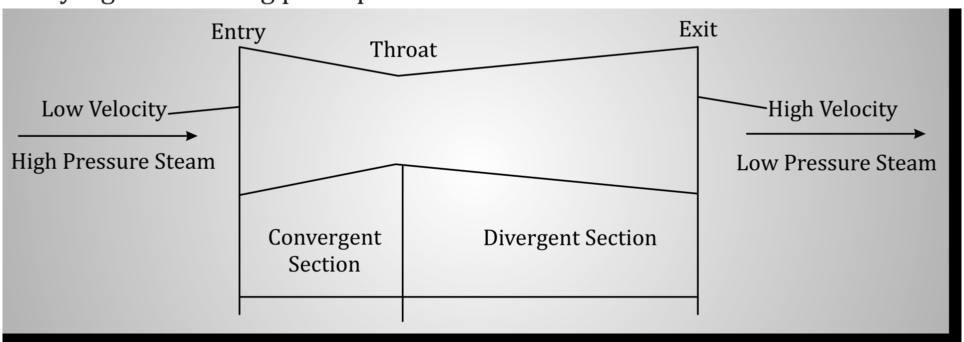


Fig 2.3 Convergent DIvergent Nozzle

The steam generated in a boiler will have high pressure and low velocity .To make use of this steam, its velocity has to be increased. Nozzle is a device which converts low velocity high pressure steam into high velocity low pressure steam. A convergent divergent nozzle is used for this purpose. It consists of a convergent part, a divergent part and a throat.

Steam having high pressure and low velocity enters the nozzle. When the steam passes between entry and throat it expands to low pressure reducing its enthalpy. But in the nozzle there is no heat transfer and hence the loss in enthalpy increases velocity of steam. Thus we obtain steam with high velocity.

2.5 IMPULSE TURBINE

In an impulse turbine, most of the energy of steam is converted into kinetic energy by the nozzle or a set of nozzles that are fixed .High velocity steam coming out of the nozzle is made to glide over a moving blade. The blades are so designed that it enables the steam to change its direction of motion and also velocity. Hence maximum force is generated on the rotary blade as per Newton's second law of motion. This force rotates the blade and power output from the turbine is obtained.

Impulse turbine: Principle of operation : In an impulse turbine steam expands in the nozzle and moves over the blades. High velocity steam from the nozzle is directed over the blades of the turbine. The turbine rotates and converts kinetic energy of steam into mechanical work. An example of an impulse steam turbine is the Delaval's turbine.

2.6 DELAVAL'S TURBINE (IMPULSE TURBINE)

An impulse turbine is a turbine that runs by the action of impulse force of the steam on the blades of the turbine .It consists of a series of curved blades on the periphery of a wheel called rotor. The rotor is connected to the shaft as shown in fig 2.4.

High pressure low velocity steam generated in a boiler is passed through a nozzle. As the steam passes through the nozzle, expansion takes place and pressure decreases and velocity increases. The high velocity steam then flows over the moving blades of the turbine resulting in change in momentum. A number of blades are fixed on the wheel and hence when a jet of steam flows over it, the wheel starts rotating at high speed. The rotor connected to the shaft also rotates. This rotation or mechanical energy is converted to electrical energy when coupled to a generator.

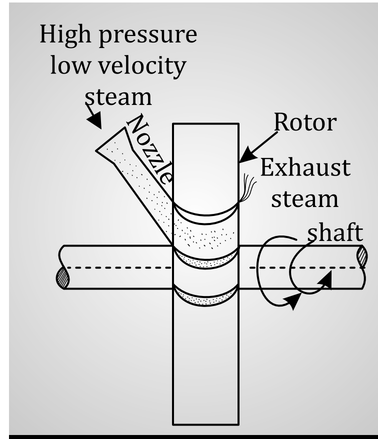


Fig. 2.4 Impulse turbine

Pressure Velocity Diagram

The lower portion shows the nozzle and blades and the top portion shows the variation of pressure and velocity of steam as it flows over the nozzle and blades. The expansion of steam takes place in the nozzle over the blades. The pressure drop is represented by curve PQ. There is no change in pressure of steam as it passes over the blades and flow is represented by line QR. Increase in velocity is shown by line AB. The blades absorb the kinetic energy of steam as it flows over them and velocity increases. This is represented by line BC.

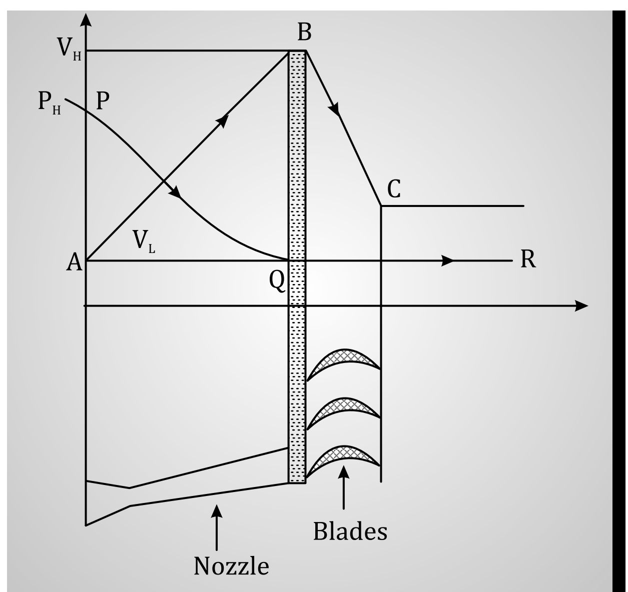


Fig. 2.5 Pressure - velocity Diagram of Impulse turbine

2.6.1 Reaction Turbine (Parsons Turbine)

The reaction turbine is a turbine that runs by the reactive force of the jet of steam. The turbine consists of several alternate rows of fixed and moving blades. The fixed blades are mounted on the stationary casing while the moving blades are mounted on the periphery of a rotating wheel called rotor. Rotor is connected to shaft. In reaction turbines there are no nozzle while the moving blades have aerofoil shape which gives nozzle effect.

Pressure Velocity Diagram for Reaction Turbines

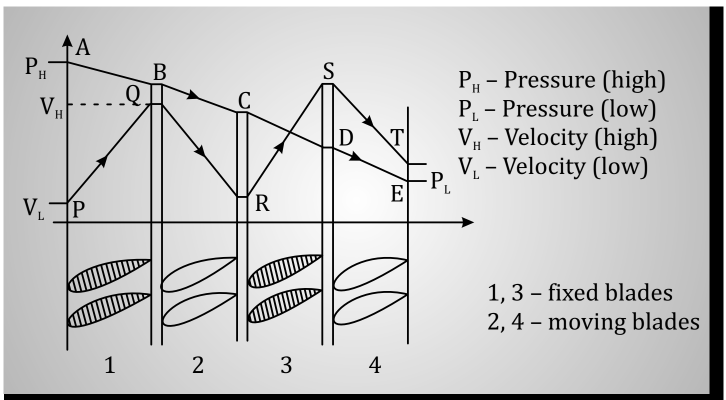


Fig. 2.6 Pressure - Velocity variation in a reaction turbine.

Steam with low velocity and high pressure is generated from a steam generator such as a boiler and this is passed over the fixed blades. The steam the moves on to the moving blades .As the steam passes from the fixed blades to the moving blades, there is a drop in pressure. The steam then passes over a series of fixed and moving blades and in the process the pressure drops gradually and velocity increases. Hence at the exit of the turbine we get high velocity low pressure steam. Hence the nozzle effect is obtained by the aerofoil shaped blades.

2.6.2 Comparison of Impulse and Reaction Steam Turbines

Sl. No.	Impulse Steam Turbine	Reaction Steam Turbine
1	Expansion of steam takes place in the nozzle before it enters the moving blades	Expansion of steam takes place over a set of fixed and moving blades.
2	Blades have symmetrical shape	Blades have aerofoil shape
3	Occupies less space	Occupies more space
4	Suitable for small capacity power plants	Suitable for medium and small power plants
5	They are high speed turbines	They are low speed turbines
6	Size of overall unit is small	Size of overall unit is large

2.7 Gas Turbines

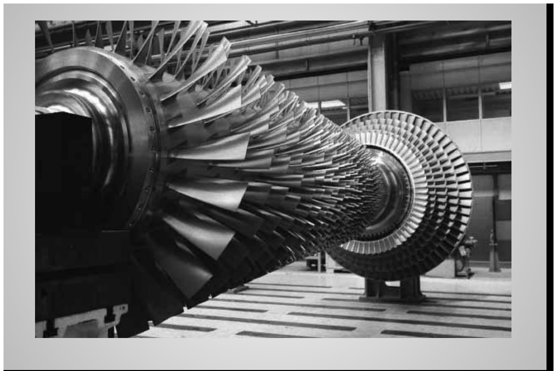


Fig. 2.7 Figure of Gas Turbine

A gas turbine is a rotary engine and works on the same principle as the steam turbine. They are used for generation of electricity, aircraft propulsion, in Marine application and in locomotives.

Advantages of gas turbines over steam turbines

1. Design is simple	2. Simple in operation
3. A wide variety of fuels can be used.	4. Requires less space

Gas turbines are classified as Open cycle gas turbine and closed cycle gas turbine.

2.7.1 Open Cycle Gas Turbine

Working principle

Air which is take from the atmosphere is compressed in a compressor at high pressure. The compressed air is allowed to flow into a combustion chamber where the fuel burns. The hot gases then flow over the turbine and finally discharged to the atmosphere.

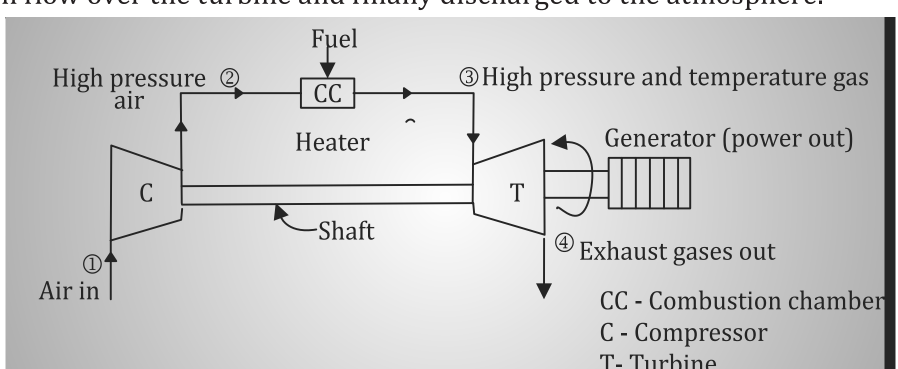


Fig. 2.8 Open cycle gas turbine

The shaft of the turbine is coupled to a generator by which electricity is produced.

Advantages

1. Initial and maintenance cost is less
2. Cooling water is not required
3. Atmospheric air is used as working fluid
4. Used in aircraft and aerospace applications

Disadvantages

1. Causes pollution
2. Requires fresh working fluid for every cycle.

2.7.2 Closed Cycle Gas Turbines

It mainly consists of a combustion chamber, heat exchanger, compressor and turbine. The compressed fluid (air) coming out of the compressor is heated in the heat exchanger. The high pressure high temperature gas coming out of the combustion chamber is then made to flow thro`ugh the turbine .Rotary motion of the turbine is converted to electrical energy by coupling the turbine to a generator. The gas coming out of the turbine is cooled to its original temperature in a heat exchanger and is passed to the compressor again. Thus the same working fluid can be used for the next cycle also.

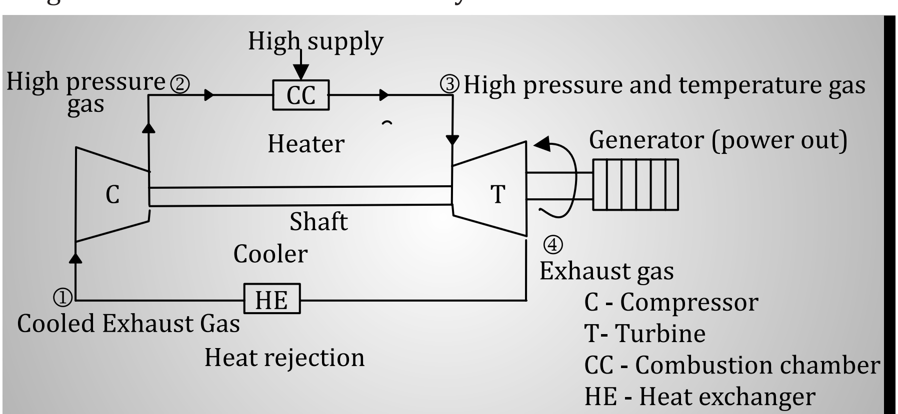


Fig. 2.9 Closed cycle gas turbine

Advantages

1. Working fluid can be re-used
2. Doesn't cause pollution
3. Working fluid other than air like inert gases can be used .
4. Thermal efficiency is higher

Disadvantages

1. Initial and maintenance cost is more
2. Large amount of cooling water is required
3. Overall weight of the unit is more.

2.7.3 Differences between Open Cycle and Closed Cycle Gas Turbine

Sl No	Open Cycle Gas Turbine	Closed Cycle Gas Turbine
1	Fresh working fluid is used in every cycle	Same working fluid is used in every cycle
2	Cooling water is not required	Large quantity of cooling water is required
3	Only atmospheric air is used as working fluid	Any fluid (usually inert gases) can be used
4	Weight of the turbine is less	Weight of the turbine is more
5	Exhaust gas from turbine exit to atmosphere	Exhaust gases are re-circulated in the cycle
6	Thermal efficiency is low	Thermal efficiency is high

2.8 Water Turbines

Water possesses potential energy .This potential energy may be utilised to do some useful work. A device which can convert the potential energy and kinetic energy of water into mechanical energy is defined as a water turbine. This mechanical energy produced by the turbine is converted into electrical energy by means of a generator mounted on the same shaft. Dams are constructed across rivers. Water stored in the reservoir flows through long pipes called pen stocks and comes out with high velocity. This high velocity water hits the blades of the water turbine and the turbine wheel starts rotating thereby generating mechanical energy which can be converted into electrical energy.

Classification of Water Turbines

1. **Based on action of flow of water:**
   - (i) Impulse turbine: Ex. Pelton turbine
   - (ii) Reaction turbine: Ex. Francis turbine
2. **Based on head available at the inlet of turbine**
   - (i) Low head turbine Ex. Kaplan turbine
   - (ii) Medium head turbine Ex. Francis turbine
   - (iii) High head turbine Ex. Pelton turbine
3. **Based on direction of flow of water:**
   - (i) Tangential flow turbine Ex. Pelton turbine
   - (ii) Radial flow turbine Ex. Francis turbine
   - (iii) Axial flow turbine Ex. Kaplan turbine
   - (iv) Mixed flow turbine Ex. Modern Francis turbine

2.9 IMPULSE WATER TURBINE (PELTON TURBINE)

It is a tangential flow impulse turbine used for high heads of water.

The pelton turbine consists of a runner, buckets, nozzle and casing.

Pelton Turbine: Named after the American Engineer Lester Allen Pelton.

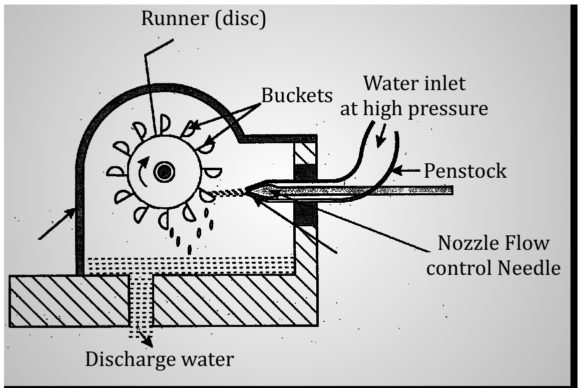


Fig. 2.10 Pelton wheel

Water having high potential energy flows in pen stocks from the reservoir. Water with high velocity enters the pen stock and flows through nozzle. The flow of water through nozzle is controlled by flow control needle. The nozzle converts the potential energy of water into kinetic energy. The jet of water from the nozzle at high velocity strikes the buckets fixed around the circumference of a runner. The impact of water on the surface of buckets produces a force which causes the runner to start rotating. After performing useful work on the buckets water is discharged to the tail race. Due to the impulsive action of water the wheel rotates and hence it is called impulse turbine.

2.10 FRANCIS TURBINE

It is an inward radial flow reaction turbine used under medium heads. it consists of a runner having guide blades on its periphery. It also consists of a draft tube and volute casing.

Francis Turbine: Named after Francis James, an English scientist and engineer.

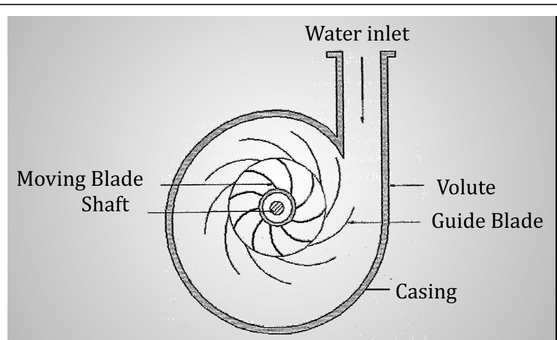


Fig. 2.11 Francis Turbine

Parts of Francis Turbine

The various parts of Francis turbine are Runner, guide vanes, draft tube and volute casing.

Working principle: The water under pressure enters the runner from the guide blades towards the centre through moving blades in the radial direction. As the water moves through the moving blades all its kinetic energy will be converted into mechanical energy and hence the runner starts rotating. The guide blades direct the water on to the runner and exits axially. After doing useful work water is discharged to the tail race through a draft tube.

2.11 Kaplan Turbine

The Kaplan turbine is an axial flow, low head turbine. It operates in an entirely closed conduit from inlet to the tail race. It consists of a scroll casing, guide blades, runner blades attached to the boss which in turn is connected to the vertical shaft, draft tube and tail race as shown in figure.

Kaplan Turbine: Named after the German Scientist Kaplan Victor.

Parts of Kaplan Turbine: The various parts of the Kaplan turbine are the scroll casing, guide vanes, draft tube and hub or boss.

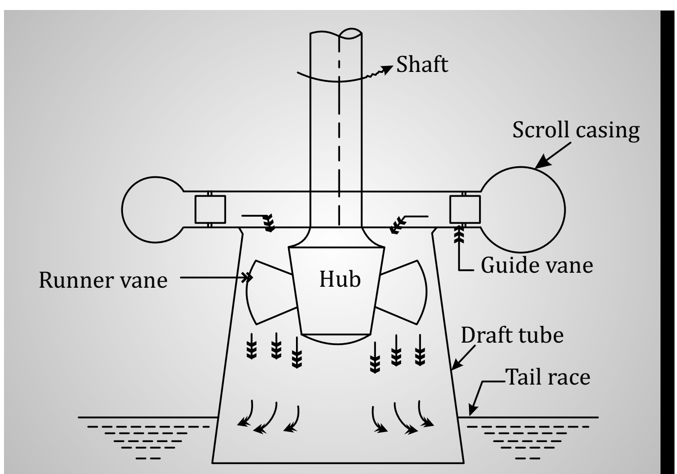


Fig. 2.12 Kaplan Turbine

Working principle: In a Kaplan turbine, the runner blades are similar to the propeller of a ship and hence is also called as propeller turbine. Water at high pressure enters the casing and flows over the guide blades or guide vanes. From the guide blades the water strikes the runner blades by changing its direction by 90° and hence flows axial to the runner. As water flows over the runner blades all its kinetic energy is converted to mechanical energy and hence the runner starts rotating. After doing mechanical work, the water is discharged to the tail race through a draft tube.

2.12 INTERNAL COMBUSTION ENGINES (IC ENGINES)

An internal combustion engine is basically a heat engine in which combustion takes place inside the engine. The fuel supplies the thermal energy when it burns inside

Example: Petrol engine, Steam engine is an external combustion engine.

Classification of IC Engines

IC engines are classified according to :-

(i) Nature of thermodynamic cycle
- (1) Ottocycle engine
- (2) Diesel cycle engine
- (3) Dual combustion

(ii) Type of fuel used
- (1) Petrol engine
- (2) Diesel engine
- (3) Gas engine

(iii) Number of strokes
- (1) Four stroke engine
- (2) Two stroke engine

(iv) Method of ignition
- (1) Spark ignition (SI)
- (2) Compression ignition (CI)

(v) Number of cylinders
- (1) Single cylinder engine
- (2) Multicylinder engine

(vi) Method of cooling
- (1) Air cooled engine
- (2) Water cooled engine

(i) Position of cylinders
- (1) Horizontal engine
- (2) Vertical engine
- (3) Vee engine
- (4) Opposed cylinder engine
- (5) Radial engine.

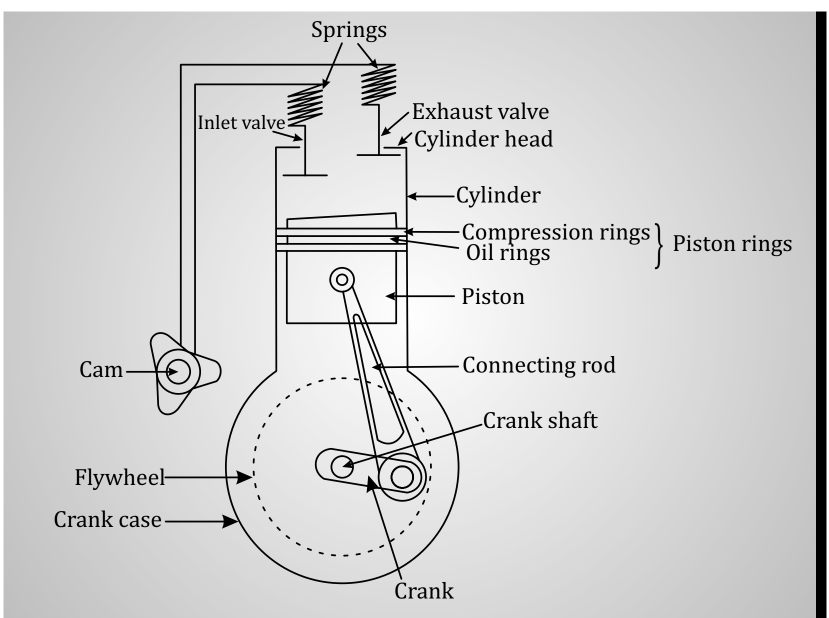


Fig. 2.13 Principle parts of IC Engine

Parts of IC Engine

1. **Cylinder :-** The heart of the engine is the cylinder in which the fuel is burnt and the power developed. The inside diameter is called bore. The piston reciprocates inside the cylinder.
2. **Piston :-** The piston is a hollow cylinder with plunger moving to and fro in the cylinder. The power developed by the combustion of fuel is transmitted by piston to crankshaft through the connecting rod.
3. **Piston rings :-** are metallic rings inserted is grooves at the top end of the piston. They maintain a gas – tight joint and prevent leakage of gases and oil
4. **Connecting rod :-** It is link that connects the piston and crankshaft. It converts linear motion of the piston into rotary motion of the crankshaft.
5. **Crank and crankshaft:-** The crank is a lever that is connected to the end of a connecting rod by a pin joint. The other end is connected to a shaft called as crankshaft
6. **Valves:-** Valves are devices which control the flow of the intake and exhaust gases to and from the engine cylinder.
7. **Flywheel:-** It is a heavy wheel mounted on the crankshaft of the engine to maintain uniform station of crankshaft
8. **Crank case:**- Is the Enclosure for the engine

IC Engine Terminology

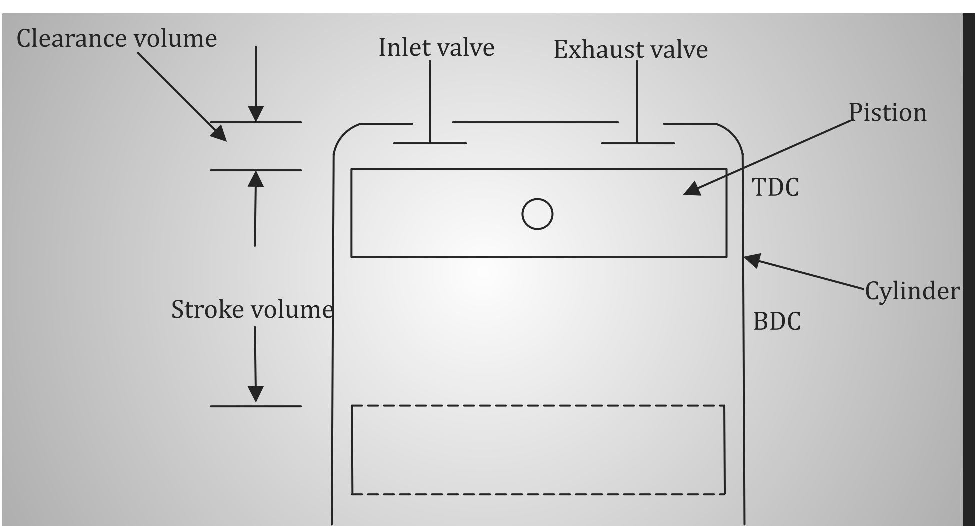


Fig. 2.14 IC engine terminology

1. **Bore :-** The inner diameter of the engine cylinder is called bore.
2. **Stroke :-** Is the linear distance travelled by the piston when it moves from one end of the cylinder to the other end from TDC to BDC.
3. **Top dead centre (TDC):-** The extreme position of the cylinder near to the cover or cylinder head is called cover and or top centre.
4. **BDC bottom dead centre or crankend :-** The extreme position of the piston near to the crank end. Also called as bottom dead centre.
5. **Clearance volume Vc :-** Is the volume of cylinder at the top of piston when the piston is at TDC
6. **Swept volume or stroke volume Vs** is the Volume swept by the piston as it moves from BDC to TDC or TDC to BDC
7. **Compression ratio :-** Rc is the ratio of total cylinder to clearance volume

$$R_c = \frac{V_s + V_c}{V_c}$$

2.12 .1 Four Stroke Petrol Engine

Working Principle of 4 stroke Petrol Engine

The working principle of 4-stroke petrol engine is based on the theoretical otto cycle. Hence it is called as otto cycle engine.

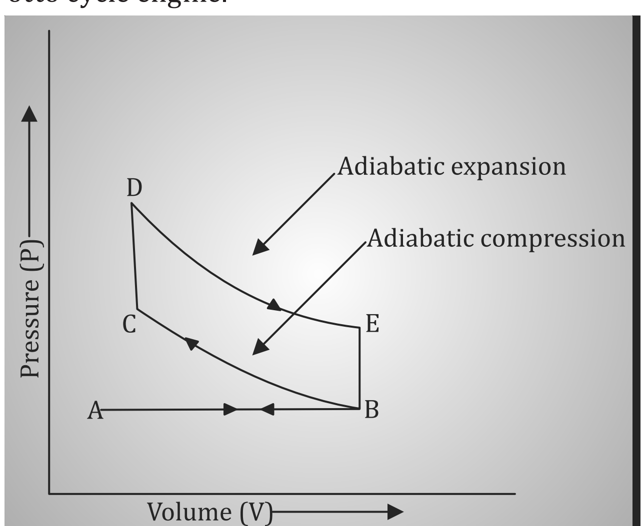


Fig. 2.15 Theoretical Diesel Cycle

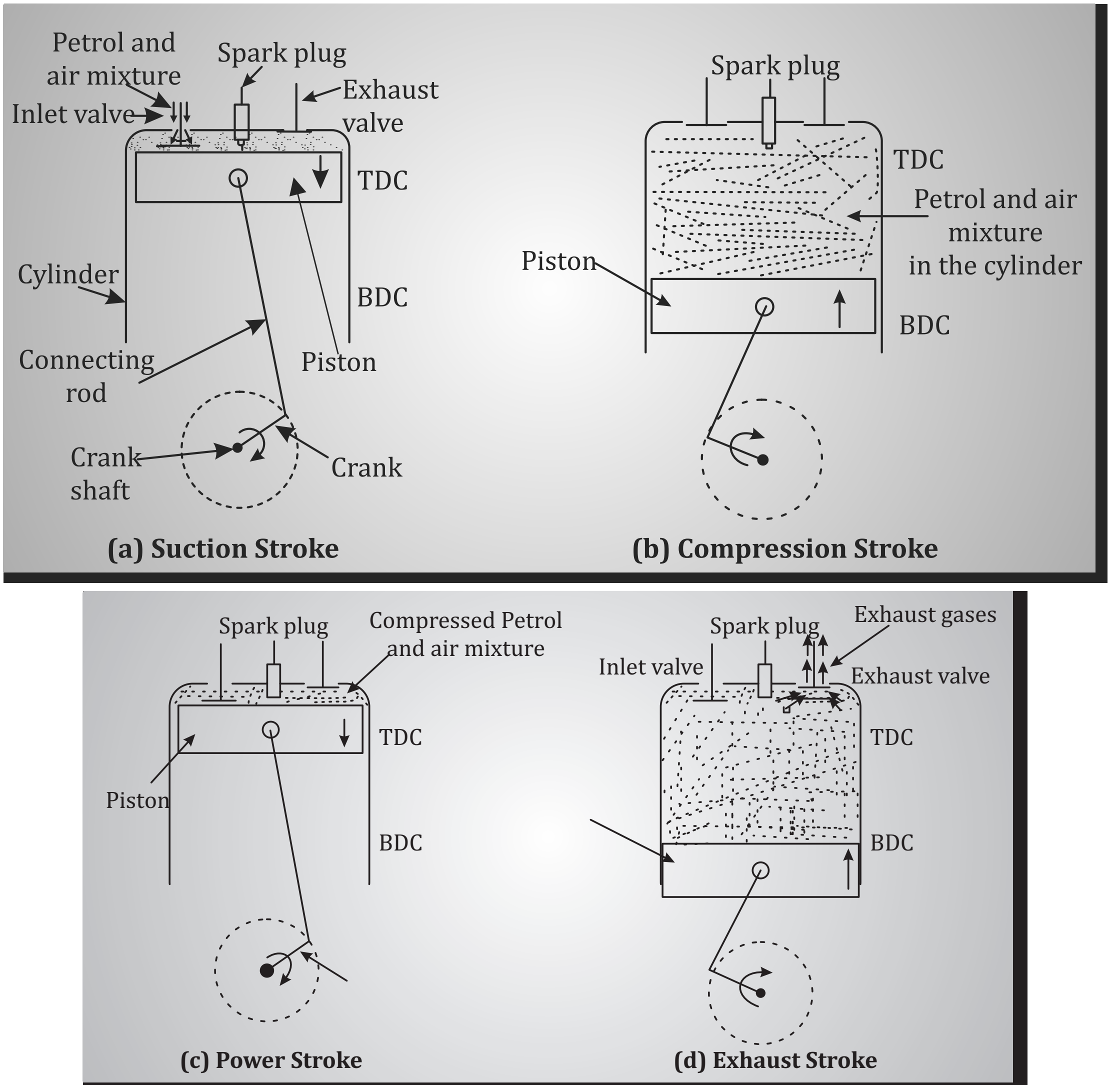


Fig 2.16 Working of 4 - Stroke Diesel Engine

In 4 – stroke engines, piston performs four different strokes to complete all the operations in the working cycle.

A four Stroke engine performs 4 strokes to complete one cycle

(a) Suction Stroke :- At the beginning of the stroke, piston is at TDC and during the stroke the piston moves from TDC to BDC. The inlet valve opens and the exhaust value will be closed. As the piston moves downwards, suction is created in the cylinder as a result fresh an petrol mixture is fed into the cylinder through the inlet value. As the piston reaches BDC, the suction stroke is completed and inlet value closes. The suction stroke is represented by line AB on P-V diagram.

(b) Compression stroke :- At the beginning of the stroke piston is at BDC and during the stroke, piston moves from BDC to TDC. Both inlet and exhaust valves are closed. As the piston moves upwards, the air - petrol mixture in the cylinder is compressed. The pressure and temperature increases adiabatically shown by curve BC. When the piston reaches to TDC the spark plug ignites the charge. The combustion of fuel takes place at constant volume as shown by the CD on the PV diagram. The compression ratio from 7:1 to 11:1.

(c) Power or expantion or working stroke :- At the beginning of the stroke piston is in TDC and during the stroke piston moves from TDC to BDC. Both inlet and exhaust valves remain closed. The combustion of fuel liberates gases and these gases start expanding. Due to expansion, the hot gases exists a large force on the piston and as a result the piston is pushed from TDC to BDC. The power impulse is transmitted down through the Piston to the crankshaft to the connecting rod. This causes the crankshaft to rotate at high speeds. Thus work is obtained is this stroke. Expansion of gases takes place shown by curve DE on PV diagram. As the piston reaches BDC, exhaust valve opens. A part of burnt gases escape through the exhaust valve out of the cylinder due to their own expansion.

(d) Exhaust Stroke :- At the beginning of the stroke piston is in BDC and during the stroke piston moves from BDC to TDC. Inlet valve is closed and exhaust valve is opened. As the Piston moves upward, it forces the remaining burnt gases out of the cylinder to the atmosphere through exhaust valve. This is shown by the line EB & BA on PV diagram. When piston reaches TDC, exhaust valve closes and this completed the cycle.

2.13 Four Stroke Diesel engine

The working principle of 4-stroke diesel engine is based on theoretical diesel cycle.

There are four strokes :-

1. Suction 2. Compression 3. Power 4. Exhaust stroke

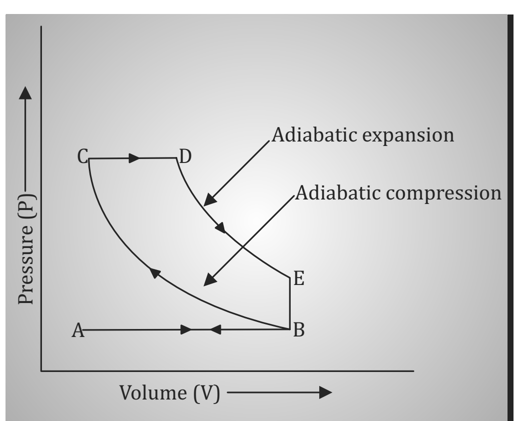


Fig. 2.17 Theoridical Otto Cycle

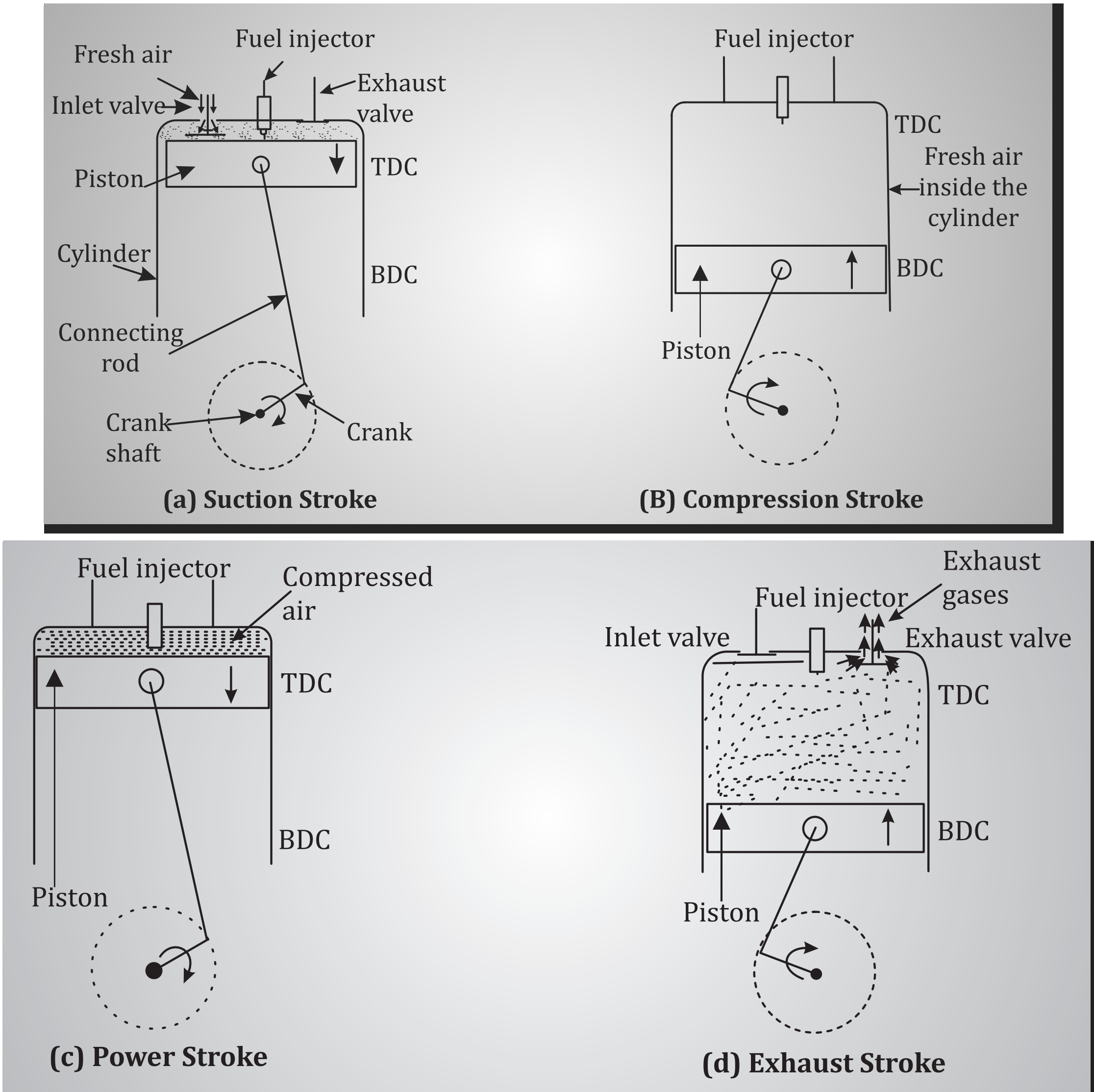


Fig 2.18 Working of 4 - Stroke Petrol Engine

(a) Suction Stroke:- At the beginning of the stroke piston is at TDC and during the stroke the piston moves from TDC to BDC. The inlet value opens and exhaust valve will be closed. The downward movement of the piston creates a suction in the cylinder and a result fresh air is drawn into the cylinder through the inlet value. When the piston reaches BDC, the suction stroke completes and this is represented by the line AB an PV-diagram as shown.

(b) Compression Stroke :- At the beginning of the stroke piston is in BDC and during the stroke piston moves from BDC to TDC. Both inlet and exhaust values are closed. As the piston moves upwards air in the cylinder is compressed to a high pressure and temperature. The compression process in adiabatic in nature and is shown by the curve BC is PV diagram. At the end of the stroke the fuel (diesel) is sprayed into the cylinder by the fuel injector. As the fuel comes in contact with the hot compressed an it gets ignited and under gas a combustion at constant pleasure. This process is shown by live CD on PV diagram. The compression ratio ranges from 16:1 to 20:1

(c) Power stroke / expansion stroke / working stroke :- At the beginning of this stroke, piston is at TDC and during the stroke, piston moves team TDC to BDC. Both inlet and exhaust values are closed. As combustion of the takes place the burnt gases expand and exhaust a large force on the piston and the piston is pushed from TDC to BDC. Power is transmitted from piston to the crankshaft. The compassion is shown by curve DE or DV diagram. Drop in pressure is represented by EB on PV diagram.

(d) Exhaust stroke :- At the beginning of the stroke piston is in BDC and during this stroke, piston moves from BDC to TDC. The inlet value is closed by exhaust value is opened. As the piston move upwards it takes the remaining burnt gases out of the cylinder from the exhaust gases. This is shown by line BA on P-V diagram. When piston reaches TDC exhaust valve closes. This completes the cycle.

2.14 Two Stroke Engines

In two stroke engines, ports are present in the cylinder in place of valves

There are 3 ports :

1. **Inlet port:** Through which admitting of charge into the crank case takes place.
2. **Transfer port:** Through which the charge is transferred from the crank case to the cylinder.
3. **Exhaust port:** Through which the burnt gases are discharged out of the cylinder.

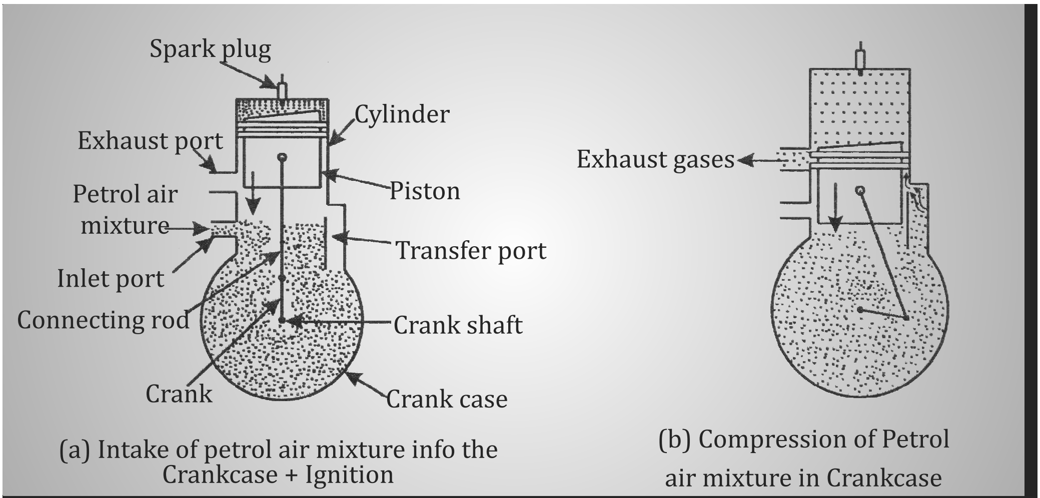
Two Stroke Petrol Engine

In a 2 stroke engine, piston performs two different strokes or crankshaft completes one revolution to complete all the operations of working cycle. In these engines there are no suction and exhaust strokes, instead they are performed while the compression and power strokes are in programs. Based on the type of fuel used 2 stroke petrol and 2 stroke diesel engine.

It works on the principle of theoretical ottocycle. The two different strokes are first stroke (Downward stroke) and second stroke (upward stroke).

1. **First stroke (Downward Stroke):-** At the beginning of this stroke, piston is at TDC. Inlet port is opened and fresh petrol-air mixture enters into the crankcase. At this position, compressed Petrol-air mixture is ignited by the spark generated by the spark plug. The combustion of fuel releases hot gases which increases the

pressure inside the cylinder. The high pressure gases exists a pressure on the piston and hence Piston moves from TDC to BDC. Thus piston performs power stroke. The power is transmitted to the crankshaft through the connecting rod. This causes the crankcraft to rotate at high speeds. This work is obtained in this stroke.



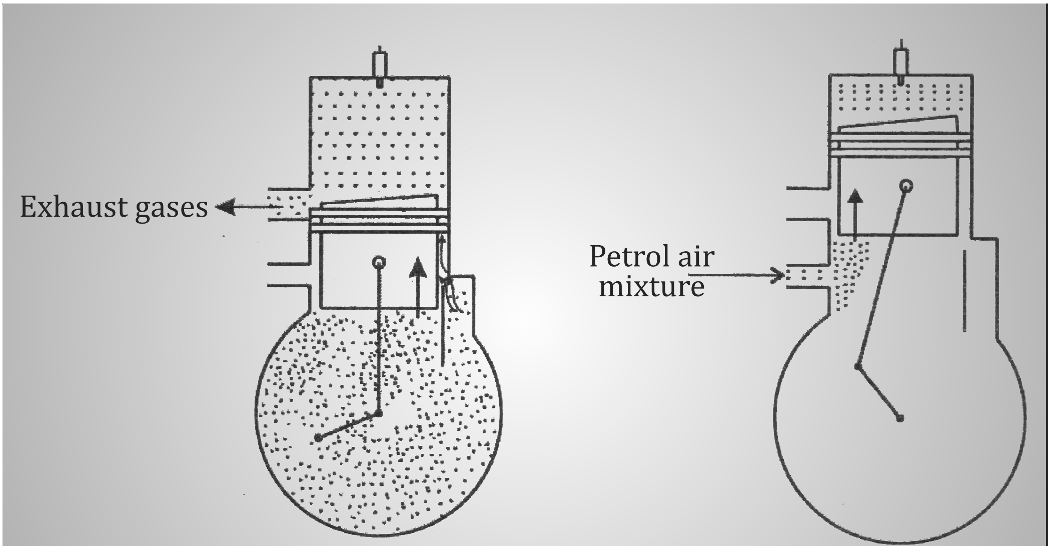
a, b First stroke :- Downward Stroke
Fig. 2.19 Working principle of 2 - stroke petrol engine

As the piston moves downwards, it uncovers the exhaust port and hence burnt gases escape out of the cylinder. As the piston moves downwards further, the transfer port opens and the charge in the crankcase is compressed by the underside of the piston. The compressed change from the crankcases rushes into the cylinder through the transfer port. The charge entering the cylinder drives away the remaining exhaust gases through the exhaust port**.**

The process of removing the exhaust gases with the help of fresh charge is known as **`Scavenging'**

2. **Second stroke (upward stroke):** At the beginning of the stroke, piston is in BDC and it covers the inlet port and stops the flow of fresh charge into the crankcase. During the stroke piston ascends and moves towards TDC. As piston moves upwards, it closes the transfer port thereby stopping the flow of fresh charge into the cylinder.

   Further upward movement of the piston closes the exhaust port and actual compression of charge begins. The inlet port is opened and upward movement of piston creates a suction in the crank and fresh charge enters into the cylinder through the inlet port. The compression of charge takes place in the cylinder till the piston reaches TDC. This complete the cycle.



c, d of Second stroke :- Upward Stroke
Fig. 2.19 Working principle of 2 - stroke petrol engine

Comparison of petrol and Diesel engines (SI and CI engines)

Sl. No.	Petrol engine (SI engine)	Diesel engine (CI engine)
1.	Draws a mixture of petrol and air during suction stroke.	Draws only air during suction stroke
2.	Carburettor is employed to mix air and petrol in the required proportion and to supply it to the engine during suction stroke.	The injector is employed to inject the fuel at the end of compression stroke
3.	Compression ratio ranges from 7 : 1 to 12 : 1	Compression ratio ranges from 16 : 1 to 20 : 1
4.	Petrol-air mixture is ignited by spark plug. This is called spark ignition.	Ignition is done by compressed air which will have been heated due to high compression ratio and high temperature of diesel. This is called compression ignition.
5.	Combustion of fuel takes place at constant volume	Combustion of fuel takes place at constant pressure.
7.	Power developed is less	Power developed is more
8	Thermal efficiency to low about 26%	Thermal efficiency is high about 40%

9.	These are high speed engines	These are low speed engines
10.	Maintenance cost is less	Maintenance cost is more
11.	lighter and cheaper due to low compression ratio	Heavier and costlier due to high compression ratio.

Comparison between 2-stroke and 4 stroke IC engines

Sl. No.	2 - Stroke Engine	4 - Stroke Engine
1.	Requires two separate stroke to complete one cycle of operator	Requires four separate strokes to compare cycle of rotation
2.	Power to developed is every rotation of crankshaft	Power to developed for every 2 revolution of crankshaft
3.	The inlet, transfer and exhaust parts are opened and closed by movement of piston itself	The inlet and exhaust are opened and closed by valves.
4.	Require lighter flywheel	Requires heavier flywheel since large turning movement
5.	Low thermal efficiency	High thermal efficiency
6.	Requires more lubricant	Requires less lubricant
7.	Fuel consumption is more	Fuel consumption is less
8.	Initial cost is less	Initial cost is more

List of formulas used in IC Engines

1. Mean effective pressure (P_m)

$$P_m = \frac{sa}{l} \text{ in bar}$$

where s = Spring content

a = Area of indicator diagram

l = Length of indicator diagram

2. Indicated power (IP) for 4 stroke Engine

$$IP = \frac{nP_m LAN}{60,000} \times \left(\frac{1}{2}\right) \text{ kw}$$

Where $P_m = P_a$

1 bar = 10^5 P_a

Where n = Number of cylinder

P_m = Mean effective prenor, pascal

L = Stroke length, m

A = Area of the cylinder, m^2

N = Speed of shaft (rpm)

$$n = \frac{N}{2} \text{ for 4 stroke}$$

or $IP = \frac{100\ nP_m\ LAN}{60}\left(\frac{1}{2}\right)$ kw where P_m = bar

For 2 stroke engine if P_m = bar

$$\boxed{IP = \frac{nP_m LAN}{60,000} \text{ kw}} \quad \frac{100\ P_m\ LAN}{60} \text{kw}$$

Brake Power (BP)

$$\boxed{BP = \frac{2\pi\ NT}{60,000}} \text{ kw}$$

Where N = Speed of Engine, rpm

T = Torque in N-m

Torque measured by using belt dynamo meter

$$\boxed{T = (T_1 - T_2) \times R}\ N - m$$

Where T_1 = Tension in tight side of the belt, N

T_2 = Tension in slack side of the belt, N

R = radius of pulley, M

Torque measured by rope brake dynamometer

$$\boxed{T = (W - S)R}\ N - m$$

Where, W = Suspended weight, N

S = Spring balance reading in N

R = radius of the pully measured to the centre of the rope

3. **Friction Power (FP)**

$$\boxed{FP = IP - BP}\ \text{kw}$$

4. **Mechanical Efficiency** (η_{mech})

$$\boxed{\eta_{mech} = \frac{BP}{IP} \times 100}$$

5. **Indicated Thermal efficiency** (η_{Ith})

$$\boxed{\eta_{Ith} = \frac{IP}{m_f \times CV} \times 100}$$

Where, m_f = mass of fuel in kg/sec

CV = calorific value of the fuel in KJ/kg

6. **Brake thermal efficiency** (η_{Bth})

$$\boxed{\eta_{Bth} = \frac{BP}{m_f \times CV} \times 100}$$

7. Brake Specific full consumption (BSFC)

$$BSFC = \frac{\text{Mass of fuel consumed in Kg/hr}}{\text{Brake power developed in kw}}$$

(Kg/kw - hr)

Problem 1

A single cylinder two-stroke cycle 1 C engine has a piston diameter of 105 mm and stroke length 120 mm. The m.e.p is 6 bar. If the crankshaft speed is 1500 rpm, calculate indicated power of the engine.

Solution

D = 105 mm; L = 120 mm P_m = 6 bar N = 1500 rpm PL = N (2 stroke)

$$\therefore \quad I_p = \frac{100\ P_m LAN}{60} \text{ kw}$$

$$= \frac{100 \times 6 \times 0.12 \times \pi\,(0.105) \;\; \times 1500}{60 \times 4} \text{ kw} = \mathbf{15.58\ kw}$$

Problem 2

A four stroke IC engine running at 450 rpm has a bore diameter of 100 mm and stroke 120 mm. The indicator diagram details are :- area of the diagram 4 cm^2, length of indicator diagram and spring value of the spring used = 10 bar/cm. Calculate indicated power of the engine.

Solution

N = 450 rpm, D = 100 mm, a = 4 cm^2, L = 120 mm, l = 6.5 cm, s = 10 bar/cm

$$P_m = \frac{sa}{l} = \frac{10 \times 4}{6.5} = 6.15 \text{ bar}$$

$$I_p = \frac{100\ P_m\ LAN}{60} = \frac{100 \times 6.15 \times a\,(0.1)^2 \times 450}{4 \times 60 \times 2}$$

IP = 2.17 kw

Problem 3

A four cylinder 4 stroke engine running at 1000 rpm develops an indicated power of 15 kw. The mean effective pressure is 5 × 10^5 N m^{-2}. Find the diameter of the cylinder and the stroke of piston when the ratio of diameter to stroke is 0.8

Solution

IP = 15 kW, P_m = 5 × 10^5 Nm^{-2} = 5 bar; N = 1000 rpm $\frac{D}{L} = 0.8$

$$\text{Indicated power developed/cylinder} = \frac{\text{Total engine power}}{\text{Number of cylinders}} = \frac{15}{4} \text{kw} = 3.75 \text{ kW}$$

$$IP = \frac{100\ P_m\ LAN}{60 \times 2} \therefore 3.75 = \frac{100 \times 5 \times 1.25D \times \pi D^2 \times 1000}{4 \times 60 \times 2}$$

$D^3 = 9.167 \times 10^{-4}\ m^3 \Rightarrow$ **D** $= 0.09714$ m = **97.14** mm

$$\frac{D}{L} = 0.8 \therefore L = \frac{97.14}{0.8} = \mathbf{121.42\ \ mm}$$

PROBLEM 4

A four stroke petrol engine of 100 mm bore and 150 mm stroke consumes 1kg of fuel/hr. The mean effective pressure is 7 bar and its indicated thermal efficiency is 30%. The calorific value of the fuel is 40 × 10³ kJ/kg. Find the crankshaft speed.

SOLUTION

Pm = 7 bar, η_{ither} = 30% Cv = 40 × 103 kJ/kg

$$L = 0.15\ m,\ D = 0.1\ m\ m = 1Kg/hr = \frac{1}{3{,}600}\ kg/s$$

$$IP = \frac{100\ P_m LAN}{60 \times 2}\ kW = \frac{100 \times 7 \times 0.15 \times \pi\ (0.1)^2 \times N}{4 \times 60 \times 2}$$

$IP = 6.87 \times 10^{-3}$ NkW

$$\eta_{ither} = \frac{IP}{CV \times mf} \therefore 0.3 = \frac{6.87 \times 10^{-3} \times N}{40 \times 10^3 \times \frac{1}{3600}}$$

N = 485.2 rpm

PROBLEM 5

The following data refers to a single cylinder 4 stroke petrol engine.
Cylinder diameter = 20 cm, stroke of piston = 40 cm
Engine speed = 400 rpm, imep = 7 bar; fuel consumption is 10 litres /hr, CV of fuel = 45,000 kJ/kg specific gravity of fuel = 0.8 find indicated thermal η.

SOLUTION

D = 20 cm = 0.2 m

Fuel consumption = 10 lit/hr

C = 40 cm = 0.4 m sp.gr = 0.8

N = 400 rpm CV = 45,000 kJ/Kg

P_m = 7bar

$$IP = \frac{100\ P_m\ LAN}{60\ \times 2}\ kw = \frac{100 \times 7 \times 04\ \times \pi\ (0.2)^2\ \times 400}{4\ \times 60\ \times 2} \qquad IP = 29.32\ kW$$

$$\eta_{ither} = \frac{IP}{CV\ \times mf} \times 100 = \frac{29.32}{45000\ \times 10 \times \frac{0.8}{3{,}600}} \times 100 = 29.32\%$$

PROBLEM 6

A two stroke diesel engine has piston diameter of 200 mm and stroke of 300 mm. It has m.ep of 2.8 bar and speed of 400 rpm. The diameter of brake drum is 1 m and effective brake road is 64 kg. Find IP, BP, mechanical efficiency and mean piston speed (average piston speed)

SOLUTION

$$IP = \frac{100\ p_m\ LAN}{60}\ kW \quad \therefore\ IP = \frac{100 \times 2.8 \times \frac{300}{1,000} \times \pi \times \frac{(02)^2}{4} \times 4}{60}$$

$$\boxed{IP = 17.6\ kW}$$

$$BP = \frac{2\pi NT}{60}\ kW = \frac{2\pi \times 400 \times 9.81 \times 64 \times 0.5}{60 \times 1,000} = 13.15\ kW$$

$$\eta_{mech} = \frac{BP}{IP} \times 100 = \frac{13.15}{17.6} \times 100 = 74.7\%$$

Average piston speed = 2LN = 2 × 0.3 × 400 = 240m/mm

Average piston speed = 4m/s

PROBLEM 7

On a single cylinder four stroke petrol engine, the following readings were taken :-

Load on the brake drum =	**40 kg**	**Fuel consumption =**	**3kg/hr**
Spring balance reading =	**5kg**	**CV of fuel =**	**42,000 kJ/kg**
Diameter of brake drum =	**120 cm**	**engine speed =**	**500 rpm**

Find the brake thermal efficiency

SOLUTION

Net load on brake drum = (40 – 5) = 35 kg

$$\text{Radius of brake drum} = \frac{120}{2} = 0.6\ m$$

$$\text{Torque on brake drum} = \frac{9.81 \times W \times R}{1,000}\ RVM$$

$$= \frac{9.81 \times 35 \times 06}{1,000} = 0.206 kN\text{-}m$$

$$BP = \frac{2\pi NT}{60}\ kW = \frac{2\pi \times 500\ 0.206}{60} = 10.78\ kW$$

$$\eta_{brith} = \frac{BP}{CV \times m_f} \times 100 = \frac{1,078 \times 100 \times 3600}{42,000 \times 3} = \mathbf{30.8\%}$$

PROBLEM 8

A gas engine working on 4 stroke cycle has a cylinder of 250 mm diameter, length of stroke 450 mm and is running at 180rpm. Its mechanical efficiency = 80% and mean effective pressure is 0.65 Pa find (1) indicated lower (ii) Brake power (iii) friction power.

SOLUTION

$$IP = \frac{P_m LAN}{60} kW = \frac{0.65 \times 10^6 \times 0.45 \times \pi \frac{0.25^{\ 2}}{4} \times \frac{180}{2}}{60 \times 1000} = 21.53\ kW$$

$$BP = \frac{\eta_{mech}}{IP} \times 100 \Rightarrow BP = \frac{80 \times 21.53}{100} \Rightarrow BP = \mathbf{17.23\ kW}$$

$$FP = IP - BP = 21.53 - 17.23 = \mathbf{4.30\ KW.}$$

PROBLEM 9

The following observations were obtained during a trial or a four stroke diesel engine Cylinder diameter = 25 cm, stroke of piston = 40 cm, Crankshaft speed = 250 rpm, brake load = 70 kg, Brake drum diameter = 2m, mep = 6 bar, Diesel oil consumption = 0.1 m³/min, sp. gr. of diesel = 0.78, average diesel = 43,900 kJ/ kg, find (i) BP (ii) IP (iii) FP (iv) mechanical efficiency (v) Brake thermal efficiency (vi) Indicated thermal efficiency.

SOLUTION

(i) $$BP = \frac{2\,\pi\,NT}{60 \times 1{,}000} kW \quad T = \frac{9.81 \times W \times R}{1{,}000} kN - m = \frac{9.81 \times 70 \times 1}{1{,}000} = 0.686 kNm$$

$$BP = \frac{2\pi \times 250 \times 0.686}{60 \times 1{,}000} = 17.95 kW$$

(ii) $$\text{Indicated power} = \frac{100\ P_m\ LAN}{60 \times 2} kNm = \frac{100 \times 6 \times 0.4 \times \pi \times (0.25)^2 \times 250}{4 \times 60 \times 2} = 24.54 kW$$

(iii) IP = IP - BP = 24.54 – 17.95 = 6.59 kW

(iv) $$\eta_{mech} = \frac{BP}{IP} \times 100 = \frac{17.95}{24.54} \times 100 = 73.14\%$$

(v) $$\eta_{brthr} = \frac{BP}{CV \times mf} \times 100 = \frac{17.95}{CV \times mf} = \frac{17.95}{43{,}900 \times \frac{0.1 \times 0.78}{60}} \times 100 = \eta_{brith} = 31.45\%$$

(vi) $$\eta_{either} = \frac{IP}{mf \times cv} = \frac{24.54}{43{,}900 \times \frac{0.1 \times 0.78}{60}} \times 100 = 43\%$$

PROBLEM 10

A 4 cylinder 2 stroke petrol engine develops 30 kW at 2500 rpm. The mean effective pressure on each piston is 8 bar and mechanical efficiency is 80%. Calculate the diameter and stroke of each cylinder, stroke to bore ratio being 1.5. Calculate fuel consumption if brake thermal efficiency is 28%, c.v. of fuel is 43,900 kJ/kg.

SOLUTION

(2 stroke 4 cylinder)

BP = 30 kW; N = 2500 rpm; Pm = 8 bar, Mech η = 0.8; L/D = 1.5 CV = 43, 9000 kJ/kg;

B Th $\eta_{Brthermal}$ = 0.28

$$\text{Mech-}\eta = \frac{BP}{IP} \therefore IP = \frac{BP}{\text{Mech } \eta} = \frac{30}{0.8} = 37.5 \text{ kW (Total for 4 cylinders)}$$

$$\therefore \text{ IP per cylinder} = \frac{37.5}{4} = 9.375 \text{ kw}$$

$$IP = \frac{100 \times P_m \text{ L A N}}{60} \text{ and } \frac{L}{D} = 1.5 \therefore L = 1.5\,D$$

$$\therefore \quad 9.375 = \frac{100 \times 8 \times 1.5\,D \times \frac{\pi}{4} D^2 \times 2500}{60}$$

$\therefore$ **D = 62 mm**

$\therefore$ **L = 1.5 × 62 = 93 mm**

$$\text{B Th. } \eta = \frac{BP}{m \times CV} \therefore m = \frac{BP}{\text{BTh.}\eta \times CV} = \frac{30 \times 3600 \text{ Kg/hr}}{0.28 \times 43900}$$

η = **8.78 Kg/hr (Total)**

PROBLEM 11

A 4 stroke diesel engine with a cylinder diameter 200 mm and stroke length 250 mm, runs at 300 rpm. Find the IP of engine. Also find the BP and FP, if the mechanical efficiency is 80% and mean effective pressure is 787 Kpa.

SOLUTION

(4 Stroke)

Data: D = 200 mm; L = 250 mm; N = 300 rpm; Mech.n = 80% Pm = 787 kP_a.

$\Rightarrow$ Indicated mean effective pressure = P_m = 787 kP_a = 0.787, MP_a = 7.87 bar

$$IP = \frac{100\, P_m \text{ LAN}}{60 \times 2} \text{kW } (p_m \text{ in bar})$$

$$= \frac{100 \times 7.87 \times 0.25 \times \frac{n}{4}(0.2)^2 \times 300}{60 \times 2} = 15.453 \text{ kW}$$

$\Rightarrow$ Mech.η $= \frac{BP}{IP}$ $\therefore$ BP = IP $\times$ Mech.η = 15.453 $\times$ 0.8

= 12.36 kW

$\Rightarrow$ Friction power = F – P = IP – BP = 15.453 – 12.36 **= 3.09 kW**

Problem 12

Following details refer to a 4 stroke engine cylinder dia = 200 mm, stroke = 300 mm; speed = 300 rpm; effective brake load = 50 kg; mean circumference of brake drum = 400 mm, mean effective pressure = 6 bar. Determine the input power, output and mechanical efficiency.

Solution

(4 stroke)

Data: D = 200 mm; L = 300 mm;

N = 300 rpm; F = 50 kg $\times$ 9.81 N, 2 π R = 4000; P_m = 6 bar

Brake drum radius $R = \frac{4000}{2\pi} = 636.62$ mm

$$\Rightarrow \quad BP = \frac{2\pi\ NT}{60 \times 1000} \text{kW} = \frac{2\pi \times 300 \times 50 \times 9.81}{60 \times 1000} \times \frac{(636.62)}{1000} \text{kW}$$

Brake drum radius $=R = \frac{4000}{2\pi} = 636.62$ mm $= 9.81\ \pi$W.

$$IP = \frac{100 P_m LAN}{2 \times 60} \text{kW } (P_m \text{ is bar})$$

$$\therefore \quad IP = \frac{100 \times 6 \times 0.3\ \frac{\pi}{4}\ 0.2\ ^2 \times 300 \text{kW}}{2 \times 60} = 14\ 14 \text{kW}$$

Mechanical efficiency $= \frac{BP}{IP} = \frac{9.81}{14.14} = 69.35\%$

Problem 13

A four cylinder, four stroke internal combustion engine develops an indicated power of 50kW at 3000 rpm. The cylinder diameter is 75mm and the stroke is 90mm. Find the mean effective pressure in each cylinder. If the mechanical efficiency is 80%, what effective brake load would be required if the effective brake drum diameter is 0.6m?

Data: i = 4, IP = 50kW, n = 3000 rpm, $n' = \frac{3000}{60} = 50$ rps, $N = \frac{n'}{2} = \frac{50}{2} = 25$ cycles/s 4-stroke),

d = 75mm = 0.075m, L = 90mm = 0.09m, η_m = 80% = 0.8, D = 0.6m.

SOLUTION

Area of cylinder $a = \frac{\pi}{4}d^2 = \frac{\pi}{4}\times 0.075^2 = 4.418\times 10^{-3}\,m^2$

Indicated power IP = $100iP_{mi}\,lN$

i.e., $50 = 100 \times 4 \times p_{ml} \times 4.418 \times 10^{-3} \times 0.09 \times 25$

∴ Indicated mean effective pressure p_{mi} = 12.575 bar = 12.575×10^5 N/m^2

Mechanical efficiency $\eta_m = \frac{BP}{IP}$

i.e., $0.8 = \frac{BP}{50}$

∴ Brake power = BP = 40kW

Also, $BP = \frac{2\pi\, n'T}{100}$

i.e., $40 = \frac{2\pi \times 50 \times T}{1000}$

∴ Torque T = 127.32 Nm

Also torque T = FR

i.e., $127.32 = F \times \frac{0.6}{2}$

∴ Effective brake load F = 424.4N

PROBLEM 14

A four cylinder four stroke petrol engine develops indicated power of 15kW 1000 rpm. The indicated mean effective pressure is 0.55 MPa. Calculate the bore and stroke of the piston if the length of stroke is 1.5 times the bore.

Data: i = 4, IP = 15kW, n = 1000 rpm,

$n' = \frac{1000}{60}$ rps, $N = \frac{n'}{2}$ (4 – stroke), $L = 1.5d$, $p_m = 0.55$ MPa = 5.5bar

SOLUTION

Area of piston $a = \frac{\pi}{4}d^2$

Indicated power IP = 100i P_{mi} aLN

i.e., $15 = 100 \times 4 \times 5.5 \times \frac{\pi}{4} \times d^2 \times 1.5d \times \frac{1000}{2 \times 60}$

or $d^3 = 6.945 \times 10^{-4}$

∴ The bore diameter d = 0.0886m = 88.6mm

Length of stroke L = 1.5d

= 1.5 × 88.6 = 132.9mm

Problem 15

A single cylinder four stroke petrol engine develops indicated power 7.5kW. The mean effective pressure is 6.6 bar and the piston diameter is 100mm. Calculate the average speed of the piston.

Data: i = 1, $N = \frac{n'}{2}(4 - \text{stroke}),\ IP = 7.5\text{kW},\ p_{mi} = 6.6\text{bar},\ d = 100\text{mm} = 0.1\text{m}$

Solution

Area of piston $a = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 0.1^2 = 0.007854\text{m}^2$

Indicated power IP = 100i p_{mi} aLN

i.e., $7.5 = 100 \times 1 \times 6.6 \times 0.007854 \times L \times \frac{n'}{2}$

∴ $Ln' = 2.894$

Velocity of piston $v = 2ln'$

= 2 × 2.894 = 5.788 m/s

Problem 16

The following are the details of 4-stroke petrol engine: (i) Diameter of brake drum = 600.3mm, (ii) Full brake load on drum = 250N, (iii) Brake drum speed = 450 rpm, (iv) Calorific value of petrol = 40 MJ/kg, (v) Brake thermal efficiency = 32%, (vi) Mechanical efficiency = 80%, (vii) Specific gravity of petrol = 0.82. Determine (a) Brake power, (b) Indicated power, (c) Fuel consumption liters per second and (d) Indicated thermal efficiency.

Data: D = 600.3 mm = 0.6003 m, R = 0.30015 m, $T_1 - T_2$ = 250 N, n = 450 rpm,

$$\mathbf{n = \frac{450}{60} = 7.5rps,\ N = \frac{n'}{2} = \frac{7.5}{2} = 3.75}$$

cycles/s (4-stroke), c = 40 MJ/kg = 40 × 10^3 kJ/kg,

η_b = 32% = 32, η_m = 80% = 0.8, ρ = 0.82

SOLUTION

Assuming the petrol engine is of single cylinder, i.e., i = 1

Torque on the brake drum T = $(T_1 - T_2)$ R = 250 × 0.30015

= 75.0375 Nm

Brake power $BP = \frac{2\pi n' T}{1000} = \frac{2\pi \times 7.5 \times 75.0.375}{1000} = 3.536 kW$

Mechanical efficiency $\eta_m = \frac{BP}{IP}$

∴ Indicated power $IP = \frac{BP}{\eta_m} = \frac{3.536}{0.8} = 4.42 kW$

Brake thermal efficiency $\eta_m = \frac{BP}{m \times CV}$

i.e., $0.32 = \frac{3.536}{m \times 40 \times 10^3}$

∴ Mass flow of the fuel

Fuel consumption in lit/s $= \frac{m}{\rho} = \frac{2.7625 \times 10^{-4}}{0.82} = 3.369 \times 10^{-4} lit/s$

Indicated thermal efficiency $\eta_i = \frac{IP}{m \times CV} = \frac{4.42}{2.7625 \times 10^{-4} \times 40 \times 10^3} = 0.4 = 40\%$

PROBLEM 17

A four cylinder two-stroke petrol engine develops 30kW at 2500 rpm. The mean effective pressure on each piston is 6 bar and mechanical efficiency is 80%. Calculate the diameter and stroke of each cylinder if the stroke to bore ratio is 1.5. Also calculate the fuel consumption, if the brake thermal efficiency is 28%. The calorific value of the fuel is 43900 kJ/kg.

Data: i = 4, BP = 30kW, n = 2500 rpm, $n' = \frac{2500}{60}$ rps, $N = n' = \frac{2500}{60}$ cycles/s (2-stroke),

p_{mi} = 8bar, η_m = 80% = 0.8, $\frac{L}{d} = 1.5$, $L = 1.5d$, $\eta_b = 28\% = 0.28$, $CV = 43900$ kJ/kg.

SOLUTION

Mechanical efficiency $\eta_m = \frac{BP}{IP}$

∴ Indicated power $IP = \frac{BP}{\eta_m} = \frac{30}{0.8} = 37.5 kW$

Also, IP = 100 ip_{mi} aLN

i.e., $37.5 = 100 \times 4 \times 8 \times \frac{\pi}{4} d^2 \times 1.5d \times \frac{2500}{60}$

∴ Bore diameter d = 0.062m = 62mm

Stroke length L = 1.5d = 1.5 × 62 = 93mm

Brake thermal efficiency $\eta_b = \frac{BP}{m \times CV}$

∴ Mass of the fuel $m = \frac{BP}{\eta_b CV} = \frac{30}{0.28 \times 43900} = 2.4406 \times 10^{-3} kg/s$

Specific fuel consumption on brake power basis = $\frac{3600m}{BP}$

$= \frac{3600 \times 2.4406 \times 10^{-3}}{30} = 0.29287 kg/kWh$

PROBLME 18

A single cylinder 4-stroke IC engine has a volume of 6 liters and runs at 300 rpm. At full load, the tension in the tight side and slack side of dynamometer belt is 700N and 300N respectively. The pulley diameter of the belt dynamometer is 1m. The fuel consumed in one hour is 4kg with a calorific value of 42,000 kJ/kg. If the indicated mean effective pressure is 6bar, calculate the indicated power, brake power, mechanical efficiency, indicated thermal efficiency, brake thermal efficiency and specific fuel consumption on brake power basis.

Data: i = L, aL = 6liters = 6000cm³ = 6 × 10⁻³m³, n = 300rpm, n′ = 300/60 = 5rps, N = n′/2 = 5/2 = 2.5 cycle/s (4-stroke), T_1 = 700N, T_2 = 300N, D = 1m, R = 0.5m, m = 4kg/h = 4/3600 kg/s, c = 42000 kJ/kg, p_m = 6bar.

SOLUTION

Indicated power IP = 100 ip_m aLN

= 100 × 1 × 6 × 6 × 10^{-3} × 2.5 = 9kW

Torque absorbed by the dynamometer T = ($T_1 - T_2$) R

= (700 – 300) × 0.5 = 200 Nm

Brake power BP = $\frac{2\pi n'T}{1000}$

$= \frac{2\pi \times 5 \times 200}{1000} = 6.283 kW$

Mechanical efficiency $\eta_m = \frac{BP}{IP} = \frac{6.283}{9} = 0.698 = 69.8\%$

Indicated thermal efficiency $\eta_i = \frac{IP}{mCV}$

$$= \frac{9 \times 3600}{4 \times 42000} = 0.1928 = 19.28\%$$

Brake thermal efficiency $\eta_b = \frac{BP}{mCV}$

$$= \frac{6.283 \times 3600}{4 \times 42000} = 0.1346 = 13.46\%$$

Specific fuel consumption on brake power basis = $\frac{3600m}{BP}$

$$= \frac{4}{6.283} = 0.6366 kg / kWh$$

PROBLEM 19

A four stroke diesel engine has a piston diameter 250mm and stroke 400mm. The mean effective pressure is 4 bar and the speed is 500 rpm. The diameter of the brake drum is 1m and the effective brake load is 400N. Find indicated power, brake power and friction power.

Data: d = 250mm = 0.25m, L = 400mm = 0.4m, p_m = 4bar, n = 500 rpm, n′ = (500/60) rps, N = n′/2 cycles/s (4-stroke), D = 1m, R = 0.5m, $T_1 - T_2$ = 400N.

SOLUTION

Assume the engine is of single cylinder, i = 1

Torque on brake drum T = $(T_1 - T_2)$ R

= 400 × 0.5 = 200 Nm

Brake power $BP = \frac{2\pi n'T}{1000}$

$$= 2\pi \times \frac{500}{60} \times \frac{2000}{1000} = 10.472 \text{ kW}$$

Indicated power IP = 100 I p_m aLN

$$= 100 \times 1 \times 4 \times \left(\frac{\pi}{4} \times 0.25^2\right) \times 0.4 \times \frac{500}{60 \times 2}$$

= 32.725 kW

Friction power FP = IP – BP = 32.725 – 10.472 = **22.253kW**

Problem 20

The following results refer to a test on a petrol engine:

Indicated power = 40 kW

Brake power = 35 kW

Fuel consumption per brake power hour = 0.3 kg.

Calorific value of fuel = 44000 kJ/kg

Calculate mechanical, brake thermal, and indicated thermal efficiencies.

Data: IP = 40 kW, BP = 35 kW, C = 44000 kJ/kg. Fuel consumption = 0.3 kg/kWh

Solution

Fuel consumption m = 0.3 × 35 = 10.5 kg/h = $\frac{10.5}{3600}$ kg / s

Mechanical efficiency $\eta_m = \frac{BP}{IP} = \frac{35}{40} = 0.875 = 87.5\%$

Brake thermal efficiency $\eta_b = \frac{BP}{m \times c}$

$$= \frac{35 \times 3600}{10.5 \times 44000} = 0.2727 = 27.27\%$$

Indicated thermal efficiency $\eta_i = \frac{IP}{m \times c}$

$$= \frac{40 \times 3600}{10.5 \times 44000} = 0.3117 = 31.17\%$$

Problem 21

A single cylinder, two stroke oil engine is running at 450rpm. Observations from a rope brake dynamometer are:

Diameter of the brake drum = 600 mm

Diameter of the rope = 20 mm

Load on the rope = 200 N

Spring balance reading = 30 N

Determine the brake power of the engine

Data: i = 1, n = 450 rpm, $n' = \frac{450}{60} = 7.5$ **rps,** $D_b = 600$ **mm = 0.6 m,** d_r **= 20 mm = 0.2 m,**

W – 200 N, S = 30 N

SOLUTION

Effective radius of brake drum, $R = \frac{D_b + d_r}{2} = \frac{0.6 + 0.02}{2} = 0.31m$

Torque on the drum T = (W – S) × R

= (200 – 30) × 0.31 = 52.7Nm

Brake power $BP = \frac{2\pi \ nT}{1000}$

$= \frac{2\pi \times 7.5 \times 52.7}{1000} = 2.483kW$

Questions with Answers

1. **Calculate the Brake power output of a single cylinder four-stroke petrol engine is given:**

   Diameter of brake wheel = 600 mm

   Brake rope diameter = 30 mm

   Dead weight = 24 Kg

   Spring balance reading = 4 Kg RPM = 450

Ans. 2.91 Kw

2. **A four stroke petrol engine is running at 2500 rpm. The stroke of the piston is 1.5 times the bore. If the mean effective pressure is 0.915 MPa and the diameter of the Piston is 140 mm. Find the indicated power of the engine. If the friction power is 13 kW, find the Brake Power output and the Mechanical efficiency.**

Ans. 61.62 kW, 48.62 kW, 78.9%

3. **A four stroke I.C. engine has a piston diameter of 150 mm and the average piston speed is 3.5 m/s. If the m.e.p is 0.786 Mpa, find the indicated power of the engine.**

Ans. 12.15 kW

4. **A four – stroke diesel engine has a piston diameter 200 mm and stroke 300 mm. It has a mean effective pressure of 2.75 bar and a speed of 400 rpm. The diameter of the broke drum is 1000 mm and the effective brake load is 32 Kg. Find the Indicated power, Brake power and Frictional power.**

Ans. (8.64 kW, 6.57 Kw, 2.07 kW)

5. **The following data collected from a 4 stroke single cylinder oil engine running at full load. Bore = 200mm, stroke = 280mm, speed = 300 rpm, imep = 5.6 bar, Torque η brake drum = 250nm oil consumed is 4.2kg / hr, C.V of oil = 41,000 kJ/ kg. Determine the Mechanical efficiency, Indicated and Brake thermal efficiencies.**

Ans. η_{mech}= 63.77, η_{ith} = 25.7%, η_{Br} = 16.4%

6. **The following data were obtained from a test on a single cylinder, 4 stroke, oil engine bore = 15cm ; stroke = 25cm; area of indicator diagram = 450 mm², length if indicator engine speed 400 rpm ; Brake torque = 225 N cm ; Fuel consumption 3kg/hr ; C.V of fuel = 44,200 kJ/kg; compute (a) the mechanical efficiency (b) Brake thermal efficiency.**

Ans. 87.07%, 25.6%

7. **A 4 stroke diesel engine with a cylinder diameter 200mm and stroke length 250mm runs at 300rpm. Find the indicate power of the engine. Also find brake power and friction power, if the mechanical efficiency is 80% and mean effective pressure is 787 kpa.**

Ans. 15.45kW ; 12.36kW; 3.09kW

8. **A 4 Stroke diesel engine has a piston diameter 200mm and stroke 300mm. It is a mean effective pressure of 2.75 bar and a speed of 400 rpm. The diameter of the brake drum is 1000m and the effective brake load is 32kg. Find the indicated power, Brake power and frictional power of the engine.**

Ans. 8.64kW ; 6.57kw ; 2.06kW

REVIEW QUESTIONS

1. Classify turbines.
2. Differentiate Impulse and reaction turbines.
3. Sketch and explain the working of Impulse steam turbine with pressure velocity diagram.
4. What are the advantages of steam turbines over other prime movers.?
5. Explain the working of open cycle gas turbine.
6. With sketch explain the working of closed cycle gas turbine
7. Differentiate between open cycle and closed cycle gas turbine
8. What are the various applications of gas turbines?
9. What are the merits of gas turbines over steam turbines?
10. Classify water turbines.
11. Differentiate between impulse water turbine and reaction water turbine
12. Describe the working of a pelton turbine with suitable sketch
13. Describe Francis turbine with a diagram
14. How does a Kaplan turbine work? Explain with a sketch
15. What are the functions of guide vanes and draft tube in reaction turbine
16. What is an internal combustion engine?
17. How are I.C engines classified?
18. Define the following terms: bore, stroke, TDC, BDC, Clearance volume and compression ratio
19. Describe the working of four stroke petrol engine with PV diagram
20. Describe the working of diesel engine

21. How does a two stroke petrol engine work? Explain
22. Give the merits and demerits of petrol engine over diesel engine
23. Compare the merits and demerits of four stroke cycle engine over two stroke cycle engine
24. Define the following: Mean effective pressure, IP, BP, FP, mechanical efficiency, indicated thermal efficiency and break thermal efficiency.
25. What is an internal combustion engine?
26. Differentiate between a internal combustion engine and an external combustion engine.
27. State the advantages of internal combustion engine over the external combustion engine.
28. How are I.C. engines classified?
29. What is a flywheel? State its function.
30. Define the following terms as applied to I.C. engines: bore, stroke, TDC, BDC, clearance volume, and compression ration.
31. How does a two stroke cycle engine differ from a four stroke cycle engine?
32. With a neat sketch explain the working of a four stroke petrol engine.
33. With a neat sketch explain the working of a two stroke petrol engine.
34. Explain with a neat sketch the working of a four stroke diesel engine.
35. Explain with a neat sketch the working of a two stroke diesel engine.
36. Tabulate the merits and demerits of petrol engine over diesel engine.
37. Compare the merits and demerits of four engine over diesel engine.
38. Give examples of automobiles in which two stroke and four stroke cycle engines are used.
39. Define the following: Mean effective pressure, IP, BP, FP, mechanical efficiency, indicated thermal efficiency and brake thermal efficiency.
40. Determine the indicated power developed by a two cylinder, two stroke cycle diesel engine running at 1000 rpm, when the indicated mean effective pressure is 5.5 bar. The engine has a piston of 150mm diameter and 200mm stroke.

Multiple Choice Questions

Turbines

1. A prime mover in which thermal energy of steam is transformed into mechanical work and provides rotary motion is known as

(a) Steam engine | **(b) Steam turbine**
(c) IC engine | (d) Steam generator

2. In an impulse turbine steam expands on

(a) Blades | **(b) Nozzle**
(c) Partly in blades | (d) None of there and partly in nozzle

3. De – laval turbine is also called

(a) Impulse turbine | (b) Gas Turbine
(c) Reaction turbine | (d) Water turbine

4. At the inlet of the nozzle of impulse Turbine, the steam is at
(a) Low pressure, low velocity (b) Low pressure, high velocity
(c) High pressure, high velocity **(d) High pressure, low velocity**

5. In reaction turbines, steam expands in
(a) Fixed blade only (b) Moving blade only
(c) Fixed and Moving blades (d) None of there

6. Parsons Turbine in
(a) Impulse turbine (b) Reaction turbine
(c) Impulse - reaction turbine (d) None of there

7. An open cycle gas turbine works on
(a) Rankine cycle (b) Diesel cycle (c) Otto cycle **(d) Brayton cycle**

8. The common working fluid used in closed cycle gas turbine is
(a) Carbon dioxide (b) Ammonia (c) Freon **(d) Helium**

9. The weight to power ratio of gas turbine is
(a) High **(b) Low** (c) Moderate (d) Equal

10. Thermal efficiency of a gas turbine is
(a) High (b) Medium **(c) Low** (d) very high

11. Open cycle gas turbine uses __________ as the working substance.
(a) Ammonia (b) Nitrogen **(c) Air** (d) CO_2

12. Closed cycle gas turbines are not commonly used is aviation field because
(a) High thermal efficiency (b) External combustion plan
(c) Coolant is required (d) None of these

13. In an impulse turbine, the pressure of the fluid in the turbine blades
(a) Decreases **(b) Constant**
(c) Increases (d) None of these

14. The Pelton wheel turbine is clarified as
(a) Radial flow (b) Axial flow
(c) Mixed flow **(d) Tangential flow**

15. In an impulse turbine, total energy at inlet to the turbine is
(a) Kinetic energy (b) Pressure energy
(c) Kinetic & pressure energy (d) None of these

16. In a Pelton wheel, the flow from pen stock passes through the following before entering into nozzle
(a) Spiral Case (b) Draft tube
(c) Volute Chamber **(d) Manifold**

17. A draft tube is used in
(a) Pelton wheel **(b) Francis Turbine**
(c) Water Turbine (d) None of there

18. A draft tube converts
(a) Pressure energy into Kinetic energy (b) Kinetic energy into Mechanical energy
(c) Velocity into pressure head (d) Potential head into pressure head

19. A Kaplan turbine is
(a) Inward flow impulse turbine
(b) Low head axial flow turbine
(c) High head axial flow turbine
(d) High head mixed flow turbine

20. A Pelton wheel is suited for
(a) High head, low discharge
(b) Low head low discharge
(c) High head high discharge
(d) Medium head medium discharge

I.C. ENGINES

1. Petrol engine works on
(a) Otto Cycle (b) Diesel Cycle (c) Dual Cycle (d) Joule Cycle

2. In a diesel cycle, engine during compression
(a) Inlet value is opened
(b) Exhaust value is opened
(c) Both values remain opened
(d) Both Valves closed

3. In a petrol engine, fuel and air are properly mixed in
(a) Fuel pump **(b) Carburettor** (c) Cylinder (d) Spark plug

4. In a petrol engine, combustion is initiated by
(a) Spark plug (b) Fuel injector (c) Fuel pump (d) None of these

5. Compression ration R_c is given by
(a) $\mathbf{R_c = \dfrac{V_s + V_c}{V_c}}$
(b) $\dfrac{V_s}{V_s + V_c}$
(c) $\dfrac{V_s + V_c}{V_s}$
(d) $\dfrac{V_s}{V_c}$

6. The compression ratio in a petrol engine is between
(a) 15 and 20 (b) 20 and 25 (c) 1 and 6 **(d) 6 and 10**

7. Stroke length of piston is defined as the ratio of
(a) ODC to IDC
(b) IDC to ODC
(c) TDC to BDC
(d) All of these

8. A cycle is complete in a two stroke engine in _______ revolution of crank
(a) 2 **(b) 1** (c) 4 (d) 8

9. The ratio of Brake power to indicated power is known as
(a) Mechanical efficiency
(b) Air standard efficiency
(c) Thermal efficiency
(d) Volumetric efficiency

10. A four-stroke IC engine completes two strokes in
(a) 180° of crank rotation (b)720° of crank rotation
(c) 360° of crank rotation
(d) 540° of crank rotation

11. A cycle in a four stroke IC engine is completed in ___ revolutions of crankshaft
(a) One **(b) Two** (c) Three (d) Four

12. A cycle in a two-stroke IC engine is completed in ___ revolutions of crankshaft
(a) One (b) Two (c) Three (d) Four

13. In a two-stroke engine, one power stroke is ___ revolution(s) of crankshaft
(a) One (b) Two **(c) Half** (d) None of these

14. Flywheel is used as an energy ______
(a) Receiver **(b) Reserviour** (c) Mixer (d) Multiplier

15. The output shaft in I.C. engine is
(a) Camshaft **(b) Crankshaft** (c) Rotary shaft (d) Axial Shaft

16. Mechanical efficiency of four-stroke engine is
(a) Medium (b) High **(c) Low** (d) Balanced

17. The motion of piston is
(a) Rotary **(b) Oscillatory** (c) Redilinear (d) Circular

18. Diesel engine is also called as
(a) Four-stroke engine (b) Two-stroke engine
(c) C.I Engine (d) S.I Engine

19. ____ is fed into the diesel engine through inlet valve
(a) Fuel (b) Diesel
(c) Air-fuel mixer **(d) Air**

20. I.C. Engines, the connecting rod connects ________ and ________
(a) Piston and Crankshaft (b) Inlet and outlet valves
(c) Piston and piston rings of (d) None

21. The Combustion of fuel in petrol engine takes place at
(a) Constant pressure **(b) Constant volume**
(c) Constant temperature (d) None of these

22. The process of breaking up of a liquid into fine droplets by spraying is called
(a) Vapourisation (b) Carburction (c) Ionization **(d) Association**

23. In a four-stroke C.I engine, during suction stroke
(a) Only air is sucked in (b) Only diesel is sucked in
(c) Both air and diesel sucked in (d) Either diesel or air is sucked in

24. The inner diameter diameter of engine cylinder is called as
(a) Stroke (b) Clearance **(c) Bore** (d) Pitch

25. In IC engines, combustion of fuel takes place
(a) Outside the cylinder **(b) Inside the cylinder**
(c) Not in the cylinder (d) None of the above

26. The function of piston rings in IC engines is to
(a) Transfer heat from piston to cylinder walls
(b) Seal between piston and cylinder liner
(c) Prevent piston from wear
(d) All of the above

27. A two stroke engine is usually identified by
(a) Flywheel (b) Weight of the engine
(c) Absence of valves (d) Presence of spark plug

28. **In an IC engine, the ratio of volume displaced by the piston per stroke to clearance volume is** known as
    (a) Compression ratio (b) Combustion ratio
    (c) Expansion ratio (d) Ratio of volumes

29. **The petrol engine works on**
    (a) Otto cycle (b) Rankine cycle
    (c) Carnot cycle (d) Diesel cycle

30. **In petrol engine, ignition takes place due to**
    (a) High temperature of compressed air
    (b) High temperature of compressed fuel
    (c) By means of a spark
    (d) By means of fuel injector

31. **During suction stroke in a petrol engine, the piston sucks**
    (a) Fuel only **(b) Air-fuel mixture**
    (c) Air only (d) None of the above

32. **If the compression ratio in petrol engines is kept very high, then**
    (a) Pre-ignition of fuel will occur (b) Detonation will occur
    (c) Ignition of fuel will be delayed **(d) None of the above**

33. **Compression ignition engine is**
    (a) Petrol engine **(b) Diesel engine**
    (c) Steam engine (d) None of the above

34. **For a given speed, the number of power strokes given by a two stroke cycle engine as compared to a four stroke cycle engine is**
    (a) Half (b) Same **(c) Double** (d) One fourth

35. **The compression ratio for a diesel engine as compared to petrol engine is**
    (a) Same (b) Lower **(c) Higher** (d) Very low

36. **Removing the burnt gases from the IC engine cylinder is known as**
    (a) Scavenging (b) Super charging
    (c) Detonation (d) Polymerisation

37. **The power developed inside the cylinder is known as**
    (a) Brake power **(b) Indicated power**
    (c) Friction power (d) None of the above

38. **The power available at the output shaft on an IC engine is**
    (a) Brake power (b) Indicated power
    (c) Friction power (d) Pumping power

39. **In a diesel engine, the fuel is injected**
    (a) Towards the end of compression stroke
    (b) Towards the end of power stroke
    (c) Towards the end of exhaust stroke
    (d) Towards the end of suction stroke

40. The system of lubrication employed in two stroke engine is

(a) Bottle oiler
(b) Ring oiler
(c) Pressure lubrication
(d) Splash lubrication

41. The indicated power of a four stroke engine is

(a) 100 p_m a*l* n′
(b) 100 p_m a*l* n′/2
(c) 100 p_m a*l* n′/4
(d) 200 pm a*l* n′/2where n′ is the speed in rps

42. Which is not an IC engine?

(a) Diesel engine
(b) Petrol engine
(c) Steam engine
(d) Steam turbine

✿✿✿✿

MACHINE TOOLS AND AUTOMATION MACHINE TOOLS OPERATION

MODULE 3

HIGHLIGHTS

- Machine Tools Operations
- Taper Turning by Swivelling the compound List
- Drilling Machine
- Milling Operations
- Robotics
- Classification of Robots based on Configuration
- Automation
- Applications of Automation

Definition : Machine Tool

It is a power driven machine used to produce the desired shape and size from a given raw material by means of a cutting tool.

A power driven tool involved in metal cutting is called a machine tool and the process is called machining. A machine tool may be defined as a power tool to produce a product by removing the excess material using a cutting tool. The excess material is removed in the form of chips. Important machine tools are Lathe, drilling machine, milling machine and grinding.

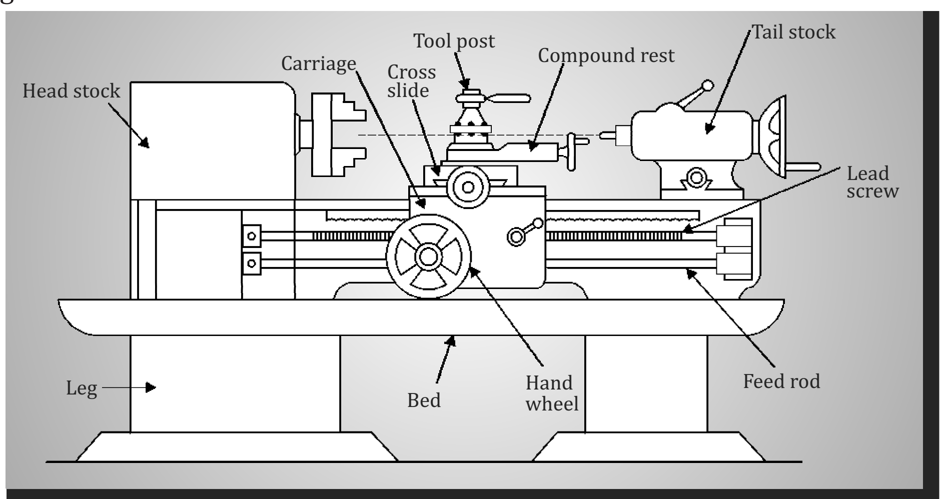


Fig. 3.1: Lathe Machine

Parts of a Lathe: The major parts of Lathe are

(1) Bed (2) Headstock (3) Tailstock
(4) Carriage (5) Feed rod (6) Lead Screw

(1) Bed: is the base or foundation of the lathe. All the parts such as Headstock, tailstock, carriage etc., are mounted on the bed. It is made of Grey cast iron.

(2) Headstock (Live center): is mounted at the left end of the lathe bed. It consists of gears and pulleys and houses the chuck and spindle.

(3) Tailstock (dead center): is mounted at the right end of the Lathe bed. It is movable. It holds the other end of a rotating work piece.

(4) Carriage: The cutting tool is moved, supported with the help of carriage. The carriage has the following parts.

- **(a) Saddle:** is made to slide along the bedways and supports the tool.
- **(b) Campound rest:** is mounted on the classlide and supports the tool post.
- **(c) Cross slide:** is mounted on the saddle and allows the cutting tool to move perpendicular to the lathe axis.

(d) **Feed rod:** is a long shaft used for boring etc.,

(e) **Lead screw:** is a long shaft with square threads on it. The rotation of the lead screw facilitates movements of the carriage during the and cutting operations.

(f) **Tool post:** is mounted on the compound rest and is used to hold the cutting tool during machining process.

(g) **Apron:** is placed below the saddle and houses the gear mechanisms, hand wheels and clutches.

3.1 Machine Tool Operations

Lathe is said to be the mother of all machine tools. In Lathe or turning machines, work piece is held between the two centres and rotated or turned. They are basically, need to produce cylindrical surfaces, flat surfaces and tapered surfaces on the material Operations like thread cutting, knurling & drilling, boring, reaming etc can also be carried out.

A Lathe is defined as a machine tool where a hard cutting tool is fed against the rotating work piece to remove the excess material.

Operations performed on Lathe

1. Turning
2. Facing
3. Taper Turning
4. Knurling
5. Thread cutting

1. **Turning :-** Turning is also called as plain turning. Turning is the operation of removing excess material from the work piece to produce a cylindrical part. Work piece is held rigidly on the chuck. The cutting tool is fed against the rotating work piece to a certain depth and moved parallel to the Lathe axis to produce a cylindrical part. This operation will reduce the diameter of the work piece.

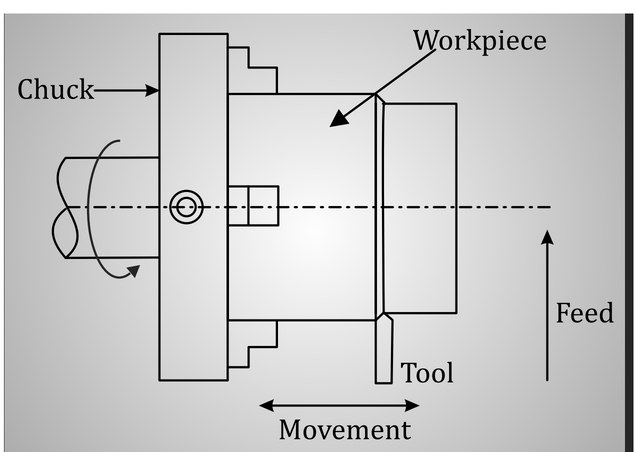


Fig. 3.2: Turning

2. **Facing :-** Is an operation to produce flat surface on the ends of the work piece. The work piece is held in the chuck and the cutting tool is fed against the rotating work piece perpendicular to the Lathe axis. The depth of cut is given by plunging tool to certain depth.

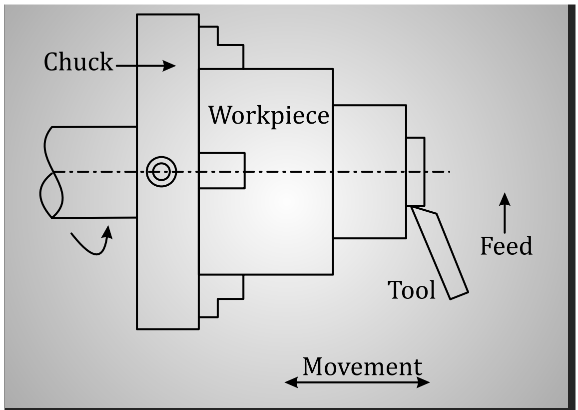
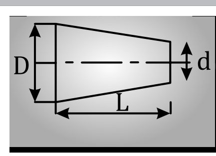


Fig. 3.3: Facing

3. **Taper Turning :-** Is an operation to produce conical surface on the work piece. The Taper can be achieved by the following methods.

(1) By Swivelling the compound rest
(2) By tailstock offsetting
(3) By taper turning attachment
(4) By using a form tool

3.2 TAPER TURNING BY SWIVELLING THE COMPOUND LIST :-



Taper angle

$$\tan\alpha = \frac{D-d}{2L}$$

where D = larger diameter of taper

d = smaller diameter of taper

L = length of taper

In this method the work piece is in line with the lathe axis and the tool is moved inclined to the lathe axis for producing required taper. Here, the compound rest which supports the tool post is swivelled to the required taper angle and locked. The tool movement is given through, the compound rest which removes the material to get required taper.

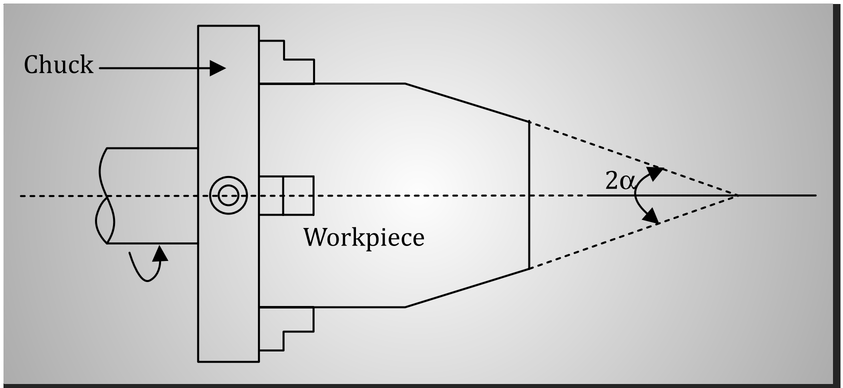


Fig. 3.4: Taper turning by swivelling the compound rest method

4. **Knurling:-** Knurling is as operation performed on lathe to generate serrated surface on the workpiece. It is used to produce a rough surface for gripping like the barrel of a micrometer as screw gauge. This is done by a hardened tool which has hardened rollers. The hardened rollers of the tool are pressed against the slowly rotating workpiece such that the impressions are formed on the surface of workpiece.

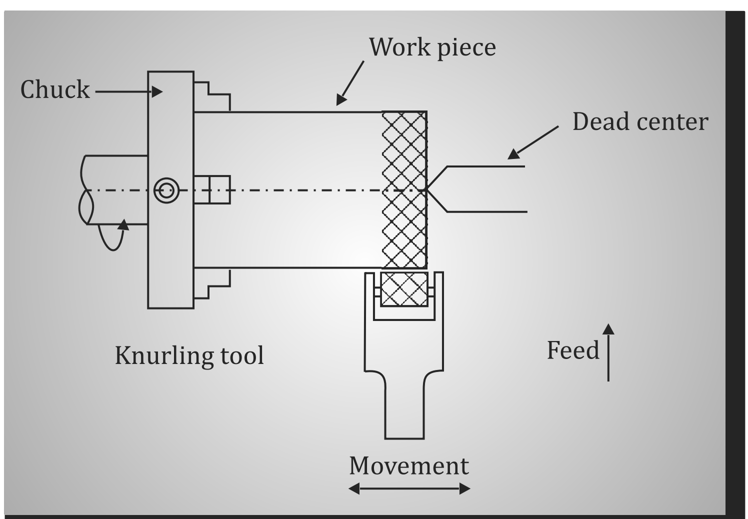


Fig. 3.5 Knurling operation

5. **Thread cutting:-** A thread is a grove formed on a cylindrical surface of the workpiece. The shape of the groove depends on the type of thread, V or square thread The work piece which is mounted between the centres will be rotating at very slow speed. The tool movement will depend on the rotation of the lead screw. The depth of cut is given by cross slide.

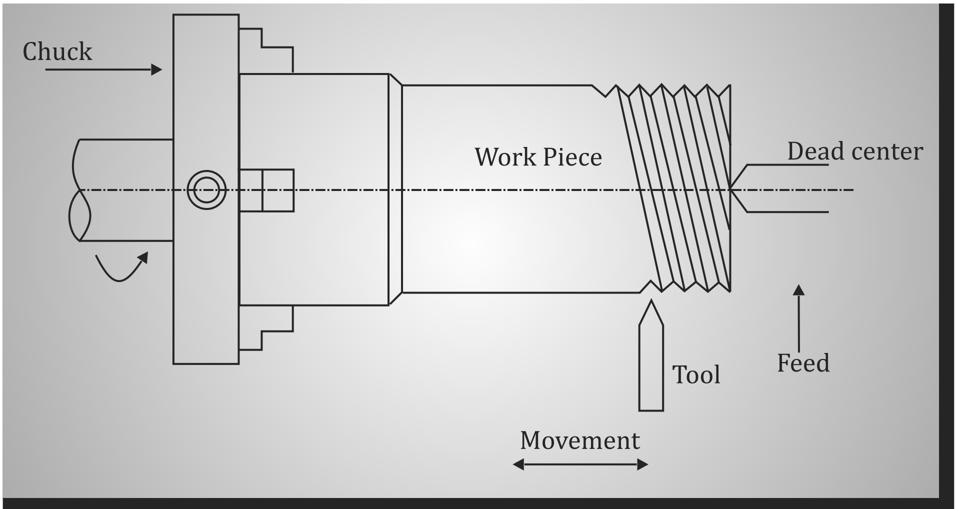


Fig. 3.6: Thread cutting

3.3 Drilling Machine

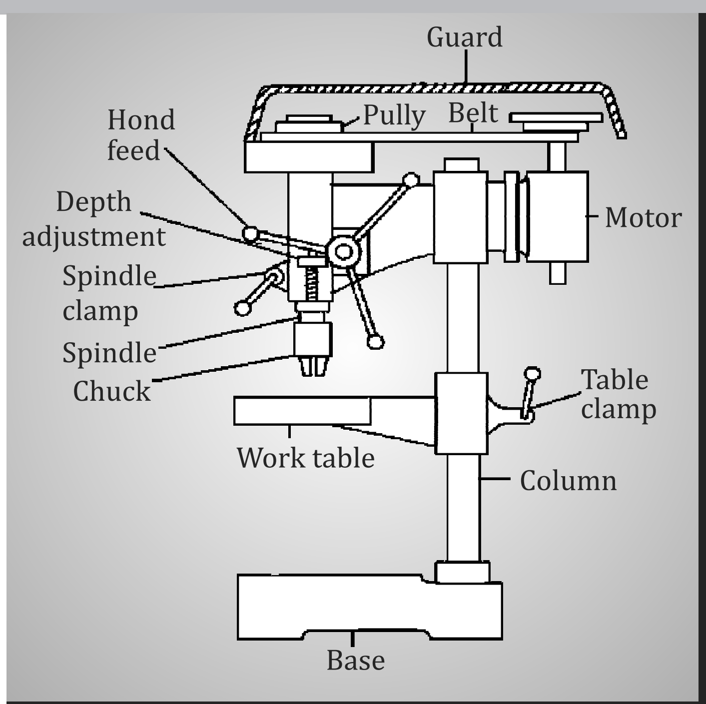


Fig. 3.7 Bench Drilling machine

Operations on Drilling Machine

(1) Drilling (2) Boring

(3) Reaming (4) Tapping

(5) Countersinking (6) Counterboring

1. **Drilling operations :-** Drilling is a machining operation to produce a cylindrical hole in a solid by metal removal by drill bit. The work piece or tool is rotated and the hole is made.

   Drilling is defined as a metal removal process carried out by facing on rotating drill bit against the rigidly clamped solid work piece to get a cylindrical hole.

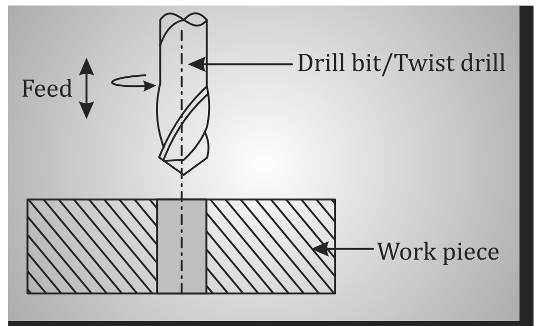


Fig. 3.8: Drilling

2. **Boring:-** Boring is a machining operation to increase the size of a previously drilled hole.

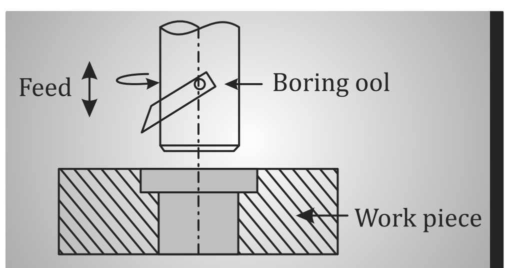


Fig. 3.9: Boring Operation

3. **Reaming:-** is a finishing operation performed as a previously drilled hole. The tool used here is a reamer

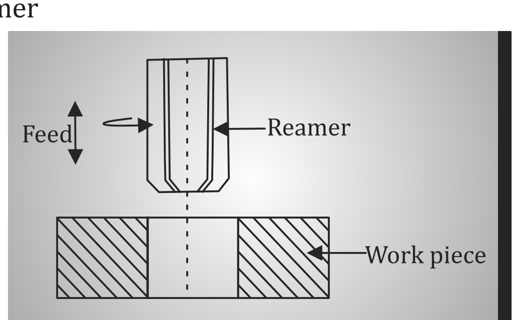


Fig. 3.10: Reaming

4. **Tapping :** Is a process of producing internal threads in a preciously drilled hole. A tap is a cutting tool with hardened threads on the body which generates threads. Tapping can be done by using a tapping attachment

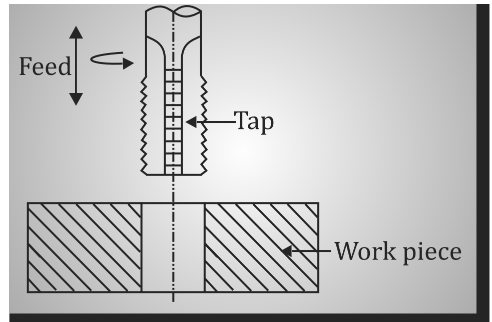


Fig. 3.11: Tapping

5. **Counter-sinking :-** Countersinking is a operation to make the end of hole in a conical shape. The tool used is a countersinking tool.

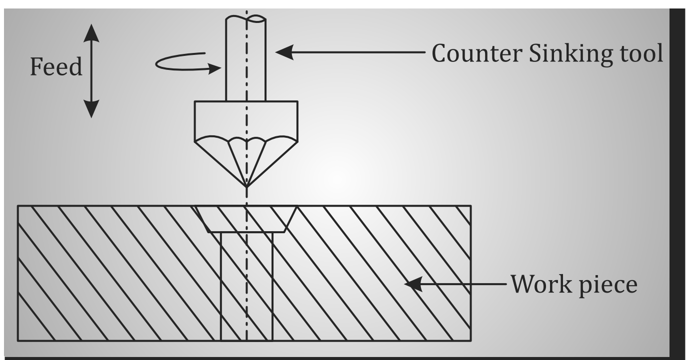


Fig. 3.12: Counter Sinking

6. **Counter-boring :-** Is an operation to increase the size of one end of a previously drilled hole to the required depth. The tool is provided with a pilot which guides the tool during counter-boring. The diameter of the pilot and drilled hole are same.

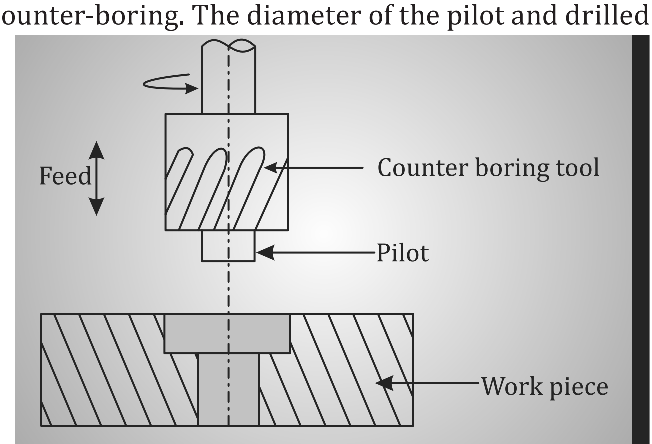


Fig. 3.13: Counter boring

3.4 Milling Operations

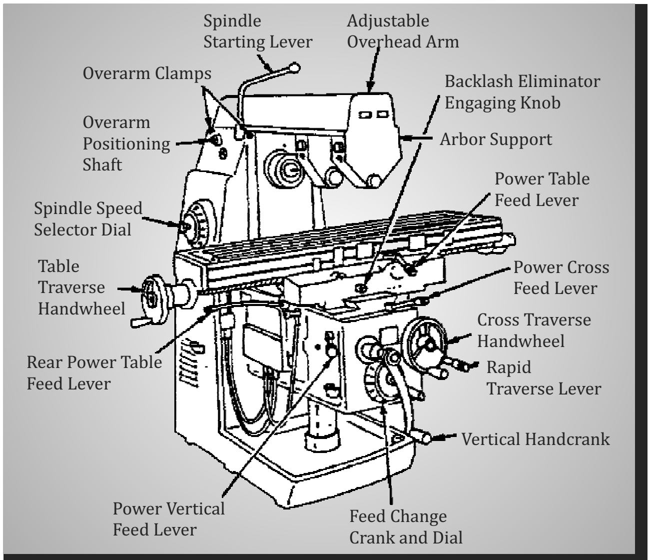


Fig. 3.14: Milling Machine

Milling is a metal removal process in which a workpiece is fed to a revolving tool, thereby removing excess material. The tool is called milling cutter.

Milling machine is a power operated machine tool where the workpiece is firmly clamped and is fed against the rotating milling cutter to get the required shape and size.

Operations performed on milling machine:-

(1) Plain milling (2) End milling (3) Slot milling

1. **Plain milling :-** This is a process to get flat surfaces on the workpiece. Here the cutter axis and workpiece surfaces are parallel. The cutter is called a slab cutter which has helical teeth.

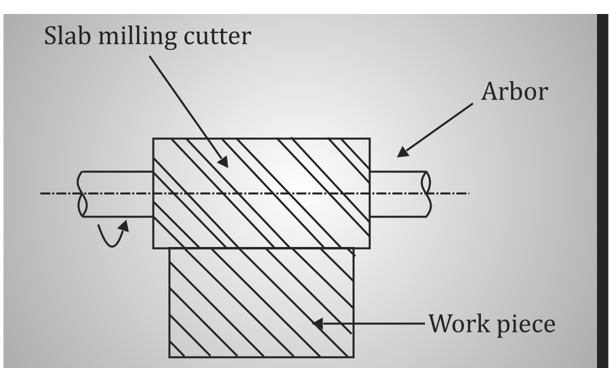


Fig. 3.15: Plain milling or slab milling

2. **End milling :-** This is a process to make slots, keyway and pockets on the workpiece. Here the cutter is perpendicular to the workpiece surface. The cutter is called end mill or end mill cutter. This has cutting teeth on both sides.

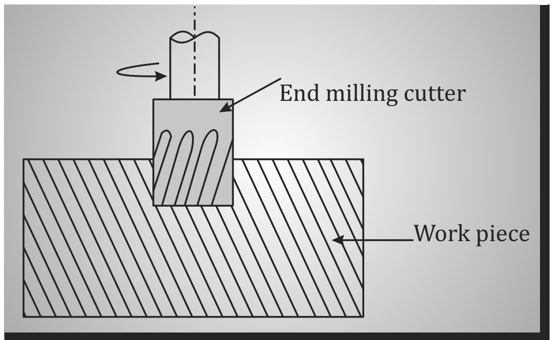


Fig. 3.16: End Milling

3. **Slot milling:-** A side and face milling cutter is used to make a slot. This process is called slot milling.

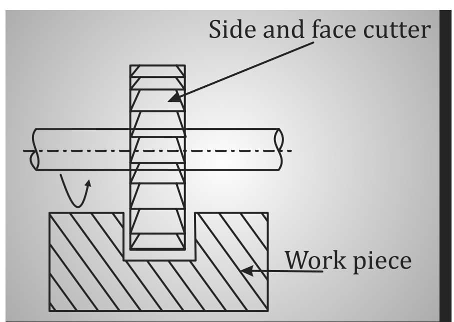


Fig. 3.17: Slot milling using side and face cutter

3.5 ROBOTICS

Robot are machines which are flexible, have the ability to hold, move, and grab items. They are controlled by micro computers which when programmed guide the machines through predetermined operations.

Definition : Robot

Robot can be defined as a programmable, multifunction manipulator designed to move materials or parts, tools or specialized devices. Robots are fitted with sensors. Hence robots are machines with some degree of intelligence.

Industrial robots are capable of handling a variety of jobs like material handling, spot welding, spray painting, mini-centre etc.

Definition : Robotics

Robotics may be defined as 'the science of designing and building robots suitable for real size application in automated manufacturing and non-manufacturing environments'.

3.6 CLASSIFICATION OF ROBOTS BASED ON CONFIGURATION

1. Polar configuration
2. Cylindrical coordinate configuration robot
3. Cartesian coordinate configuration robot (Rectilinear)
4. Joint arm configuration Robot (Revolute)
5. SCARA

1. Polar configuration: In this configuration there are two rotary motions, one about vertical axis and another about horizontal arms in parts A and B The arm C has a linear motion parallel to the horizontal axis. Joint is known as **TRL** Movement of arm C can be presented by polar coordinates (R, θ)

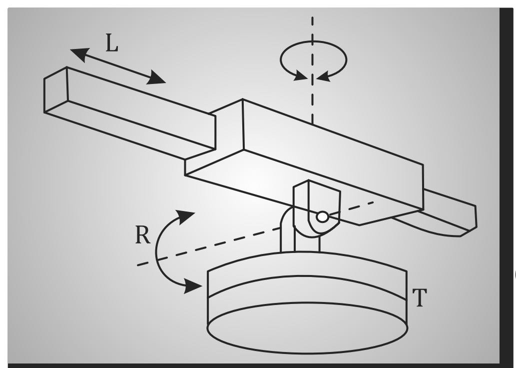


Fig. 3.18: Polar Configuration robot

2. Cylindrical coordinate configuration robot: This has two linear motions L and O and one rotary motion T. Joint is **TLO.** It has a vertical column (A) about which arm (B) can be moved up and down (L) The linear joint O gives radial movement of arm Arm B is rotated about column joint (T).

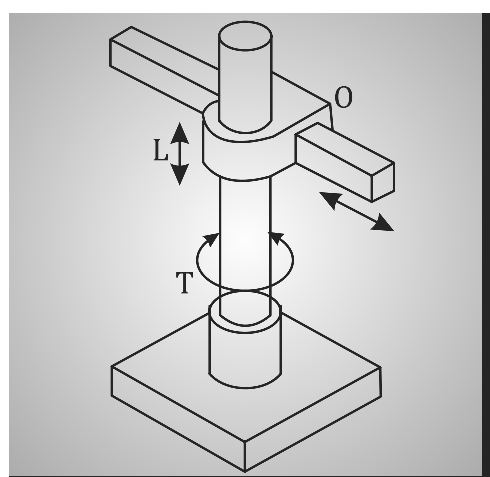


Fig. 3.19: Cylindrical Coordinate Configuration robot

3 **Cartesian coordinate Robot :-** Cartesian co-ordinate Robot has three linear motions. One about vertical and two about horizontal axes. **LOO** notation denotes one linear joint L and two orthogonal joints (0,0). It is also known as rectilinear robot.

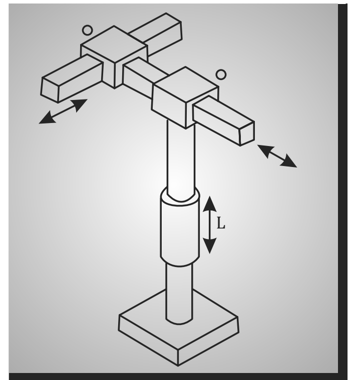


Fig. 3.20: Cartesian coordinate configuration robot

4 **Jointed arm:-** It resembles the configuration of a human arm. It has a shoulder joint and an elbow joint. The arm can be swivelled about the base by the combination of 3 notations **TRR**.

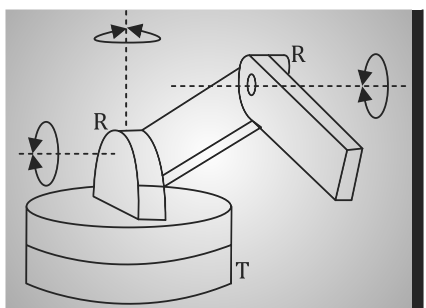


Fig. 3.21: Joint arm configuration robot

5 **SCARA:-** It means selective compliance assembly Robot arm. It is similar to jointed elbow axis of rotation. The axis are vertical instead of horizontal and arm is rigid in vertical direction but compliant in horizontal direction. This permits the robot to perform insertion jobs in vertical direction.

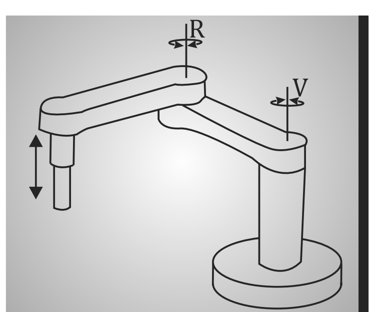


Fig. 3.22: SCARA

Application of Robots

1. Robots are used for processing involving hazardous, unpleasant work environment such as heat, sparks, fumes etc. Example Foundry, spray painting etc.
2. Used in material transfer application e.g., pick and place transfer from conveyor to conveyor.
3. Used in material handling application
4. Used in spray painting processes for automobiles and industrial products
5. Used for drilling, grinding, polishing and debarring.
6. Used in Assembly operations and inspection process

Advantages of Robots

1. Provides consistency and repeatability.
2. Lifting and moving heavy objects.
3. Working in hazardous environment.
4. Increasing productivity.
5. Achieving more accuracy than human beings.
6. Performing monotonous jobs.

Disadvantages of Robots

1. Lack of capability to respond is emergencies.
2. Initial and installation cost is high.
3. Replacement of workers causes problem.

3.7 Automation

Definition : Automation

Automation is defined as `**A Technology concerned with the application of mechanical, electronic and computer based systems to operate and control production**'.

Automation produces the final product at minimum cost, involving labour intervention as minimum and product has high accuracy.

A completely automated production system involves automatic machine tools like machining center etc., to remove material as desired, industrial robots, material landing lines and inspection systems and computer systems for planning, data collection and feedback.

Types of Automation

1. Fixed Automation
2. Programmable Automation
3. Flexible Automation

1. **Fixed Automation:** Here, the sequence of operation is fixed by the equipment configuration. This is used for mass production. It involves high investment cost, high production rate and cannot accommodate changes. Ex:- mechanized assembly lines.
2. **Programamble Automation:** Here we can accommodate any changes is sequence of operations for a new product by changing the program. It is suitable for batch production and high investment are observed ex CNC machines
3. **Flexible Automations:** Here no time is lost for production when product changes over to new product. It is an extension of programmable automation.

   Code for new product has to be fed to computer and change in settings and tools are done automatically. These system can produce various combinations of products. Hence, continuous production rates, high investments and flexibility is design are observed. Ex: flexible manufacturing system for performing machining operations.

3.8 Applications of Automation

1. Numerically control.
2. Automated production lines.
3. Automated assembly.
4. Robots in manufacturing.
5. FMS (Flexible manufacturing system).
6. CAD CAM and CIM.
7. Building automation systems (BAS).
8. Automation in daily size.

Advantages of Automation

1. Increased productivity.
2. Reduced production cost.
3. Human fatique is minimized
4. Reduced maintenances.
5. Control over production process.
6. Improvement in the quality of products.
7. Human safety is ensured.

Disadvantages of Automation

1. High initial investment.
2. May lead to unemployment.
3. Skill upgradation for labour involves cost.

Numerical Control [NC] : Is a form of programmable automation is which the processing equipment is controlled by means of numbers, letters and symbols For a particular work part or job, program of instructions are coded using numbers, letters and codes. NC is used in machine tool applications such as drilling, milling and turning metal parts and also is assembly.

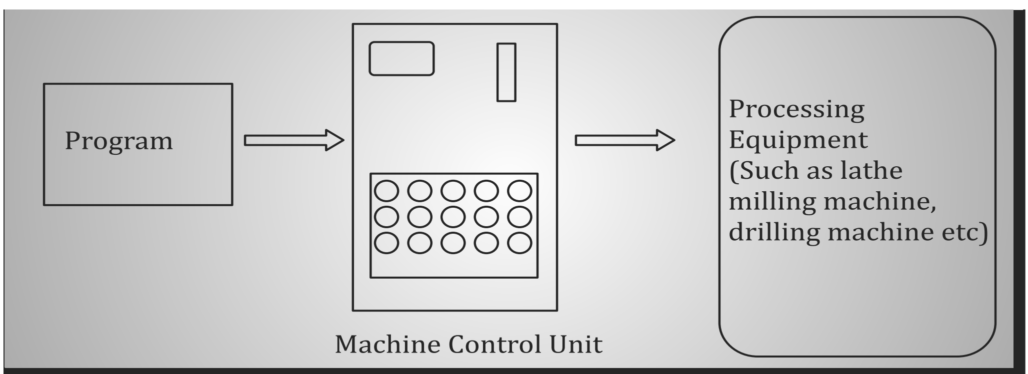


Fig. 3.23: Numerical control system

Basic components of NC grove: A NC system consists of

(1) Program of instructions

(2) Machine control unit

(3) Processing equipment

1. **Program of instruction:** It is the detailed step-up-step commands fed to the control unit that directs the processing equipment. The program is coded in a medium called punch tape and is submitted to the machine control unit.
2. **Machine control unit:** It consists of electronics and control hardware that read and interpret the program for instruction. Also it converts these instructions into mechanical actions of the machine tool. They use micro processors.
3. **Processing equipment:** Is the component that performs eight useful work. The processing equipment performs machining operations such as milling machines drilling, lathe etc and also motors and controls.

Advantages of Numerical Control

1. Reduces time required for machining.
2. Reduces the number of jigs and fixtures.
3. Reduces time to machine.
4. Reduces human error.

Disadvantages of Automations

1. High initial cost.
2. Requires special skill to program codes.
3. Operation training and maintenance needed.

Definition : Computer Numerical Control (CNC)

It may be defined as a numerical control system in which a dedicated microcomputer or stored program is used to perform as the machine control unit.

Computer of CNC

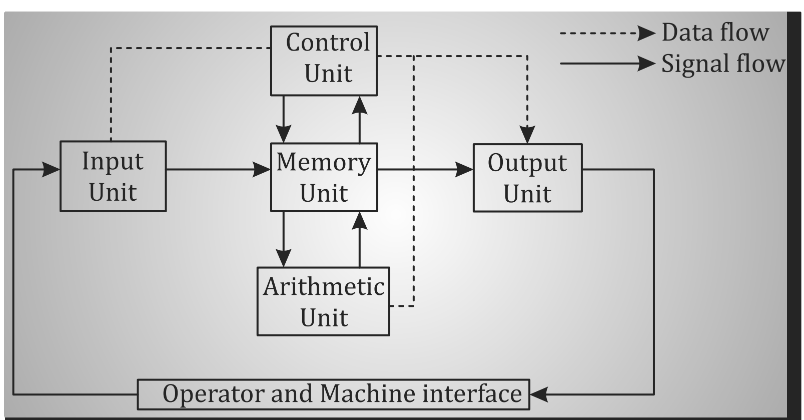


Fig 3.24: Computer Numerical Control System

1. **Input Unit:** Receives all the commands from operator interface and feedback status in the form of AC, DC, and analog signals. Software is the input by means of magnetic devices.
2. **Control Unit:** Receives instructions from memory unit and interprets them one at a time. This information from operator and machine interface is processed, interacted and manipulated by hardware logic and computer programs. Control unit then sends proper signals for executing instructions.

3. **Memory Unit:** Acts as a storage device for storing instructions, data received from input and results of arithmetic operations. It also supplies information to output unit. Programes are stored in RAM (Random access memory) and ROM (read only memory)
4. **Arithmetic Unit:** Performs arithmetic calculations and results are stored in memory unit.
5. **Output Unit:** The output from memory unit and signals are converted to compatible signals from Analog to control axis drive servomotors. Output signals are used to turn off devices, display information, etc.
6. **Operator Interface:** Consists of (a) punched tape (b) magnetic devices.
7. **Machine interface:** Consists of all devices used to monitor and control machine tool like control valves, servo mechanisms.

Advantages of CNC

1. Improves reliability.
2. Provides greater flexibility.
3. More compatible.

Applications of NC/CNC Machines

These machines are used to machine parts.

1. With complex machining requirements.
2. Which require high precision.
3. Where many changes are needed.
4. Requiring fast and slow speed of machining.
5. Required in small quantities of respective batches.

Review Questions

1. Classify machine tools
2. Explain the following operations performed on lathe
   (a) Facing (b) Boring (c) Turning (d) Taper turning
   (e) Knurling (f) Thread cutting
3. What is a taper? Explain taper turning by swivelling the compound rest
4. How do you classify drilling machines?
5. Sketch and explain the following drilling operations:
   (a) Boring (b) Counter boring (c) Counter sinking (d) Reaming
   (e) tapping
6. Differentiate between drilling and boring
7. What are the common milling operations?

8. Describe the following milling operations with suitable sketches
   (a) Slab milling (b) Angular milling (c) Slot milling (d) End milling
   (e) Face milling (f) Gang milling

Multiple Choice Questions

1. Lathe bed is made of
(a) Mild steel **(b) Cast Iron**
(c) Brans (d) Cast steel

2. Knurling is the operation of producing
(a) Threads (b) Conical surface
(c) Diamond shaped Pattern (d) enlarging a hole

3. Producing helical groove on a revolving cylindrical surface is called
(a) Taper Turning **(b) Thread Cutting**
(c) Grooving (d) Parting

4. The operation of formal internal threads is known as
(a) Reaming **(b) Tapping**
(c) Counter sinking (d) Counter boring

5. Countersinking is the operation of
(a) Enlarging the end of a cylindrical hole
(b) Producing a square hole
(c) Producing a conical seating at the end of a hole
(d) Finishing the hole

6. Reaming is the operation of
(a) Enlarging the end of the hole
(b) Cone shaped enlargement at end of hole
(c) Smoothing the hole
(d) Sizing and finishing of a hole

7. The operating of milling two parallel surfaces of a workpiece simultaneously is called
(a) Gang Milling (b) Face Milling
(c) End Milling **(d) Straddle Milling**

8. An end milling cutter is used for
(a) Facing (b) Profiling
(c) Slotting **(d) All of the above**

❀❀❀❀

ENGINEERING MATERIALS AND JOINING PROCESS

MODULE

4

HIGHLIGHTS

- Introduction
- Ferrous and Non-ferrous Metals
- Composites
- Application of Composites
- Welding Brazing and Soldering
- Electric Arc Welding
- Gas Welding
- Soldering
- Brazing

4.0 INTRODUCTION

Engineering metals emerged from the iron age which laid the foundation for today's usage of metals in engineering. Iron is a soft metal. The iron-carbon alloys came into importance in the recent years. Hence Ferrous metals and alloys are of utmost usage today. There are non ferrous metals also like Magnesium, Aluminium, Copper, Nickel etc., and there too have found use in the engineering field.

Material is defined as that which consists of matter or occupies space. Engineering materials are used in design and manufacturing of aircrafts, engines, ship building etc. Materials which have applications in engineering are called engineering materials. Fabrication is an important process which involves joining process like soldering, brazing and welding.

Classification: Engineering materials are clarified into broadly into four types

(1) Metals & alloys (2) Ceramics (3) Polymers (4) Composites

1. A **metal** is an elemental substance while alloy is formed when two or more metals are mixed together **Example:** Iron and Steel.
2. **Ceramics** are compounds of metallic & non metallic elements which are very hard in nature. **Example:** Silicon carbide and magnesium oxide.
3. **Polymers** are direct derivatives of carbon which have long chain molecules with 3D structures. **Example:** Plastics and polyethylene.
4. **Composites** are special materials where one or more reinforcements are added to the base metal matrix to form a heterogeneous mixture.

   Example: FRP and carbon reinforced rubber.

4.1 FERROUS AND NON FERROUS METALS

Classification of Ferrous Metals and its Alloys

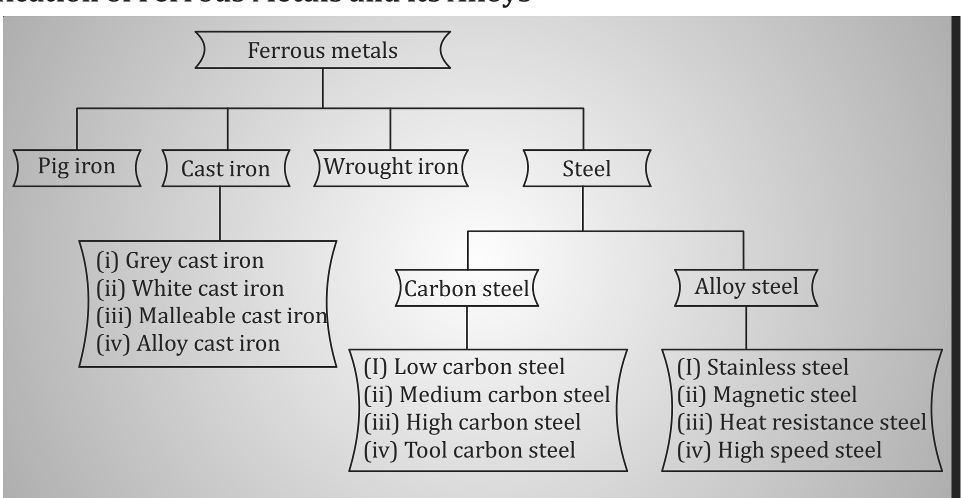


Fig 4.1: Classification of Ferrous Metals

Pig iron

It is the first stage of iron directly extracted from the ore through blast furnace. These contain high percentage of carbon and other impurities. It is hard and brittle.

It is obtained from blast furnace. It is produced from iron ore is blast furnaces where coke is used as a reducing agent. Carbon is present is big iron as graphite.

Cast Iron

Is derived from pig iron and contains 2-4% of carbon. It hard and has wide application in industry.

Pig iron when remelted gives cast iron. It is an alloy of iron and carbon where carbon percentage is 6.5%. Carbon is present in carbon as graphite. The existence of combined carbon makes it brittle and hard. The properties of cast iron are affected by the size of carbon particles. Cast iron is brittle but hard. It has low ductility and malleability. There are different types of cast iron.

(1) Grey cast iron: Carbon is present graphite flakes. It is used for castings due to its low melting temperature and good fluidity when it is in molten state, the graphite flakes in grey cast iron improves damping property. It also has good resistance to wear. The properties of grey cast iron are low tensile strength no ductility and brittleness. Grey cast iron is used as beds for machine tools and also is IC engines.

(2) White cast iron: Carbon is present as iron carbides. When fractured, it gives silver metallic appearance. White cast iron is obtained with the proper proportion of chemicals.

Properties of white cast iron
(i) High compressive strength (ii) Presence of cementite makes it brittle (iii) High hardness, resistance to wear and abrasion. (iv) Poor machinability.
Uses of white cast iron
It is used widely for pump liners, grinding balls, dus and extrusion white iron is used for manufacture of malleable cast iron.

(3) Malleable Cast Iron: It is produced by heat treatment of white last iron. The heat treatment is carried on for many days.

The annealing treatment for malleable cast is on makes it shock resistant. There is no brittleness as in the case of cast iron.

Uses of Malleable Cast Iron
They are widely used in automobile industries, for IC engine components such as crankshafts and camshafts etc., They are also used in electrical industries switch gear, power transmission and distribution system.

(4) Ductile cast iron: It has graphite in the form of modules. Some elements like sodium etc., are added which make the graphite to precipitate in all directions.

Properties of Ductile cast iron
(i) Toughness and ductility is improved. (ii) It resembles steel is its character. (iii) It resembles steel is its character. (iv) Has high yield point
Uses of Ductile cast iron
It has good resistance to shock and is used in dies, purchases and sheet metal work. Can be used are door in furnaces. It also has good corrosion resistance.

(5) Alloyed cast iron: About 4% silicon is added to cast iron to increase softness and improves the casting properties nickel in cast iron improves the maintainability and wear resistance.

Chromium is also added to nickel to improve wear resistance. Phosphorous added to cast iron improves the shrinkage in castings. It also improves the strength of the castings.

Sulphur when added to alloyed cast iron improves hardening effect. Molybdenum in uses wear resistance. Higher content of sulphur above 0.2% is not desirable.

Wrought Iron

Is a refined form of iron with very little impurities. It is tough, malleable and ductile. Used in cranes.

Steel

It is an alloy of iron and carbon. Steels contain carbon percentage of 1.5%. As the carbon percentage is steel increases, its yield strength increases and ducticity decreases.

Properties of Steel
(i) Properties of steel can be modified by addition of alloying elements (ii) Heat treatment of steel provides descried ductility and strength. (iii) Machinability and weldability are good in steel (iv) Used in structures to a large extent

Classification of steel

Steels are broadly classified as

(i) Plain Carbon steels

(ii) Alloy steels

(iii) Tool Steels

(i) Plain Carbon Steels: These contain iron and carbon and some elements such as sulphur and phosphorous. They are classified based on the percentage of carbon present in stem as low carbon steel, medium carbon steels and high carbon steels.

(a) Low carbon steels: Also called as mild steel. They have carbon percentage of 0.05 to 0.3%. They are widely used in all engineering applications.

Properties of Low carbon steels
(i) They are ductile and tough, but weak in strength
(ii) They can be easily welded
(iii) Can be surface hardened by process called carbonizing
(iv) They are least expensive to produce
(v) Do not respond to heat treatment
Uses of Low carbon steels
(i) They have good formability, hence used in structural members and industrial applications
(ii) Used in riverts, bolts, shafts, chain etc
(iii) Used in brake housings, pipelines, channels and brans
(iv) Used in forging elements, in bridge work, workshop components

(b) Medium carbon steels: They contain carbon is the range of 0.3 to 09%. They respond to heat treatment.

Properties of Medium carbon steels
(i) Some elements like manganese, tungsten etc, when added, act as hardening material.
(ii) Heat treatment affects the electrical and thermal conductivity of steel
(iii) Mechanical properties change significantly when heat treated.
Uses of Medium carbon steels
(i) They are used in drop forgings, axles etc
(ii) used in springs, wises, lopes, harmers etc
(iii) Carbon content in the range of 0.9% are used in chisels and harmers
(iv) They are widely used for railway tracks and couplings, cans, cylinders and tubes etc

(c) High carbon steels: Steels containing more than 0.65% carbon are called high carbon steels. The percentage of carbon ranges team 0.65 to 0.9% They have high wear resistance and hardness.

Properties of High carbon steels
(i) They respond well to heat treatment
(ii) Wear resistance character is good
(iii) They have difficulty in machining, welding and forming
(iv) When chromium, tungsten or vanadium are added as alloying elements, they become hard.
Uses of High carbon steels
(i) They are used for hamers, screw drivers
(ii) Steels with carbon percentage of 0.7 - 0.8% are used for anvil faces, hammer winches, springs and wires.
(iii) Steels with a higher percentage of carbon 0.8-0.9% are used for cold chisels, blades, purchases etc

Is widely used alloy of iron produced by combining carbon, sulphur, silicon and manganese. It consists of 0.1 - 2% carbon. It is classified into carbon steel and alloy steel.

The Carbon percentage in carbon steels are as shown below:

Low carbon or mild steel	0.05 – 0.3
Medium carbon steel	0.3 – 0.6
High carbon steel	0.6 – 1.5
Tool Steel	0.9 – 2.0

Alloy Steels

Nickel, manganese, silicon are alloying elements to get nickel steel, chromium nickel steel, chrome vanadium steel etc.,

Steels with other elements than carbon to provide specific characteristics are known as alloy steels. Some of the major alloying elements added to steel are chromium, silicon, tungsten, Manganese, Cobalt, cooper Zirconium etc. They elements, when added provide specific quality. To steel to produce the desired characteristics. Alloy steels have different characteristics from carbon steels. Alloys steels have the following properties

Properties of Alloy Steels
• To improve ductility.
• Elastic Limit of Steel increases which improves load bearing properties.
• Increases resistance to corrosion and wear
• Fatigue strength improves.
• They can have uniform grain size.
• Improves magnetic and electrical properties.

Classification of Alloy Steels

Alloys steels can be classified as

(a) Chromium steels
(b) Nickel Steels
(c) Manganese steels
(d) Molybdenum steel
(e) Stainless steels
(f) Tungsten steel

(a) Chromium Steels

Properties of Chromium Steels
i) It helps in the grain refinement process and increases strength and resistance to corrosion.
ii) They are used for ball bearings also and when 2% carbon is added it shows excellent magnetic property
iii) If chromium is added in excess, lten the steel exhibits high temperature and corrosion resistance property.

(b) Nickel steels: When Nickel is added to steel it improves toughness and fatigue strength. It also increases the corrosion resistance property.

Properties of Nickel steels
• Low carbon steels of 3.5% nickel are widely used in structural applications.
• Steels with 5% no find application is heavy duty trucks and Ic engine components like crankshaft etc.
• When steel of 25% nickel is used where toughness is required.
• When steel with around 35% nickel is used, the thermal expansion co-efficient is zero and hence widely used for measuring instruments.

(c) Manganese steels: Manganese improves the strength and hardness of steel. They have greater yield strength and can resist more impact loading.

Properties of Manganese steels
• With sulphur, manganese steel brings about good machinability.
• When 13% of manganese is added to steel, it become wear resistant and non-magnetic.

(d) Molybdenum Steels: These steels are used high speed tool steels.

Properties of Molybdenum Steels
• They increase harden ability
• They are wear resistant
• When used with Nickel and chromium, key exhibit high harden ability and hence used in aircraft industry.

(e) Stainless Steels: These are steels which do not get easily stained and are resistant to corrosion

Properties of Stainless Steels
• They are resistant to corrosion and oxidation • They posers good creep strength • They have high strength and toughness. • They are used in turbine blades and surgical equipment.

(f) Tungsten steels: They posses good heat resistant properties

Properties of Tungsten steels
• Increases hardensability of steel • They are widely used in cutting tools. • It provides higher wear and abrasion resistance.

Tool Steels: They are used for forming tool for various mechanical workshop applications. They contain about 1.5% carbon.

They find application is cutting, shearing and extrusion.

Non ferrous metals and alloys

Metals and alloys which do not contain iron are called as non ferrous metals. They are used in electrical industries to a large extent. Low strength, Low melting point and high shrinkage property.

Properties of non-ferrous alloys
• Possess good thermal and electrical conductivity. • Have resistance to corrosion. • Ductile and can be cold worked. • They are non-magnetic in nature. (1) Good corrosion resistance. (2) Ease of casting. (3) Ease of cold working. (4) Good electrical properties. **Example:** Aluminium, copper, lead etc.,

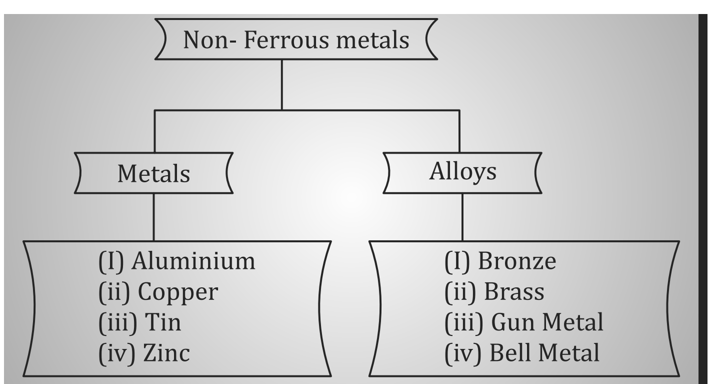


Fig 4.2: Classification of Non-Ferrous Metals

Metals

1. **Aluminium:** Is widely used metal in recent years which has replaced iron and steel. It is light in weight and non – corrosive. It is a white colour metal extracted from bauxite.
2. **Copper:** Is a red colour metal extracted team pyrite. It is soft, malleable, ductile and strong.
3. **Lead:** Heavy metal extracted from its ore `Galena'. It is bluish grey colour, soft, malleable & ductile. It does not react with acid and hence used in battery.
4. **Tin: Is** obtained from `Tin stone' which is an oxide having brilliant white with yellow tinge. It is very soft and can be rolled into sheets. Doesn't corrode.
5. **Zinc:** Is extracted from `Zinc blend' and `Calamin'. It is a heavy metal, bluish white in colour. Has good corrosion resistance and used in coating ferrous metals called galvanazing.

Alloys

Definition : Alloy

When two or more metals are mixed together in different proportions to get a homogeneous mixture it is called as an Alloy. They have better properties than metals.

Alloys: Aluminum alloys, copper alloys, magnesium alloys nickel alloys, zinc alloys and tin alloys.

1. **Aluminum Alloys:-** Aluminium melts at 660°C. It is one of the lowest density metals having density 2.7 g/cc. Can be alloyed with manganese; silicon, copper, zinc, magnesium, etc., There are different series.

   1000 series for pure aluminium.

   2000 series for copper.

   3000 series for manganese etc.

   Alluminium is light metal and finds much use in engineering application.

Properties of Aluminium Alloys

- It has good thermal and electrical conductivity.
- Good resistance to corrosion
- High ductility and mallaebility.
- Can be used for casting, rolling and extension. However they posses low hardness and ultimate strength.

Uses of Aluminium Alloys
• In engines and aircraft bodies • In spacecraft • In wires, motors and generator windings • They are used for fuel pumps and IC engine components. • It has high strength to weight ratio and has found use in engineering applications.

2. **Lead and Lead Alloys:** They are the softest materials. They are used for cables and gaskets. It has anticorrosion properties. They are used in chemical industry. Lead is an alloying element in brass & bronze.

Properties of Lead and Lead Alloys
• Malleable and dutcile. • Good lubrications properties. • Improves machinability. • It has low melting point. • Has low electrical conductivity.
Uses of Lead and Lead Alloys
• Widely used is storage batteries and cables • Used as an antiknock agent in Petrol engines. • Gaskets, joints, cables, soldering, chemical industries. • Bearings and bushes.

3. **Magnesium Alloys:** It is one of the lightest metals with 1.74 g/cc as density and MP is 650 °C and moderate strengths. Magnesium alloys are designated as AZ81 which means 8% Al and 1.% Zn AS41 is 4% Aluminium and 1% Si, Strength of Mg alloys is drastically reduced at higher temperatures. Mg alloys are used in aerospace industry due to weight advantage.

4. **Copper alloys:** Its melting point is 1083°C and density 8.93 g/cc. It has high thermal conductivity and electrical conducting copper has special properties such as good corrosion resistance non-magnetic, bright yellow colour, catalytic properties. Copper has good fabrication properties such as good machinability; ductility. Copper can be welded by electron beam welding and laser beam welding. Copper can be alloyed with Tin, Zinc, Nickel etc.,

Properties of Copper alloys
• Highest electrical and thermal conductivity. • Non-magnetic. • It is ductile, malleable and soft. • It can be cast.

Uses of Copper alloys
They find application is electrical wires, cables etc since they have high thermal conductivity, they are used in thermal applications like heaters, radiators and heat exchanges. They are also used pipes and tubes jar hot and cold water circulation.

Classification of copper alloys:

(a) Brass: Brass is an alloy of copper and zinc. It may contain lead, tin and aluminium is small percentage addition of zinc improves its strength and machinability.

Properties of Brass

- Strength is higher where composed to copper
- They have good thermal and electrical conductivity
- Higher machinability
- Less corrosion
- High hardness

Uses of Brass

Used in thermal applications like heaters and heat exchangers, radiator cores and pipes, valves and valve fittings and pumps.

b. Bronze :- Is an alloy of copper with tin normal range of composition is 75-95% Cu and 5-25% Sr. The bronze alloy is harder with good wear resistance and highly ductile. Bronze with small content of phosphorous is called bronze.

Properties of Bronze

- They have higher corrosion resistance compared to brars.
- Fatigue strength is good.
- They can be machined easily and posers good bearing properties.

Uses of Bronze

- Used for bearings and supports
- In pumps, impresser & fittings.
- In utensils for day-to-day use.
- In electrical contact suitable.

Classification of Bronze

Bronze is classified into two types

(i) Gun metal: It contains 88% cell, 10% tin and 1% Zinc. They are used in castings and can be joyed . they find use in gears and bearings.

(ii) Phosphor bronze: Contains 93.7% copper and a small percentage of 6% tin and 0.3% phosphorous. They can be used for castings. They are also used for using.

5. **Nickel Alloys :** Nickel has 8.85 gm/cc density and its melting point is 1452 °C. It is hard as steel with addition of carbon it becomes malleable. Nickel with alloy gives high strength Mord metal – Ni + Cu alloy.

   Nichrome wire is used as resistance wire in furnaces.

   Nickel has higher density than steel. Melting point is 1455°C. The most common alloy nickel is **`Monel Metal'** . It contains 60%. Nickel and 38% copper with 2% manganese and aluminium. It is a strong material with resistance to corrosion.

   Nickel with 55% copper is an alloy called **`Constantan'.** It has high electrical resistivity and hence used for electrical resistors.

   Other alloys like **`Inconel'** and **`Invar'** are also alloys of nickel.

   Inconel has high corrosion resistance, good toughness and used at high temperature.

   Invar is used for hair springs, watch springs measuring instruments and tuning forks as that's low coefficient of thermal expansion.

Properties of Nickel Alloys
• Nickel is ferromagnetic in nature. • It has zero coefficient of thermal expansion (d) • Widely used as a commercial alloy • Good catalyst for chemical reactions. • Good corrosion properties. • Machineable properties
Uses of Nickel Alloys
• Used as an alloying material. • Used is electrical heaters. • Used as a thermocouple material since it produces eny. • Used in measuring instruments since they have low coefficient of thermal expansion

6. **Tin alloy:** MP = 232 °C. It is soft, malleable and ductile material.

   Babbit material = Tin 88% and 8% antimony and 4% Cu.

7. **Zinc base alloys:** MP = 419.5 °C. It is neither malleable nor ductile at room temperature but can be rolled into sheets and drawn into wires at 100 °C. High resistance to corrosion.

   Brass is alloy of Zn + Cu.

   Zinc based alloys are used in washing machine, oil burners, refrigerators, Radio, TV sets.

4.2 Composites

Definition: Composites

Composites are defined as a heterogeneous combination of two or more dissimilar materials which, when combined are stronger than the individual materials.

The composite material contains two separate and distinct chemical phases. One is called '**Matrix**' which is continuous and second one is discontinuous and is called as '**dispersoids** or **reinforcement'**. Example: Concrete, glass filled polymer, fiber reinforced aluminium etc.,

Composite materials are materials made from two or more constituent materials. They are formed by a base material, reinforcing elements and fillers and binders. They have superior strength. These materials are manufactured separately combined to form one single material with greater improved strength.

The base material can be a metal or ceramic.

The reinforcement is done with particles or sheets or fibres.

Definition: Examples of composite material is GFRP (glass fibre reinforced plastic), KFRP (kevlar fibre reinforced plastic), concrete etc.

The mechanical properties of a material are

Stress: It is the internal resistance of a material per unit area due to application of internal force.

$$\text{Stress } \sigma = \frac{\text{Load(F)}}{\text{Area}} \text{N/m}^2$$

Strain: It is the change in unit length of the material due to the application of external force.

$$\text{Strain}(\varepsilon) = \frac{\text{Change in length(dL)}}{\text{Original length(L)}}$$

Elasticity: It is the capacity of a material to return to its original shape after a force is removed.

Toughness: Toughness of a material is its ability to absorb shock and impact energy.

Mallaebility: It is the property of a material to be pressed and rolled into thin foils.

Ductility: It is the property of plastic deformation. The drawing of metals into wires and rods.

Brittleness: The property of a material to crack under load is called Brittleness.

Composite contains three parts

Matrix – holds together the reinforcement

Reinforcement – fibre

Interface – bonding surface or zone to obtain desirable properties is a composite.

Properties of composite materials:

- High strength to weight ratio
- High fatigue strength
- Corrosion resistant
- High damping properties
- Anisotropic.

Advantages of Composites

1. Higher strength – weight ratio.
2. Increased stiffness to density ratio.
3. Increased fatigue resistance.
4. Better elevated temperature properties.
5. Better wear resistance.
6. lower thermal expansion coefficient.
7. Light in weight
8. Any shape can be developed
9. Corrosion resistant
10. Good finish
11. Good weather resistant
12. Non - magnetic
13. High dielectric strength
14. High reliability and life expectancy

Disadvantages

1. Re use may be difficult
2. Brittle
3. Special tools required for machining
4. High cost
5. Maintaining accuracy is difficult
6. Analysis is difficult

Classification of Composites

Based on Matrix material.

1. **Metal Matrix composites (MMC)**: These materials use a metal as matrix and reinforce it with fibres like silicon carbide and glass. They are light in weight and used in automobiles.
2. **Polymer Matrix Composites: (PMC's)** Use wide variety of fibres such as glass, carbon, polysters, etc., used in aerospace, marine, automobile and all major applications.
3. **Ceramic Matrix Composites: (CMC's)** Consist of ceramic as matrix and reinforce it with short fibres. They are used at high temperature environment like components in automobile and aircraft gas turbine engines.

Classification based on reinforcement

(a) Particulate Reinforced Composites: Particles are used are reinforcements.

(b) Fibre Reinforced Composites: A fibrous reinforcement is having its length much greater than its cross section. Mixing of fibres is difficult. Hence short fibres are used composites with preferred orientation need long fibres.

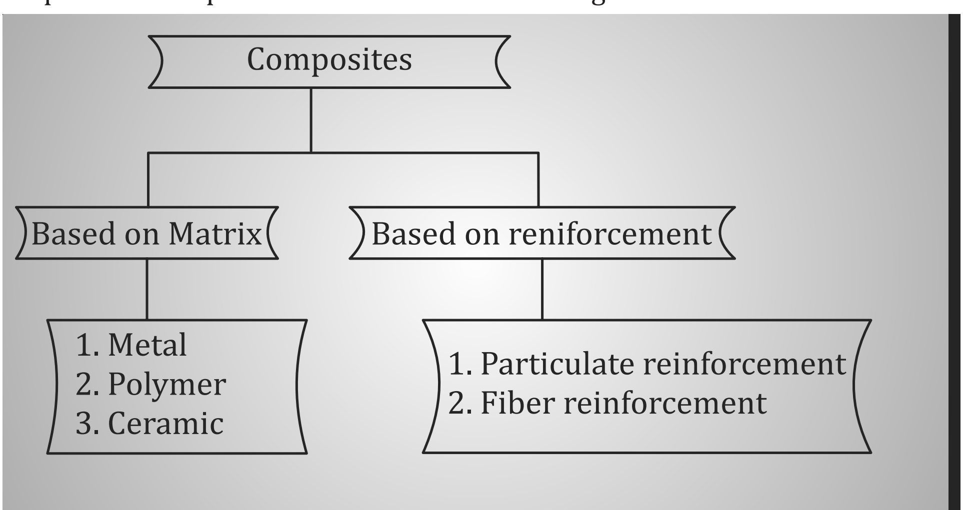


Fig 4.3: Classification of Reinforcement

A Composite in which two or more reinforcements are combined is called Hybrid Composites.

4.3 Application of Composites

(1) **Aircraft**

(2) **Road Transport**

(3) **Marine**

(4) **Building**

(5) **Packing**

(6) **Domestic and office furniture**

- In civil engineering for bridges, columns etc
- Pipe and duct systems
- Sanitary ware
- Window & door frames
- Used in automobiles is suspension systems and IC engine components, in can body, dash board and bumpers.
- Application is aircraft parts like propellers, seats, gear doors and instrument enclosures
- Also used in helicopter components.

Aircraft Application: Boeing, Airbus etc., spend large amount of fund for research and development of raw materials to reduce height of the aircraft and increase fuel economy. Polymers alloys have high strength to height ratio and are used in today's aircraft. Aircraft Body – we use Aluminium based MMC. Salient features of composites used in aerospace application are

(i) High strength to weight ratio
(ii) Excellent fatigue performance
(iii) Resistance to impact
(iv) Corrosion free and flexibility in design.

Automobile Application: Fibre Reinforced Plastics (FRP) are used. Aluminium based MMC are used in engine block, piston etc. FRP's are widely used in Steering wheel, doors, interiors of vehicles etc., FRP features are:

(i) Light weight, (ii) Resistance to impact,
(iii) Low thermal conductivity (iv) Corrosion

4.4 Welding Brazing and Soldering

Welding is defined as the metallurgical process of joining two or more similar or dissimilar materials with the application of heat and with or without application of pressure and using a filler material to produce a homogeneous joint.

Classification of Welding: Welding process can be classified as (1) Plastic or pressure welding (2) Fusion or non-pressure welding.

(1) Plastic or Pressure Welding: It is a process in which the metal parts to be joined is heated to the plastic state and there fused together by applying external pressure. No filler metal is need in this process.

Example: Forge welding, resistance welding.

(2) Fusion or Non Pressure Welding: It is a process where the parts to be joined the heated above the melting temperature and then allowed to solidity by cooling. Here filler material is used to fill the gap.

Example: Arc welding and gas welding

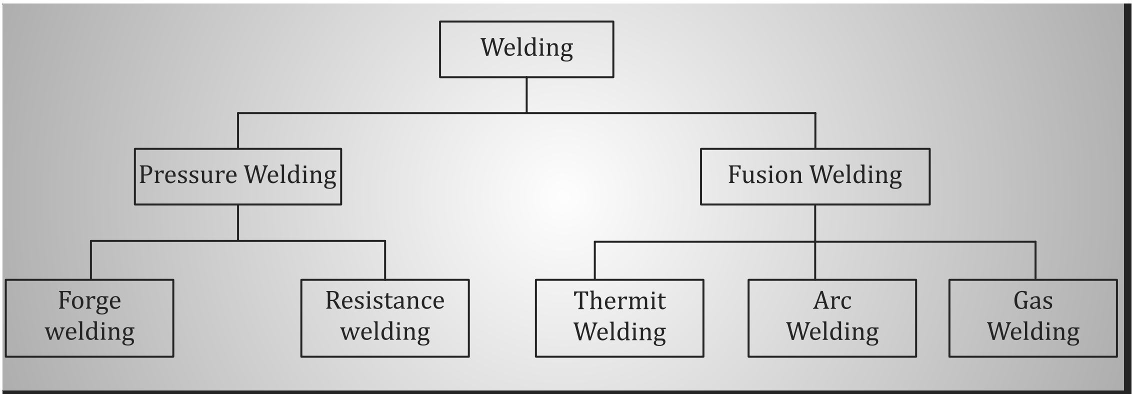


Fig 4.4: Classification of Welding

Applications of welding

1. Used in manufacturing automobiles, aircrafts, refrigerator, boilers and building construction.
2. Repair and maintenance work like joining broken parts, rebuilding worn out components etc.

4.5 Electric Arc Welding

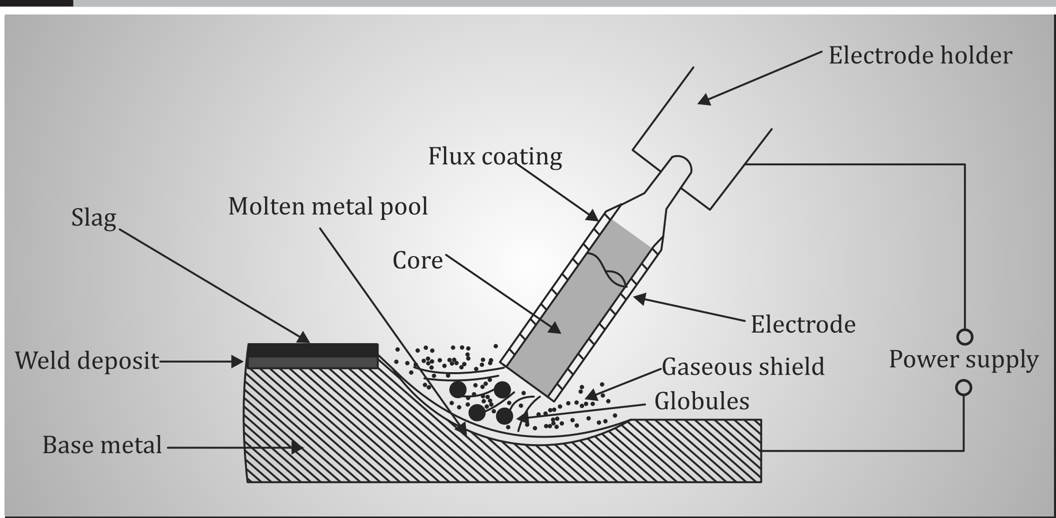


Fig 4.5: Electric Arc Welding Process

Principle of Arc welding: In this process, heat is produced by an electric arc. The arc is produced by striking the electrode on the workpiece and having a small gap of 2 – 4 mm. An arc is struck between the electrode and the work piece. Therefore electrical energy is converted to heat energy. The high temperature at the tip of the electrode is sufficient to melt the workpiece and the electrode melts and combines with the molten metal of the workpiece thereby forming a homogeneous joint.

Here electrode holder forms one pole of the circuit and the parts to be welded forms the outer pole. The electrode acts as a filler material. The arc struck between the electrode and work piece produces a temperature of 5000 – 6000° C to get molten metal. Also electrode tip melts and is transferred to the molten metal in the form of droplets of molten metal and hence a joint or a bond is formed.

Applications of Arc Welding: Fabrication work for aircraft industries, joining of large pipes, construction of bridge.

Arc welding machines: Arc welding processes use electric power as its source of energy. To supply the current, two types of power sources are available. AC and DC.

Electrode used in Arc Welding: Arc welding makes use of a "**filler metal**" to supply additional material to fill the gap between the work pieces. The filler metal used in the welding process is called "electrode". It is made of a metallic wire called '**core**' which is of the same chemical composition as the work piece metal. This core is uniform coated with a material called as '**flux**'.

There are two types of electrodes consumable and non-consumable electrodes and to burn the mixture at the tip is called as welding torch. The two cylinders are connected to the welding torch by flexible cables.

FIg 4.6: Welding mechine

Working Process: Suitable proportions of oxygen and acetylene gases are let into the welding torch and burnt in atmosphere. The temperature of the flame at the tip of the torch is in the range of 3200°C and this heat is sufficient to melt the work piece metal. A slight gap exists between the work pieces, a filler metal can be used to supply additional material to fill the gap. The deposited metal fills the joint and bonds the joint to form a single piece of metal.

4.6 Gas Welding

By regulating the ratio of oxygen and acetylene we get different flames.

Gas Welding Process: Gas welding is a fusion type of welding process. This makes use of a strong flame generates by the combustion of various gases to melt the work piece. These gases are mixed in proper proportions to get different flames.

The various combination of gases used in this process are (1) Oxygen and acetylene (2) Oxygen & hydrogen (3) Oxygen & LPG

Oxy-acetylene gas Welding Process: The Oxy-acetylene equipment consists of two cylinder and one of oxygen and another acetylene gas. Pressure regulations are provided to control the pressure of the gas as per requirement. The device used to mix both oxygen and acetylene gases in the proper proportion.

Oxy-acetylene Welding Process

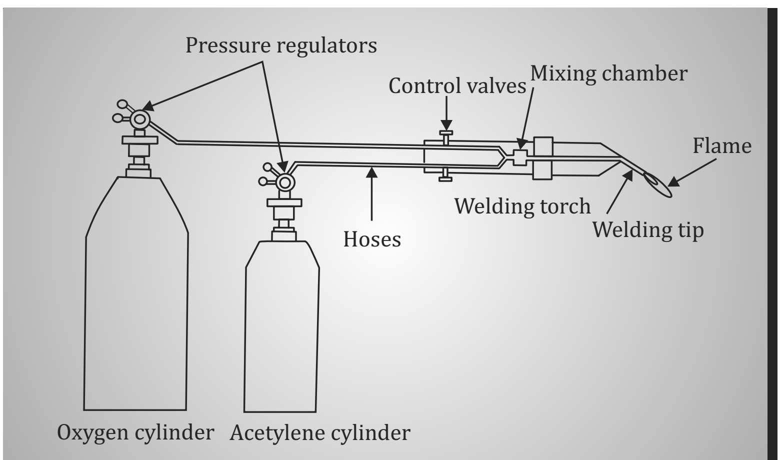


Fig 4.7: Oxy-acetylene welding process

Oxygen and acetylene is the most commonly used in gas welding and the flame is called '**Oxyacetylene flame**'.

Types of flames produced in Gas Welding

1. **Neutral Flame:** Oxygen and acetylene are mixed in equal proportions. A neutral flame is produced when approximately equal volumes of oxygen and acetylene are burnt at the torch tip. The flame has a nicely defined inner whitish cone surrounded by a sharp blue flame as shown in fig (a). This flame is commonly used for welding mild steel, aluminium, copper etc., and also can be used for metal cutting.
2. **Oxidising flame:** Excess of oxygen in neutral flame results in oxidising flame shown in fig (b). The oxidising flame appears similar to the neutral flame but with a short

inner white cone and the outer envelope is narrow and brightest in colour. Oxidising flame is used for welding copper base metals, zinc base metals etc.,

3. **Reducing flame:** When the volume of oxygen supplied to the neutral flame is reduced, the resulting flame will be a carburizing or reducing flame i.e. rich in acetylene and less of oxygen as shown in fig(c). A reducing flame can be recognised by acetylene feather that exists between the inner core and outer envelope. The outer flame envelope is longer than that of neutral flame and much brighter in colour. Reducing flame is used for welding non-ferrous metals.

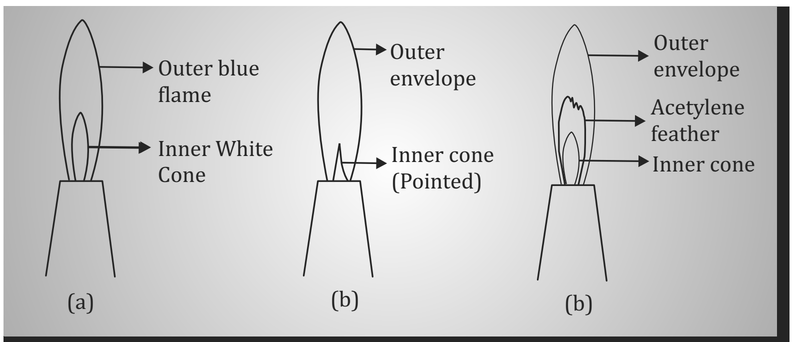


Fig 4.8: Types of flames

4.7 Soldering

It is one of the oldest forms of mechanical process where two metal surfaces are joined by another metal which is in liquid form. The third metal solidifies after cooling and forms a good joint between the two metals. Soldering metal normally melts at a temperature less than 450°C.

Soldering is a process of joining two metal pieces by the addition of filler metal whose melting temperature in significantly lower than the parent materials. The filling material is called solder and its melting temp is less than 450 °C. Flux is used in between the metals to remove non-metallic oxide films from the metal surface. Heat is applied on the solder by electrical soldering iron. The solder solidifies between the two surfaces by cooling in atmospheric temperature and forms a joint between two metal surfaces.

Types of Solder

Solder commonly used is alloy of lead and tin. Since melting point of lead is lower than tin, more percentage of lead means lower melting temperature. There are two types of Solder, Soft solder and Hard solder. Soft solder contains 63% tin and 37% of lead by weight.

Hard solder contains lead and silver and go up to 400° C.

Comparison between Welding, Brazing and Soldering

Sl. No.	Description	Welding	Brazing	Soldering
1	Joint Strength	Strongest	Medium	Lowest
2	Melting of base metal	Melting & fusing (in metallurgy)	No effect (in metallurgy)	No effect (in metallurgy)
3	Composition of filler metal	Similar to base metal	Not similar	Not similar
4	Use of filler metal	Not always needed	Needed always	Needed always
5	Joiner surfaces	Similar surfaces	May be dissimilar materials less	May be dissimilar materials
6	Heat affected zone	High	Less	negligible
7	Surface finish	Requires surface finish like filing/grinding	Good	Good. No finish is needed
8	Joining temperature	Very High	450 °C to 1000 °C	Less than 450 °C

Advantages of Soldering

1. Process is simple and economical.
2. Re-work can be done.
3. Energy required to do the joint is low.
4. Repeatability is good.
5. Easy to remove the joint.

Disadvantages of Soldering

1. Joint strength is low

4.8 Brazing

Brazing is a process of joining two similar or dissimilar metals by a filler metal called '**Spelter**'. Whose melting temperature is above 450°C but below the melting point of base metal. Filler metals used are copper and copper alloys, Silver and Silver alloys.

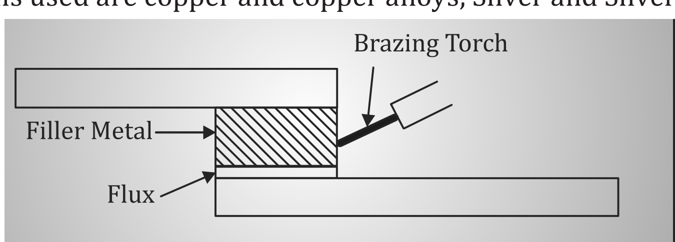


Fig 4.9: Brazing

Methods of brazing

There are four methods, they are

(1) Torch Brazing
(2) Furnace Brazing
(3) Induction Brazing and
(4) Resistance Brazing

Advantages of Brazing

1. Skill not required.
2. Provides additional strength.
3. Gives leak proof joint.

Disadvantages of Brazing

1. Joint strength is lower than welding
2. Requires high metal cleanliness
3. Cannot operate under

Review Questions

1. What are the uses of welding?
2. How are welding process classified.?
3. Explain the process of electric arc welding with sketch.
4. What is gas welding. Describe oxy-acetylene welding with sketch .
5. Explain the three flames in oxyacetylene welding.
6. Describe the brazing operations used to braze two parts.
7. Explain soldering. Why is flux necessary in soldering.?
8. Distinguish between welding ,soldering and brazing.
9. Describe the features of neutral ,oxidising and reducing flames.

Multiple choice Questions

Joining Processes

1. In welding, the metals to be joined are heated to a molten state and allowed to solidify in presence of a filler material is known as
   (a) Plastic welding
   (b) Fusion welding
   (c) Thermit welding
   (d) None of the above
2. Oxyacetylene welding is done with
   (a) Neutral flame
   (b) Oxidising flame
   (c) Corbonsing flame
   (d) All of the above

3. Materials used for coating the electrode is called
   (a) Protective layer (b) Binder
   (c) Flux (d) Slag
4. The flux used for brazing is
   (a) Resin (b) soft tin (c) Borax (d) Lead
5. The purpose of flux in soldiering is to
   (a) Improve Fluidity
   (b) Lower the melting temperature
   (c) Prevent contamination by atmosphere
   (d) None of the above
6. A homogeneous mixture of two or more metals is called
   (a) Alloy (b) Composite (c) Ceramics (d) None of the above
7. _______ is an alloy of non-ferrous metal
   (a) Zinc (b) Copper **(c) Bronze** (d) Lead
8. Composite material is widely used because of
   (a) High Strength-to-height ratio (b) High stiffness ratio
   (c) High strength **(d) All of the above**
9. Filler material used in welding is
   (a) Spelter **(b) Electrode** (c) Solder (d) None
10. Solder is basically
    (a) Tin silver base (b) Tin lead base
    (c) Silver lead base (d) Bismuth lead base
11. The temperature range in arc welding grocers is about ______
    (a) 2000 - 3000°C (b) 3000 - 4000°C
    (c) 4000 - 5000°C **(d) 5000 - 6000°C**
12. ______ Transformer is used in Arc welding
    (a) Step up **(b) Step down** (c) Set up (d) None
13. In DC welding ______ is used
    (a) Transformer **(b) Generator** (c) Transistor (d) None

Materials & Joining process

14. The melting point of specter is
    (a) 100°C (b) < 200°C (c) > 45°C **(d) >450°C**
15. Welding is ______ metal joining process
    (a) Temporary **(b) Permanent** (c) Loose (d) Quick
16. The voltage is arc weld is
    (a) 1000 V (b) 100 Amps (c) 10 mer **(d) 20 V**
17. Temperatures developed is arc welding
    (a) 3400 °C (b) 450 °C (c) 100 °C **(d) up to 6000 °C**

18. Solder is essentially a
    (a) Tin silver base **(b) Silver lead base**
    (c) Tin and lead base (d) Bismuth lead base
19. Excess amount of acetylene is used for producing
    (a) Oxidising flame (b) Neutral flame
    (c) Carbonizing flame (d) None
20. Brass is an alloy of
    (a) Cu and Sn (b) Al and Cu **(c) Cu and Zn** (d) Zn and Sn
21. Most abundantly used composite material
    (a) Steel rods **(b) RCC** (c) Cement (d) Brick
22. Best process for joining dissimilar metals
    (a) Pressure welding **(b) Brazing**
    (c) Fusion welding (d) Soldering
23. Joint is strongest in
    (a) Arc welding **(b) Brazing** (c) Soldering (d) Gas welding
24. Filler material used is welding is
    (a) Spelter **(b) Electrode** (c) Solder (d) none
25. A method of joining two similar or dissimilar metals using a special fusible alloy is
    (a) Brazing (b) Welding (c) Soldering (d) Heating
26. Most ductile material is
    (a) Hard steel **(b) Medium carbon steel**
    (c) Tool steel (d) Stainless steel
27. The composite material has ________ property
    (a) Matrix material (b) Reinforce material
    (c) Enhanced property (d) Malleable
28. Cutting tools are normally made by
    (a) High speed steel (b) Low carbon steel
    (c) Stainless steel (d) Silicon steel
29. The frame or body of lathe is made up of
    (a) Forged steel (b) Mild steel
    (c) Cast iron (d) Copper

❀❀❀❀

Notes

REFRIGERATION AND AIR CONDITIONING

MODULE 5

HIGHLIGHTS

- Introduction
- Application of Refrigeration
- Properties of an ideal or good Refrigerant
- Parts of Refrigeration
- Vapour Compression Refrigeration (VCR)
- Vapour Absorption Refrigeration (VAR)
- Principle of Air Conditioning
- Room Air Conditioners
- Working of Window or Split Air Conditioner

Fig 5.1: Coller

Fig 5.2: Air Conditioner

Fig 5.3: Refrigerator

5.0 Introduction

Definition: Refrigeration

Refrigeration is defined as a process of reducing and maintaining the temperature of a body or a system below that of the surrounding atmosphere.

This is achieved by continuously extracting heat from the body or a system and rejecting it into the surroundings with the aid of external energy. Hence refrigeration process produces cooling effect in a body.

5.1 Application of Refrigeration

1. To preserve food.
2. In making ice.
3. Air conditioning applications.
4. Dairy and form products.

Refrigerant: A medium which continuously extracts heat from the space within the refrigerator where temperature is to be reduced and maintained below that of the surroundings and rejects it to the surroundings is called a refrigerant.

5.2 Properties of an Ideal or Good Refrigerant

1. Low boiling temperature.
2. Low freezing temperature.
3. Low specific volume.
4. Non-toxic.
5. Non-corrosive.
6. High cop.
7. Odourless.
8. Low specific heat of liquid.
9. Non flammable and non-toxic.
10. Low cost.

The principle of refrigeration can be defined according to the basic concepts:

1. Heat flows from a system at higher temperature to another at lower temperature.
2. Fluids, by absorbing the heat, change from liquid state to vapour state and subsequently condense by giving off the heat.
3. The boiling and freezing temperatures of a fluid depend on its pressure and can be condensed.
4. Heat can flow from a system at low temperature to a system at higher temperature by the aid of external work as per the second law of thermodynamics.

Properties of some refrigerants:

Sulphur dioxide:- Has good refrigeration properties sulphur dioxide is a toxic, pungent gas, and requires heavy compressor.

Carbon dioxide:- It is Odourless, non - flammable, non toxic

Ammonia :- Ammonia is toxic, flammable and with a pungent irritating odour. Boiling point of Ammonia is -33.3°C used in vapour absorption system.

Freon 12 and Freon 22:- Non - flammable, non irritating odour, good COP and used in domestic refrigerators. Have good thermo dynamic and chemical properties. It is non - toxic. They are suitable for low, medium and high temperature applications.

5.3 Parts of a Refrigerator

1. Evaporator
2. Condenser
3. Circulating system and
4. Expansion device

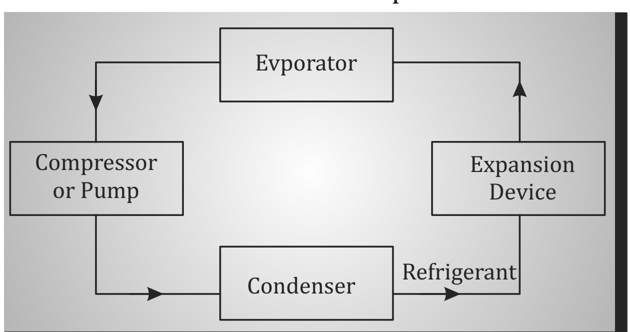


Fig 5.4 Parts of a Refrigerator

1. **Evaporator:** Is the heart of the refrigerator where the liquid refrigerant is evaporated by the absorption of heat from the refrigerator cabinet in which the substances to be cooled are kept-
2. **Circulating System:** Consists of compressors or pumps which are necessary to circulate the refrigerant to undergo the refrigeration cycle. They increase the temperature and pressure of the refrigerant.
3. **Condenser:** Is an appliance in which the heat from the refrigerant is rejected at higher temperature to another medium, usually atmospheric air. In a condenser the refrigerant vapour gives off its latent heat to the air and consequently condenses into liquid so that it can be re-circulated in the refrigeration cycle.
4. **Expansion device:** The expansion valve serves as a device to reduce the pressure and temperature of the liquid refrigerant before it passes to the evaporator. The liquid refrigerant from the condenser is passed through an expansion valve where it reduces its prepare and temperature.

Unit of refrigeration

A ton of refrigeration is the amount of heat absorbed to produce one ton of ice in 24 hours when initial temperature of water is 0°C. **One ton of refrigeration = 210 kJ/min = 3.5 kW**

Co-efficient of performance (C.O.P) is defined as the ratio of heat absorbed in a system to the work supplied.

$$COP = \frac{Q}{W} = \frac{\text{Heat absorbed}}{\text{Work supplied}}$$

Relative coefficient of Performance: $\text{Relative COP} = \frac{\text{Actual coefficient}}{\text{Theoritical coefficient}}$

Types of Refrigeration Systems

1. Vapour Compression Refrigeration (VCR)
2. Vapour Absorption Refrigeration

5.4 Vapour Compression Refrigeration(VCR)

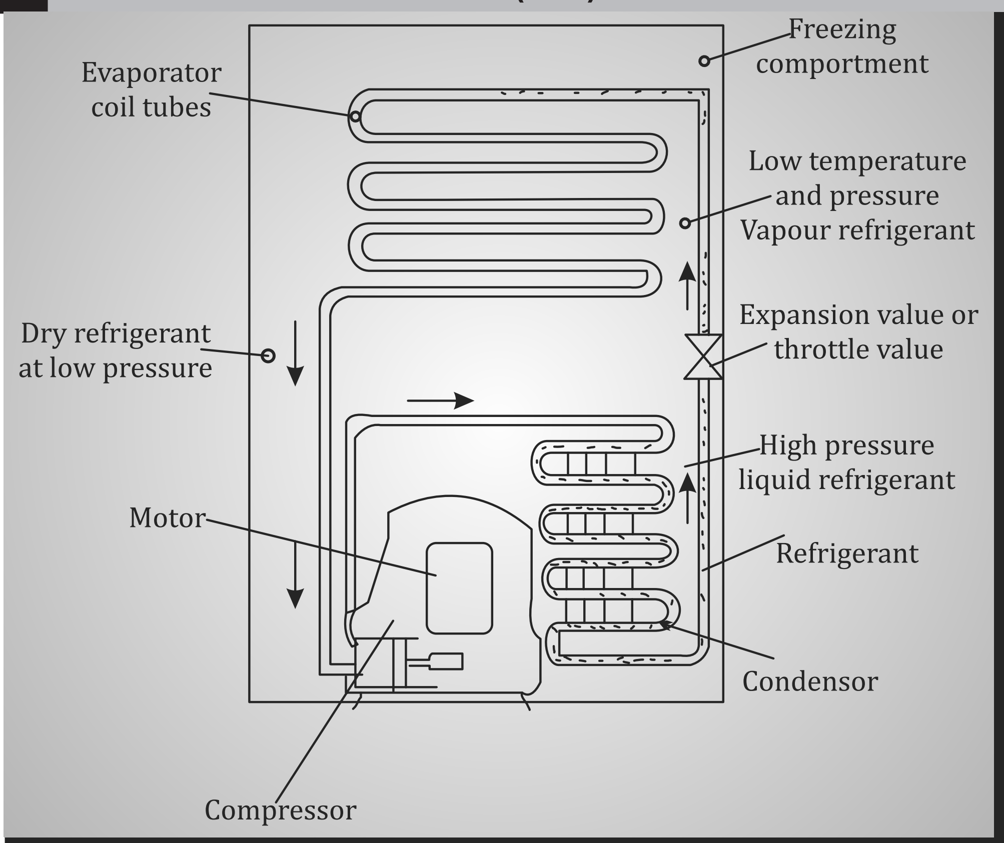


Fig. 5.5: Vapour compression refrigeration system

Principle of working of VCR: It consists of evaporator, compressor, condenser and throttle valve.

In a VCR, a refrigerant alternatively undergoes a change of phase from liquid to vapour (evaporation) and from vapour to liquid phase (condensation) during the working cycle in the evaporator, the refrigerant will be in liquid state. It absorbs latent heat of evaporation from the space which is to be cooled and undergoes a change of phase from liquid to vapour.

The vapour at low pressure and temperature is drawn into the compressor where it is compressed to a high pressure and temperature. The compressed vapour enters the condenser. The condenser, the vapour refrigerant condenses by giving its latent heat of condensation to the circulating cooling medium and undergoes a change of phase from vapour to liquid. The high pressure liquid refrigerant leaves the condenser and passes through the throttle or expansion valve. Where it is expanded to low pressure and temperature. The temperature of refrigerant falls down. The low pressure, low temperature liquid refrigerant again enters the evaporator where it absorbs the heat from the space and evaporates. The low pressure – low temperature vapour is drawn into the compressor and the cycle repeats.

5.5 Vapour Absorption Refrigeration(VAR)

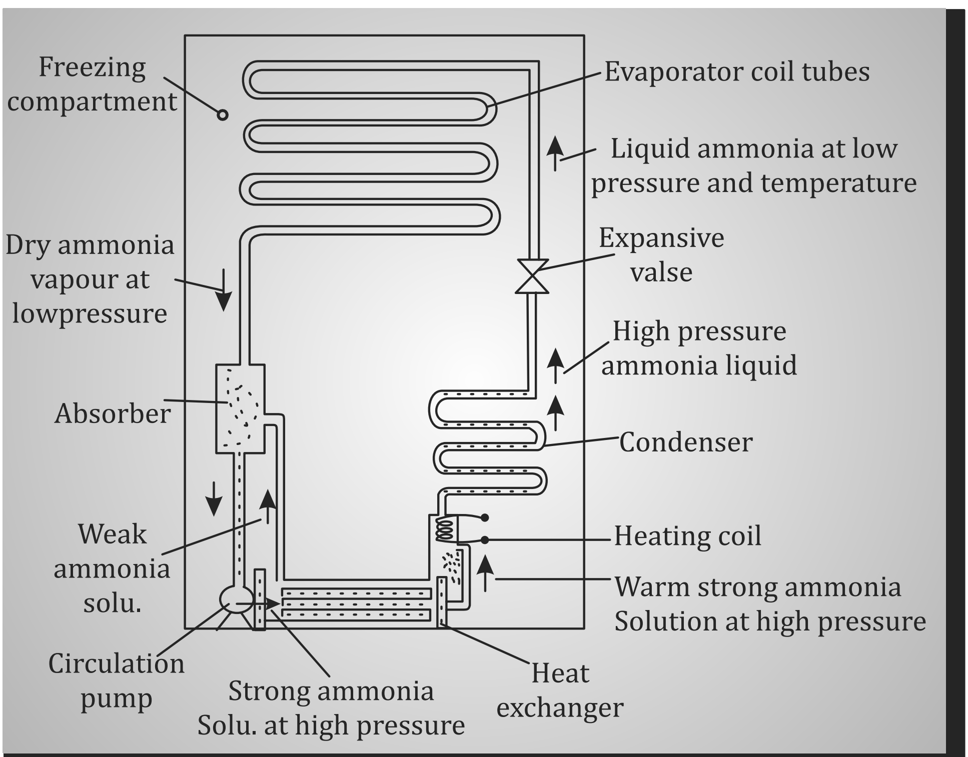


Fig 5.6: Vapour Absorption refrigeration

It consists of an absorber, a circulation pump, heat exchanger, heater cum separator, condenser, expansion valve.

In this refrigerator, ammonia is used as a refrigerant. The ammonia in liquid state vaporises in evaporator tubes by absorbing its latent heat of vaporisation from the freezing compartment thus keeping it cool and subsequently gives off its latent heat of condensation when it condenses in a condenser. The ammonia liquid from the condenser is heated in a heater to vaporise it. The refrigerant used in this system must be highly soluble in the solution known as 'absorbent'. Ammonia is the refrigerant and water is the absorber.

In the evaporator, liquid ammonia refrigerant absorbs its latent heat of vaporisation from the space that is to be cooled and it undergoes a change of phase from liquid to vapour. The low pressure ammonia vapour is then passed to the absorber.

In the absorber, low pressure ammonia vapor is dissolved in weak ammonia solution at low pressure and becomes strong ammonia solution. This strong ammonia solution is then pumped to a heater through heat exchanger at high pressure at high pressure. While passing through the heat exchanger the strong ammonia solution is warned by hot weak ammonia solution. The vapors of ammonia at high pressure now passes to a condenser.

In a condenser, high pressure ammonia vapor rejects its latest heat of condensation to cold water and changes its phase from vapor to liquid. Low temperature, high pressure liquid ammonia is expanded to low pressure. Which again enters the evaporator where it absorbs the heat from the space (cooling) and the cycle repeats.

Differences between vapor absorption and vapor compression refrigeration system

Sl. No.	Principle	VCR	VAR
1	Working method	Refrigerant vapor is compressed	Refrigerant vapors is absorbed and heated
2	Type of energy supplied	Works on Mechanical energy	Works on Heat energy
3	Work or Mechanical energy supplied	Mechanical energy required in more since refrigerant vapors are compressed to high pressure	Mechanical energy required to run the pump is less since pump is required only to circulate the refrigerant
4	COP	COP is higher	COP is lower
5	Capacity	Design capacity is limited since single compressor can produce upto 1000 tons of refrigerant	Absorption system can be designed to capacities above 1000 tons
6	Noise	Is more due to compressor	Quiet is operation
7	Refrigerant	Freon - 12	Ammonia
8	Leakage	More leakage	No leakage
9	Maintenance	High	Low

5.6 Principle of Air Conditioning

Air conditioning is a branch of science that deals with study of comfort environment conditions for humans.

For comfort conditions, the following parameters or factors need to be considered.

(a) Temperature: The desired temperature in space where the human being works should be equal to the comfort temperature. This varies from person to person. The comfort temperature for human living is 21 °C ± 3 °C.

(b) Purity of Air: When the oxygen percentage in air is less or if CO_2 is more, then the air is stale. Hence a good quality of air is needed oxygen concentration less than 12% and CO_2 more than 5% are not desirable for human comfort.

Also odour, dust, bacteria and toxic gases are considered for quality of air. Smoke is not preferred when we need purity of air.

Odours from chemical and industrial hazardous by products are not preferred.

(c) Humidity of Air: The humidity control of air involves increasing or decreasing the moisture content of air depending on hot or cold weather.

The comfort level of humidity is 60%. Relative humidity in summer and 40% relative humidity in winter.

5.7 Room Air Conditioners

These are also called as window air conditioners, room air conditioner or split air conditioner as they are used to condition the air in the room.

The basic function of the window AC is to provide comfortable temperature, filtering and circulating the air into the room. It also provides ventilation.

Major components of a window air conditioner are:

(a) Compressor
(b) Evaporator
(c) Condenser fan
(e) Capillary tube
(f) Evaporator fan
(g) Dampers
(h) Control switches
(i) Control switches

5.7.1 Classification of Air Conditioning System

1. According to Application
   (a) Industrial
   (b) Comfort Air Conditioning
2. According to arrangement of Major Components
   (a) Unitary System
   (b) Central Air Conditioning System
3. According to the season of the year
   (a) Winter Air Conditioning
   (b) Summer Air Conditioning
   (c) Monsoon Air Conditioning

The major classification of air conditioning is into comfort air conditioning and industrial air conditioning system.

5.7.2 Comfort Air Conditioning

It provides a suitable temperature for comfort for a human being. It is used for the following purposes

(a) Domestic Applications
(b) Hospitals
(c) Cinema Theatres
(d) Shops
(e) Auditorium
(f) Restaurants etc.,

5.7.3 Industrial Air Conditioning

(a) Laboratories where precision in measurements in required
(b) Operation Theatres
(c) Pharmaceutical industries to reduce bacteria in the air.
(d) Humidity control in Industries
(e) Industrial Applications
(f) Super computers where dust free emissionment is required.

5.8 Working of Window or Split Air Conditioner

An air conditioner continuously draws the air from an indoor space to be cooled and discharges back into the same indoor space that needs to be cooled.

A room air conditioner mainly consists of an evaporator, condenser, compressor, capillary tube, two fans one each for the evaporator (blower) and condenser units. The evaporator fan continuously draws the warm air from the room through the air fitter by passing over the evaporator. The refrigerant inside the evaporator coil gets vaporized by absorbing its latest heat of evaporation from the warm air and hence air gets cooled. The motor runs the evaporator fan to deliver the cooled air into the room. This air mixes with the air present in the room, thereby b ringing down the temperature to comfort conditions.

The refrigerant vapor from evaporator is compressed to high temperature in compressor. The high pressure vapor enters the condenser where it reject it's the latent heat of condensation and gets cooled by the outside atmospheric air circulated by a condenser fan. The high pressure refrigerant is then passed through a capillary where it is reduced to low pressure & low temperature. The low pressure and temperature refrigerant again enters the evaporator where it absorbs the heat from the room and the cycle repeats.

Sl. No.	Refrigeration	Air Conditioning
1	Always cools to lower temperature	Cools in Summer and heats in winter
2	To pressure perishable articles	To provide human comfort
3	Humidity cannot be controlled	Can be controlled

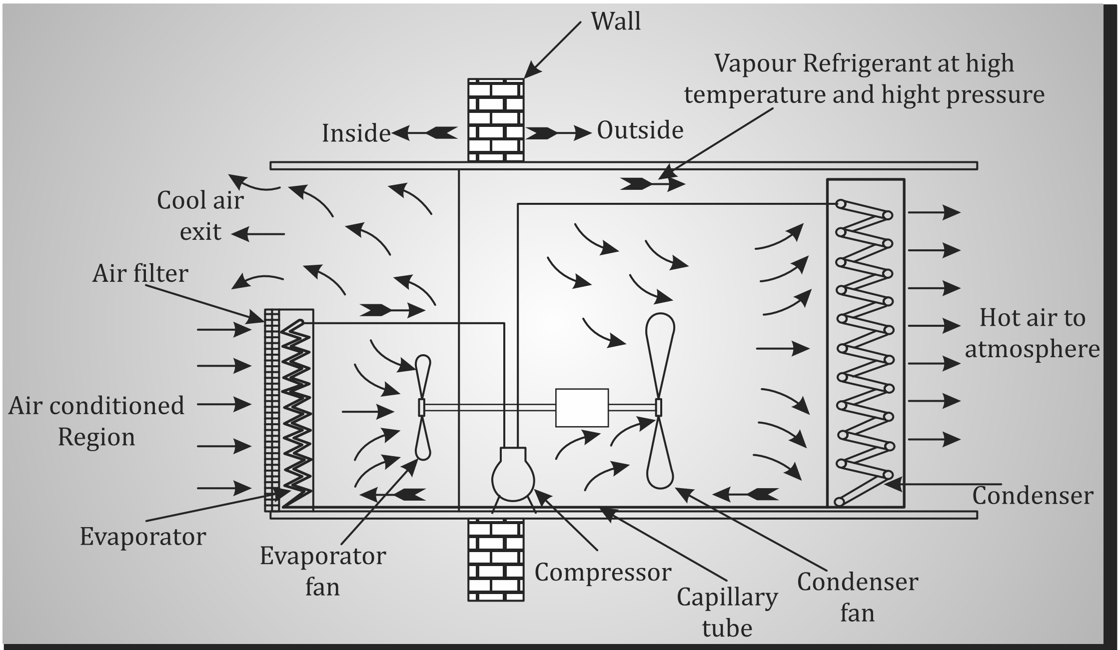


Fig 5.7: Room or Window air Conditioner

Review Questions

1. Explain the principle of refrigeration.
2. What is a ton of refrigeration?
3. What are the different types of refrigeration?
4. Define COP of a refrigerator.
5. What are the properties of a good refrigerant.?
6. Explain Vapour compression refrigeration with sketch.
7. Explain Vapour absorption refrigeration with a diagram.
8. Explain the desirable properties of refrigerants.
9. Describe the properties of Carbon-di-oxide,Ammonia,Sulphur di-oxide, Freon 12 and Freon 22
9. What is air-conditioning? Explain the principle of window Air-conditioner with sketch.
10. Distinguish between refrigeration and air-conditioning.
11. Explain the process of selection of AC for 10 × 10 room.
12. What is De-humidification?
13. What is Psychrometry?
14. Define Dry bulb temperature and Wet bulb temperature
15. What is the use of psychrometric chart.

16. Differentiate between Humidification and De-humidification
17. What is the difference between room air conditioner and window air conditioner?
18. What is split AC?

Multiple Choice Questions

Refrigeration

1. In SI units, one tonne of refrigeration is equivalent to
   (a) 1.5 kw (b) 2.5 kw **(c) 3.5 kw** (4) 4.5 kw
2. COP is always
   (a) Less than unity (b) Greater than unity
   (c) Equal to unity (d) None of these
3. The desirable property of a refrigerant is
   (a) Low boiling point (b) Low freezing point
   (c) High specific heat (d) None of the above
4. Freon 12 consists atoms of
   (a) Carbon, hydrogen & chlorine (b) Carbon, hydrogen & flourine
   (c) Carbon, chlorine, flourine (d) Carbon, oxygen, flourine
5. Air conditioning means
   (a) Cooling and heating (b) De - humidifying
   (c) Removal of impurities (d) All of the above
6. Monochloro difluoro methane is refrigerant called
   (a) Freon (b) NH_3 (c) Water (d) Chlorine
7. Vapour absorption system works in
   (a) Mechanical energy (b) Both mechanical & thermal energy
   (c) Thermal energy (d) None of these
8. The principle of refrigeration is based on
   (a) Law of conservation of energy (b) I law of thermo dynamics
   (c) II law of thermo dynamics (d) None of these
9. In a refrigerator, heat exchange takes place in
   (a) Evaporator (b) Compressor
   (c)Throttle valve **(d) Condensor**
10. One ton of refrigeration is = ______ kw
    (a) 1.5 (b) 2.5 **(c) 3.5** (d) 5.5
11. The boiling point of Ammonia is
    (a) +100°C **(b) –33.3°C** (c) 33.3°C (d) 20°C
12. The unit of refrigeration is
    (a) C.O.P **(b) Ton refrigeration**
    (c) Coulomb (d) None of these

Notes

APPENDIX A

HIGHLIGHTS

- Question Bank
- Model Question Paper - 1
- Model Question Paper - 2
- Examination Question Paper June/July 2015
- Examination Question Paper Dec 2015/Jan 2016
- Examination Question Paper Dec 2016/Jan 2017

QUESTION BANK

MODULE 1 ENERGY RESOURCES

1. What are the various sources of energy? Explain each one briefly

Ans: Refer 1.2

2. Sketch and explain the windmill

Ans: Refer 1.10

3. Briefly explain the hydro-electric power plant.

Ans: Refer 1.5

4. Explain with schematic diagram the working of a nuclear reactor. Mention its disadvantages.

Ans: Refer 1.6

5. Distinguish between renewable and non-renewable sources of energy with examples.

Ans: Refer 1.2

6. Explain the three principal solar energy conversion processes with fig.
   (a) Solar photovoltaic Principle (b) Solar flat plate collector
   (c) Solar pond.

Ans: Refer 1.7, 1.8.1, 1.9

7. Write short notes on bio-fuels.

Ans: Refer 1.11

8. Write short notes on petroleum based solid, liquid and gaseous fuels.

Ans: Refer 1.3

9. Define the following terms:
   (i) Wet steam, (ii) Dry steam
   (iii) super heated steam (iv) Dryness fraction
   (vi) Degree of super heat

Ans: Refer 1.12

10. Explain the phenomenon of formation of steam with Temp and enthalpy diagram.

Ans: Refer 1.12

11. With a sketch, explain the working of a water tube boiler.

Ans: Refer 1.18

12. With a sketch, explain the working of a fire tube boiler.

Ans: Refer 1.17

13. Differentiate between fire tube and water tube boilers.

Ans: Refer 1.16.

14. List the advantages and disadvantages of water tube boilers over fire tube boilers.

Ans: Refer 1.16

15. What are boiler mountings and accessories? Briefly explain any two in each.

Ans: Refer 1.19

Module 2 Turbines and IC Engines

1. **What is a Prime mover?**

Ans: Refer 2.1

Steam Turbines

2. Sketch and explain a simple impulse turbine indicating parts.

Ans: Refer 2.6

3. Describe a simple reaction steam turbine with sketch showing pressure and velocity diagram.

Ans: Refer 2.6.1

4. Differentiate between impulse and reaction turbines.

Ans: Refer 2.6.2

Gas Turbines

5. Mention the advantages of gas turbines over steam turbines.

Ans: Refer 2.7

6. Mention and advantages of gas turbines over Internal combustion engines.

Ans: Refer 2.7

7. Sketch and explain a closed cycle gas turbine.

Ans: Refer 2.7.2

8. Sketch and explain a open cycle gas turbine.

Ans: Refer 2.7.1

Water Turbines

9. Explain the principle of an impulse water turbine. Describe such a type of turbine.

Ans: Refer 2.9

10. Bring out the differences between impulse and reaction hydraulic turbines.

Ans: Refer 2.9

11. Describe a Kaplan turbine.

Ans: Refer 2.11

12. Sketch and explain the working of Francis Turbines.

Ans: Refer 2.10

Internal Combustion Engines

1. How are I.C engines classified?

Ans: Refer 2.12

2. With a sketch, explain the 4-stroke engine.

Ans: Refer 2.12

3. Derive an expression for indicated power of a 4-stroke I.C engine.

Ans: Refer 2.23

4. Describe the operation of a four stroke cycle petrol engine with pressure-volume diagram and necessary sketches.

Ans: Refer 2.12.1

5. Explain the four strokes of a compression ignition engine.

Ans: Refer 2.13

6. What is the difference between Otto cycle and Diesel cycle?

Ans: Refer 2.23

7. Differentiate between spark engine and compression ignition engine.

Ans: Refer 2.14

8. Describe the operation of a two stroke cycle I.C. engine with sketches.

Ans: Refer 2.14

9. What is the difference between two stroke cycle and four stroke cycle I.C. engine.?

Ans: Refer 2.14

10. Define (a) Indicated power (b) brake power
(c) Thermal efficiency (d) mechanical efficiency
(e) SFC

Ans: Refer 2.14

11. A two stroke cycle internal combustion engine has piston diameter of 110 mm and a stroke length of 140 mm. The mep exerted on the head of the piston is 600 kN/m^2. If it runs at speed of 1000 r.pm., find the indicated power developed. (Ans: IP = 13.3 kW)

12. The indicated power of a two cylinder 4-stroke cycle petrol engine is 20 hp when it runs at a speed of 1000.r.pm. If the mep is 6 bar, determine the necessary bore and stroke assuming the stroke is 1.2 times the bore. (Ans: D = 117 mm, L = 140 mm.)

13. The indicated power of a four stroke cycle has engine having a cylinder diameter of 300 mm nd stroke 450 mm is 80 hp at a piston speed of 6 m/s, find the mep and the speed of the crank shaft. (Ans: p = 5.66 bar, N = 400 r.p.m)
14. The Indicated power of a six cylinder 4-stroke I.C. engine is 150 kW at an average piston speed of 320 m/min. The stroke bore ratio is 1.2:1. If the mean effective pressure is 650 kN/m^2, determine the shaft speed. (Ans: N = 698.7 r.p.m)
15. The indicated power of a petrol engine is 450 kW and the engine consumes 118.8 kg of petrol per hour. If the calorific value of petrol is 46060 kJ/kg, find the indicated thermal efficiency. (Ans: η_{ith} = 29.6%)
16. A four cylinder stroke cycle petrol engine has 100 mm bore and 120 mm stroke. It consumes 3.7 kg of fuel per hour having a calorific value of 9800 kcal/kg and its indicated thermal efficiency is 41 per cent. The mep is 7.1 bar. Find the crank shaft speed. (Ans: 790.6r.p.m)
17. A gas engine working on a 4 stroke engine has a cylinder diameter of 0.25 m and length of stroke 0.45 m and running at 180 r.p.m. Its mechanical efficiency is 80% when mean effective pressure is 6 bars. Find the IP, Bp. If the calorific value is 42,000 kJ/kg and brake thermal efficiency is 25%, compute the brake specific fuel consumption.
18. Following observations were recorded during a test on a single cylinder, 4-S oil engine, Bore = 300 mm, Stroke = 450 mm, speed = 300 rpm, Indicated Mean Effective pressure = 6 bar, Net brake load = 1.5 kN, brake drum diameter = 1.8 m, brake rope diameter = 2cm, fuel consumption = 0.0013kg/s, specific gravity of fuel = 0.78, CV of fuel = 439000 kJ/kg, Calculate (a) IP, (b) BP, (c) Frictional power (d) Mechanical efficiency (e) Indicated thermal efficiency and (f) brake thermal efficiency.

Note: Work out similar problems on I.C Engines

Module 3 Machine Tools

Lathe

1. Explain the turning operation of a lathe.

Ans: Refer 3.1

2. Sketch and explain the thread cutting operation that can be performed by a lathe.

Ans: Refer 3.1.6

3. How do you obtain the taper by swivelling the compound rest method in lathe.

Ans: Refer 3.2

Drilling Machine

4. Explain with sketches the various drilling operation that can be performed on drilling machine.

Ans: Refer 3.3

5. Distinguish between: (i) Turning and facing

Ans: Refer 3.1

6. Differentiate between: (a) Drilling and Boring (b) Counter sinking and Counter boring (c) Drilling and reaming (d) Reaming and boring

Ans: Refer 3.3

Milling Machine

7. Sketch and explain plane milling, end milling and slot milling operations done by a milling machines.

Ans: Refer 3.4

Robotics

8. Explain the following Robot configurations (a) cylindrical coordinate (b) Cartesian Coordinate (c) Spherical Coordinate.

Ans: Refer 3.5

9. State the advantages and disadvantages of Robots.

Ans: Refer 3.6

Automation

10. Explain the different types of automation.

Ans: Refer 3.8

11. Write short notes on NC/CNC machines.

Ans: Refer Pg. 3.8

Module 4 Engineering Materials and Joining Processes

Engineering Materials

1. Classify engineering materials. Define each of them with common examples.

Ans: Refer 4.1

2. Explain briefly ferrous metals and its alloys.

Ans: Refer 4.1

3. List the applications of ferrous and non-ferrous metal and their alloys.

Ans: Refer 4.1

4. Write short notes on non-ferrous metals and alloys.

Ans: Refer 4.1

5. What is composite materials?. Give its classification and discuss in brief about various types of composite materials.

Ans: Refer 4.2

6. What are the advantages of composite materials? List their applications.

Ans: Refer 4.2

Welding

7. Differentiate between welding, soldering and brazing

Ans: Refer 4.4

8. Describe the Arc welding.

Ans: Refer 4.5

9. What do you understand by gas welding? Describe in brief the oxy-acetylene welding. How are neutral, oxidizing and reducing flames obtained in a welding torch?

Ans: Refer 4.6

MODULE 5 REFRIGERATION AND AIR-CONDITIONING REFRIGERATION

Refrigeration

1. Define the refrigeration. Describe the vapour compression refrigeration.

Ans: Refer 5.4

2. Sketch and explain the vapour absorption refrigeration.

Ans: Refer 5.7

3. Define the following terms
   (a)Unit of refrigeration (b)Refrigerating effect (c) COP

Ans: Refer Pg. 5.3

4. List the various refrigerants and mention the desirable properties of good refrigerants.

Ans: Refer 5.4

Air-Conditioning

5. Sketch and explain the room air conditioner.

Ans: Refer 5.8

6. Write short notes on applications of air conditioners.

Ans: Refer 5.6, 5.7

Model Question Paper 1

Time: 3 hrs. **Max.Marks: 80**

Module-1

1. a. With a neat sketch briefly explain the Hydro-electrical power plant. **(08 Marks)**

Ans: Refer 1.5

b. Write the difference between Renewable & Non Renewable energy resources. **(08 Marks)**

Ans: Refer 1.2

OR

2. a. Briefly explain the construction & working of Lancashire Boiler with a neat sketch. **(08 Marks)**

Ans: Refer 1.17

b. Define: i) Wet Steam; ii) Enthalpy of wet steam; iii) Dryness fraction **(08 Marks)**

Ans: Refer 1.12

Module-2

3. a. Explain the De Laval's Turbine and Parsons's Turbine with a neat sketch. **(08 Marks)**

Ans: Refer 2.6, 2.6.1

b. With a neat sketch explain the working principle of Pelton wheel turbine. **(08 marks)**

Ans: Refer 2.9

OR

4. a. With a neat sketch briefly explain the 4 stroke Diesel engine. **(08 Marks)**

Ans: Refer 2.13

b. The following observations were obtained during a trial on a 4 stroke diesel engine. Cylinder diameter = 25 cm, stroke of the piston = 40 cm, crankshaft speed = 250 rpm, Brake load = 70 kg, brake drum diameter = 2 m, Mean Effective pressure = 6 bar, Diesel oil consumption = 0.1 m^3/min, Specific gravity of diesel = 0.78, Calorific value of diesel = 43,900 kJ/kg. Find Break Power, Indicated Power Friction power, Mechanical Efficiency, Break Thermal Efficiency, and Indicated Thermal Efficiency. **(08 Marks)**

Ans: Refer 2.14, Problem 9

Module-3

5. a. Explain with neat sketches,

i) Plain milling ii) End milling

iii) Slot milling **(08 Marks)**

Ans: Refer 3.4

b. Explain the following machining operations on lathe machine with suitable sketches:
   i) Turning
   ii) Thread cutting
   iii) Knurling
   iv) Facing **(08 Marks)**

Ans: Refer 3.1

OR

6. a. Write classification of robot configurations and explain Cartesian coordinate with a suitable sketch. **(08 Marks)**

Ans: Refer 3.5

b. Define automation and explain flexible and fixed automation. **(08 Marks)**

Ans: Refer 3.7

Module-4

7. a. Write classification of ferrous and non-ferrous metals and explain briefly. **(08 Marks)**

Ans: Refer 4.1

b. Write a short note on composites. **(08 Marks)**

Ans: Refer 4.2

OR

8. a. Define soldering and explain electric are welding with a suitable sketch. **(08 Marks)**

Ans: Refer 4.5

b. Explain Oxy-0acetylene welding process with a sketch. **(08 Marks)**

Ans: Refer 4.6

Module-5

9. a. Define the following:
   i) Ton of refrigeration
   ii) Refrigerating effect
   iii) Ice making capacity
   iv) COP **(08 Marks)**

Ans: Refer 5.3

b. Explain principle and working of vapour compression refrigeration with sketch. **(08 Marks)**

Ans: Refer 5.4

10. a. Explain with a sketch working of room air conditioner **(08 Marks)**

Ans: Refer 5.8

b. List out properties of a good refrigerant and explain any two **(08 Marks)**

Ans: Refer 5.2

Model Question Paper 2

Time: 3 hrs. **Max. Marks: 80**

Module-1

1 a. Explain the working of a hydroelectric power plant with a neat sketch. **(10 Marks)**

Ans: Refer 1.5

b. Distinguish between renewable and non-renewable sources of energy with suitable examples. **(06 Marks)**

Ans: Refer 1.2

OR

2 a. With a neat sketch, explain the working of a water tube boiler. Show the path of flue gases. **(10 Marks)**

Ans: Refer 1.18

b. Draw a neat sketch of temperature-enthalpy diagram and indicate the following on it; Latent heat of evaporation, Amount of super heat, Sensible heat, Degree of superheat, Saturation temperature. **(06 Marks)**

Ans: Refer 1.12

Module-2

3 a. Discuss the advantages of steam turbines over other prime movers. **(10 Marks)**

Ans: Refer 2.7

b. Draw a neat sketch of a simple impulse water turbine indicating the parts. Explain its working. **(06 Marks)**

Ans: Refer 2.9

OR

4 a. Explain the working of a four stroke petrol engine with neat sketches. **(10 Marks)**

Ans: Refer 2.12.1

b. A 4 - cylinder two stroke engine develops 30 kW at 2500 rpm. Calculate the diameter and stroke of each cylinder if the stroke to bore ratio is 1.5. The mean effective pressure on each piston is 6 bar and its mechanical efficiency is 80% **(06 Marks)**

Module-3

5 a. Explain the process of taper turning by swiveling of the compound rest with a neat sketch. **(10 Marks)**

Ans: Refer 3.2

b. Differentiate between:

(i) Drilling and reaming (ii) Boring and counter boring **(06 Marks)**

Ans: Refer 3.3

6 a. Briefly Explain the following machining processes on a lathe with the help of neat sketches:

(i) Knurling (ii) Facing (iii) Drilling. **(08 Marks)**

Ans: Refer 3.1

b. Explain with a neat sketch the taper turning by swiveling compound rest method and also the countersinking process in a lathe. **(08 Marks)**

Ans: Refer 3.3

7 a. Briefly explain the different types of Automation. **(08 Marks)**

Ans: Refer 3.8

b. Sketch the polar and Cartesian coordination of Robotic Configuration. **(08 Marks)**

Ans: Refer 3.5

Module-4

8 a. Write a note on Ferrous Alloys. (Any two) **(08 Marks)**

Ans: Refer 4.1

b. Briefly explain the types and applications of Non-ferrous alloys (Any three) **(08 Marks)**

Ans: Refer 4.1

OR

9 a. With a neat sketch briefly explain Oxy-acetylene Welding method. **(08 Marks)**

Ans: Refer 4.6

b. With a neat sketch briefly explain the Soldering Method. **(08 Marks)**

Ans: Refer 4.7

Module-5

10 a. Briefly explain the construction & working of Vapor compression Refrigeration. **(08 Marks)**

Ans: Refer 5.4

b. Differenitate between Vapour Absorption and Vapour Compression Refrigeration. **(08 Marks)**

Ans: Refer 5.4

OR

11 a. What is air-conditioning? How is it achieved in a domestic air conditionerr? **(08 Marks)**

Ans: Refer 5.8

b. Explain the properties of a good refrigerant. **(08 Marks)**

Ans: Refer 5.2

First/Second semester B.E. Degree examination, June/July 2015

Module-1

1 a. What are the advantages and disadvantages of renewable and non renewable energy sources? **(05 Marks)**

Ans: Refer 1.2

b. What is calorific value? Compare biofuels with petroleum fuels in terms of calorific value. **(05 Marks)**

Ans: Refer 1.3

c. Explain with neat sketch, working of Babcock and Wilcox boiler. **(10 Marks)**

Ans: Refer 1.8

2 a. Explain briefly the principle of conversion of solar energy directly in to electrical energy in a solar cell. **(10 Marks)**

Ans: Refer 1.8.2

b. Write a short note on wind energy and its conversion. **(10 Marks)**

Ans: Refer 1.10

Module-2

3 a. Differentiate between reaction and impulse turbines. **(05 Marks)**

Ans: Refer 2.6.2

b. With neat sketch explain the working of pelton wheel. **(10 Marks)**

Ans: Refer 2.9

c. Differentiate between petrol engine and diesel engine **(05 Marks)**

Ans: Refer Pg. 2.22

4 a. With neat sketch explain working of 4 stroke diesel engine. **(10 Marks)**

Ans: Refer 2.13

b. With neat sketch explain the working of closed cycle gas turbine. **(06 Marks)**

Ans: Refer 2.7.2

c. Define: Thermal efficiency and mechanical efficiency of IC engine. **(04 Marks)**

Ans: Refer 2.23

Module-3

5 a. Name the various operations carried but on lathe. Explain taper turning by swivelling compound rest. **(08 Marks)**

Ans: Refer 3.2

b. What is milling? With neat sketch explain end milling and plane milling operations. **(06 Marks)**

Ans: Refer 3.4

c. Differentiate between: (i) Counter sinking and counter boring, (ii) Reaming and Boring. **(06 Marks)**

Ans: Refer 3.3

6 a. Define Robot. Write the classification based on robot physical configuration. Write down the applications of industrial robot. **(08 Marks)**

Ans: Refer 3.6

b. What is automation? Explain the types of automation with examples. **(07 Marks)**

Ans: Refer 3.7

c. With block diagram explain basic components of NC system. **(05 Marks)**

Ans: Refer 3.8

Module-4

7 a. What are ferrous metal? Write a note on stainless steel. Write down its applications. **(08 Marks)**

Ans: Refer 4.1

b. Differentiate between ferrous and non ferrous materials. **(06 Marks)**

Ans: Refer 4.1

c. What is soldering? Classify soldering process. **(06 Marks)**

Ans: Refer 4.7

8 a. Define welding, Explain electric arc welding process. Write down its demeritrs. **(08 Marks)**

Ans: Refer 4.5

b. Differentiate between welding, Brazing and soldering. **(06 Marks)**

Ans: Refer 4.7

c. Define composite materials. Write down its practical applications. **(06 Marks)**

Ans: Refer 4.2, 4.3

Module-5

9 a. what are the required properties of a good refrigerant? **(06 Marks)**

Ans: Refer 5.2

b. With neat sketch explain the working of vapour compression refrigeration system. **(10 Marks)**

Ans: Refer 5.4

c. What is a air conditioning? Why it is necessary? **(04 Marks)**

Ans: Refer 5.5

10 a. Define: (i) Refrigeration effect (ii) Unit of Refrigeration (iii) COP of Refrigeration. **(06 Marks)**

Ans: Refer 5.3

b. List the commonly used refrigerants. **(04 Marks)**

Ans: Refer 5.3

c. Explain with neat sketch the principle of room air-conditioner. **(10 Marks)**

Ans: Refer 5.8

First Semester B.E. Degree Examination, Dec.2015/Jan.2016
CBCS Scheme

Time: 3 hrs. **Max.Marks: 80**

Module-1

1 a. Define solar constant and explain liquid flat plate collector with a neat sketch. **(08 Marks)**

Ans: Refer 1.8.1

b. Explain principle of nuclear power plant with a neat sketch. **(08 Marks)**

Ans: Refer 1.6

OR

2 a. Define enthalpy and explain formation of steam with a T-S diagram. **(08 Marks)**

Ans: Refer 1.12

b. Explain Babcock and Wilcox boiler with a neat sketch. **(08 Marks)**

Ans: Refer 1.18

Module-2

3 a. Define Turbine & explain De Laval turbines with a neat sketch and P-V Diagram. **(08 Marks)**

Ans: Refer 2.6.2

b. Explain closed cycle gas turbine with a neat sketch. **(08 Marks)**

Ans: Refer 2.7.2

OR

4 a. Explain 4-stroke SI engine with a neat sketch and PV diagram. **(08 Marks)**

Ans: Refer 2.12

b. Define indicated power and brake power. A four stroke IC engine running at 450 rpm has a bore diameter of 100 mm and stroke length 120 mm. The indicator diagram details are : Area of the diagram 4 cm^2, length of the indicator diagram 6.5 cm and the spring value of the spring used is 10 bar/cm. Calculate indicated power of the engine. **(08 Marks)**

Module-3

5 a. Explain with neat sketches,

i) Plain milling ii) End milling

iIi) Slot milling **(08 Marks)**

Ans: Refer 3.4

b. Explain the following machining operations on lathe machine with suitable sketches:

i) Turning ii) Thread cutting

iii) Knurling iv) Facing **(08 Marks)**

Ans: Refer 3.1, 3.2

OR

6 a. Write classification of robot configurations and explain Cartesian coordinate with a suitable sketch. **(08 Marks)**

Ans: Refer 3.6

b. Define automation and explain flexible and fixed automation. **(08 Marks)**

Ans: Refer 3.7

Module-4

7 a. Write classification of ferrous and non-ferrous metals and explain briefly. **(08 Marks)**

Ans: Refer 4.1

b. Write a short note on composites. **(08 Marks)**

Ans: Refer 4.2, 4.3

OR

8 a. Define soldering and explain electric arc welding with a suitable sketch. **(08 Marks)**

Ans: Refer 4.5, 4.7

b. Explain oxy-acetylene welding process with a sketch. **(08 Marks)**

Ans: Refer 4.6

Module-5

9 a. Define the following:

i) Ton of refrigeration. ii) Refrigerating effect.

iii) Ice making capacity iv) COP **(08 Marks)**

Ans: Refer 5.3

b. Explain Principle and working of vapour compression refrigeration with a sketch. **(08 Marks)**

Ans: Refer 5.4

OR

10 a. Explain with a sketch working of room air conditioner. **(08 Marks)**

Ans: Refer 5.8

b. List out properties of a good refrigerant and explain any two. **(08 Marks)**

Ans: Refer 5.2

First/Second Semester B.E. Degree Examination, Dec. 2016/Jan. 2017
CBCS Scheme

Time: 3 hrs. **Max. Marks: 80**

Module-1

1 a. Define renewable and non-renewable energy resources and differentiate them. **(06 Marks)**

Ans: Refer 1.2

b. With the help of T-H diagram, explain the generation of steam at constant pressure. **(10 Marks)**

Ans: Refer 1.12

2 a. Define: i) Dryness fraction ii) Sensible heat
iii) Latent heat iv) Enthalpy of stem. **(04 Marks)**

Ans: Refer 1.12

b. Draw a neat diagram and explain the construction and working of "Liquid flat plate collector" used for water heating applications **(12 Marks)**

Ans: Refer 1.8.1

Module-2

3 a. What is steam turbine? Show the classifications of steam turbine. **(06 Marks)**

Ans: Refer 2.3

b. With a neat sketch, explain the working of Franci's turbine. **(10 Marks)**

Ans: Refer 2.10

4 a. With the help of `P-V' diagram, explain the operation of 4-S petrol engine. **(08 Marks)**

Ans: Refer 2.12.1

b. Following data are collected from a 4-S single cylinder engine at full load. Bore = 200mm ; Stroke = 280mm ; Speed = 300rpm. Indicated mean effective pressure = 5.6 bar, Torque on the brake drum = 250N-m, fuel consumed = 4.2kg/hour, and calorific value of fuel = 41,000kJ/kg.

Determine :

i) Mechanical efficiency ii) Indicated thermal efficiency, and
iii) Brake thermal efficiency. **(08 Marks)**

Module-3

5 a. With simple sketches, explain the following lathe operations :

i) Facing ii) Cylindrical turning. **(06 Marks)**

Ans: Refer 3.1, 3.2

b. Define automation. Discuss the types of automation along with their merits and demerits. **(10 Marks)**

Ans: Refer 3.7

OR

6 a. Show the differences between drilling and boring. **(04 Marks)**

Ans: Refer 3.3

b. Define robot. State the different types of robot configurations. **(04 Marks)**

Ans: Refer 3.6

c. Draw a neat diagram to show the robot arm movement in Cartesian configuration and explain. **(08 Marks)**

Ans: Refer 3.6

Module-4

7 a. State the characteristics and applications of: 1) Aluminum and its alloys ii) Copper and its alloys. **(08 Marks)**

Ans: Refer 4.1

b. Differentiate between soldering and brazing. **(04 Marks)**

Ans: Refer Pg. 4.7

c. State the advantages and disadvantages of welding over other types of joining processes. **(04 Marks)**

Ans: Refer 4.7

OR

8 a. List the advantages and limitations of composites. **(08 Marks)**

Ans: Refer 4.2

b. With a neat diagram, explain the Oxy-acetylene welding process. **(08 Marks)**

Ans: Refer 4.6

Module-5

9 a. Define refrigeration. State the applications of refrigeration. **(04 Marks)**

Ans: Refer 5.1

b. Define the following refrigeration terms:

i) Refrigerant ii) ton a of refrigeration

iii) Cop iv) relative COP **(04 Marks)**

Ans: Refer 5.3

c. With the help of a flow diagram, explain the function of "Vapour compression refrigeration cycle:. **(08 Marks)**

Ans: Refer 5.4

OR

10 a. What is refrigerant? State the desired properties of refrigerant. **(06 Marks)**

Ans: Refer 5.0

b. Draw a neat diagram of a room air conditioner and explain. **(10 Marks)**

Ans: Refer 5.8

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GLOSSARY

APPENDIX **B**

Module 1

1. Solar Constant
2. Solar Thermal Harvesting
3. Windmill
4. Solar pond
5. Solar PV
6. Hydro Power
7. Nuclear Power
8. Flat Plate Collector
9. Superheated steam
10. Fire tube boiler
11. Wate tube boiler

Module 2

12. Prime mover
13. Impulse turbine
14. Reaction turbine
15. Combustion
16. Draft tube
17. Penstock
18. Head
19. Indicated power
20. Brake Power
21. Friction Power
22. Crankshaft
23. Mean velocity
24. Carbinettor

Module 3

25. Lathe
26. Machine Tool
27. Milling Cutter
28. Tailstock
29. Heads lock
30. Reaming
31. Boring
32. Robot
33. Numerical control
34. Computerised numerical control
35. RAM
36. ROM

Module 4

37. Alloy
38. Hardness
39. Strength
40. Composites
41. Reinforcement

42. Fibre
43. Matrix

Module 5

44. Humidity
45. Psychrometry
46. Refrigerant
47. Freon
48. Evaporator
49. Condensor
50. Airconditionar