ANNAMACHARYA
INSTITUTE OF TECHNOLOGY AND SCIENCES
(AUTONOMOUS)

Kadapa, Y S R Dist. - 516003 (A.P)
India

Course Structure & Syllabi (R23)
for
B. Tech (Regular-Full time)

(Effective for the students admitted into I year from the Academic Year **2023-2024** onwards)

and

Course Structure & Syllabi (R23)
for B.Tech (Lateral Entry Scheme)

(Effective for the students getting admitted into II year through Lateral Entry Scheme from the Academic Year **2024-2025** onwards)

BASIC CIVIL AND MECHANICAL ENGINEERING

(Common to All branches of Engineering)

(23HES0101)

Course Objectives:

• Get familiarized with the scope and importance of Civil Engineering sub-divisions.

• Introduce the preliminary concepts of surveying.

• Acquire preliminary knowledge on Transportation and its importance in nation's economy.

• Get familiarized with the importance of quality, conveyance and storage of water.

• Introduction to basic civil engineering materials and construction techniques.

Course Outcomes: On completion of the course, the student should be able to:

CO1: Understand various sub-divisions of Civil Engineering and to appreciate their role in ensuring better society.

CO2: Know the concepts of surveying and to understand the measurement of distances, angles and levels through surveying.

CO3: Realize the importance of Transportation in nation's economy and the engineering measures related to Transportation.

CO4: Understand the importance of Water Storage and Conveyance Structures so that the social responsibilities of water conservation will be appreciated.

CO5: Understand the basic characteristics of Civil Engineering Materials and attain knowledge on prefabricated technology.

UNIT I

Basics of Civil Engineering: Role of Civil Engineers in Society- Various Disciplines of Civil Engineering- Structural Engineering- Geo-technical Engineering- Transportation Engineering

- Hydraulics and Water Resources Engineering - Environmental Engineering-Scope of each discipline - Building Construction and Planning- Construction Materials-Cement - Aggregate - Bricks- Cement concrete- Steel. Introduction to Prefabricated construction Techniques.

UNIT II

Surveying: Objectives of Surveying- Horizontal Measurements- Angular Measurements- Introduction to Bearings Levelling instruments used for levelling -Simple problems on levelling and bearings-Contour mapping.

UNIT III

Transportation Engineering Importance of Transportation in Nation's economic development- Types of Highway Pavements- Flexible Pavements and Rigid Pavements - Simple Differences. Basics of Harbour, Tunnel, Airport, and Railway Engineering.

Water Resources and Environmental Engineering: Introduction, Sources of water- Quality of water- Specifications- Introduction to Hydrology–Rainwater Harvesting-Water Storage and Conveyance Structures (Simple introduction to Dams and Reservoirs).

Textbooks:

1. Basic Civil Engineering, M.S.Palanisamy, , Tata Mcgraw Hill publications (India) Pvt. Ltd. Fourth Edition.

2. Introduction to Civil Engineering, S.S. Bhavikatti, New Age International Publishers. 2022. First Edition.

3. Basic Civil Engineering, Satheesh Gopi, Pearson Publications, 2009, First Edition.

Reference Books:

1. Surveying, Vol- I and Vol-II, S.K. Duggal, Tata McGraw Hill Publishers 2019.

Fifth Edition.
2. Hydrology and Water Resources Engineering, Santosh Kumar Garg, Khanna Publishers, Delhi. 2016
3. Irrigation Engineering and Hydraulic Structures - Santosh Kumar Garg, Khanna Publishers, Delhi 2023. 38^{th} Edition.
4. Highway Engineering, S.K.Khanna, C.E.G. Justo and Veeraraghavan, Nemchand and Brothers Publications 2019. 10^{th} Edition.
5. Indian Standard DRINKING WATER — SPECIFICATION IS 10500-2012.

PART B: BASIC MECHANICAL ENGINEERING

Course Objectives: The students after completing the course are expected to

- Get familiarized with the scope and importance of Mechanical Engineering in different sectors and industries.
- Explain different engineering materials and different manufacturing processes.
- Provide an overview of different thermal and mechanical transmission systems and introduce basics of robotics and its applications.

Course Outcomes: On completion of the course, the student should be able to

CO1: Understand the different manufacturing processes.

CO2: Explain the basics of thermal engineering and its applications.

CO3: Describe the working of different mechanical power transmission systems and power plants.

CO4: Describe the basics of robotics and its applications.

UNIT I

Introduction to Mechanical Engineering: Role of Mechanical Engineering in Industries and Society- Technologies in different sectors such as Energy, Manufacturing, Automotive, Aerospace, and Marine sectors.

Engineering Materials - Metals-Ferrous and Non-ferrous, Ceramics, Composites, Smart materials.

UNIT II

Manufacturing Processes: Principles of Casting, Forming, joining processes, Machining, Introduction to CNC machines, 3D printing.

Thermal Engineering – working principle of Boilers, Otto cycle, Diesel cycle, Refrigeration and air-conditioning cycles, IC engines, 2-Stroke and 4-Stroke engines, SI/CI Engines, Components of Electric and Hybrid Vehicles.

UNIT III

Power plants – working principle of Steam, Diesel, Hydro, Nuclear power plants.

Mechanical Power Transmission - Belt Drives, Chain, Rope drives, Gear Drives and their applications.

Introduction to Robotics - Joints & links, configurations, and applications of robotics. (Note: The subject covers only the basic principles of Civil and Mechanical Engineering systems. The evaluation shall be intended to test only the fundamentals of the subject)

Textbooks:

1. InternalCombustion Engines by V.Ganesan, By Tata McGraw Hill publications (India)Pvt.Ltd.

2. A Tear book of Theory of Machines by S.S. Rattan, Tata McGraw Hill Publications,(India) Pvt. Ltd.
3. An introduction to Mechanical Engg by Jonathan Wicker and Kemper Lewis, Cengagelearning India Pvt. Ltd.

Reference Books:

1. Appuu Kuttan KK, Robotics, I.K. International Publishing House Pvt. Ltd. Volume-I
2. 3D printing & Additive Manufacturing Technology- L. Jyothish Kumar, Pulak M Pandey, Springer publications
3. Thermal Engineering by Mahesh M Rathore Tata McGraw Hill publications (India) Pvt.Ltd.
4. G. Shanmugam and M.S. Palanisamy, Basic Civil and the Mechanical Engineering, Tata McGraw Hill publications (India) Pvt. Ltd

BASIC CIVIL AND MECHANICAL ENGINEERING

PART A: BASIC CIVIL ENGINEERING

UNIT I:

Engineering is a profession that puts scientific knowledge to practical use. i.e., Engineering is an applied science. Engineers look for better and optimized ways to use existing resources and often develop new resources & new materials.

Basic Necessities of life:

Basics of Civil Engineering:

CIVIL ENGINEERING is one of the oldest professional engineering disciplines that deals with designing, constructing, and maintaining the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings.

Role of Civil Engineers in Society:

- The main role of civil engineers is in surveying, planning, designing, estimating, and executing structures.
- To solve different engineering problems with the help of field experience, laboratory techniques, numerical methods, and mathematical models, using computer and information technology.
- To implement management techniques for better materials, machinery, and money management.
- To carry out soil investigation for the design of foundations of structures.
- To invite tenders and to select contractors for the work.
- To survey, level, and fix the alignments (center-line) of roads, railways, canals, tunnels, pipes, etc.

- To carry out planning of buildings as per their functional needs and also has a role in town and regional planning.
- To carry out the design of structures as per the principles of structural analysis and design. Civil engineers should ensure that the design is safe, durable, and economical.
- To supervise the work during execution and to ensure the progress of work.
- To conduct a valuation of land or building to find its sale, purchase price, or taxation.
- Civil engineers have to maintain public health by providing pure water for drinking, treating wastewater before disposing into a water course, and collecting the solid waste of town and disposing of it.
- Improved economic power of the country brings a respectable status in the world. The world has realized that a government should not involve itself in production and distribution but should develop infrastructure to create an atmosphere for economic development. Hence civil engineering has a very important role in the development of the infrastructures.

Role of Civil Engineers in Infrastructure Development:

- Measure and map the earth's surface.
- Plan new townships and extension of existing towns.
- Build suitable structures for the rural and urban areas for various utilities.
- Build tanks and dams to exploit water resources.
- Assured water supply.
- A good drainage system.
- Pollution-free environmental conditions.
- A well-planned and built network of roads and road crossings.
- Railways connections to all important cities and towns.
- Airports and harbors of national and international standards.

Disciplines of Civil Engineering:

Civil Engineering is a wide field that includes many types of structures such as residential buildings, public buildings, industrial buildings, roads, bridges, tunnels, railways, dams, canals, canal structures, etc. The following are the various disciplines of civil engineering.

- Architecture and Town Planning
- Surveying and Levelling
- Building Materials
- Construction Technology
- Structural Engineering
- Transportation Engineering
- Geotechnical Engineering
- Environmental Engineering

- Hydraulics, Water Resources and Irrigation Engineering
- Remote Sensing and GIS

Scope of Civil Engineering:

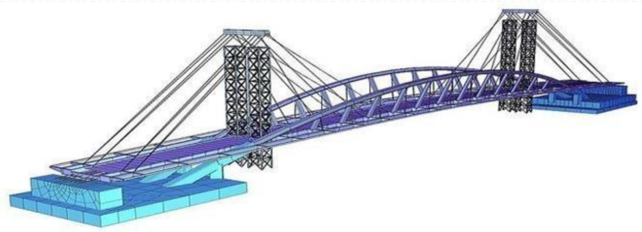
The main scope of Civil engineering or the task of Civil engineering is planning, designing, estimating, supervising construction, managing construction, execution, and maintenance of structures. The scope of Civil engineering is twofold:

- According to the field of work, area of services, and type of structures
- Functions of civil engineering

Structural Engineering:

The structure is the assembling of two or more basic elements such as a beam, slab, column, truss, frame, shells, etc. Structural engineering is concerned with the structural design and structural analysis of buildings, bridges, towers, flyovers (overpasses), tunnels, offshore structures like oil and gas fields in the sea, aerostructure, and other structures. This involves identifying the loads that act upon a structure and the forces and stresses that arise within that structure due to those loads and then designing the structure to successfully support and resist those loads. The loads can be the self-weight of the structures, other dead load, live loads, moving (wheel) load, wind load, earthquake load, load from temperature change, etc. The structural engineer must design structures to be safe for their users and to successfully fulfill the function they are designed for (to be serviceable). Due to the nature of some loading conditions, sub-disciplines within structural engineering have emerged, including wind engineering and earthquake engineering.

Design considerations will include strength, stiffness, and stability of the structure when subjected to loads that may be static, such as furniture or self-weight, or dynamic, such as wind, seismic, crowd, or vehicle loads, or transitory, such as temporary construction loads or impact. It also requires the knowledge of different tools to carry out the analysis and design of structural components such as the matrix method of analysis, finite element method, etc. Other considerations include cost, constructability, safety, aesthetics, and sustainability.



STRUCTURAL ENGINEERING

Geotechnical Engineering:

Geotechnical engineering studies rock and soil-supporting civil engineering systems. It's majorly divided into two branches.

- Soil Mechanics
- Foundation Engineering

Soil Mechanics branch of science concerned with the properties and behaviour of soil and its application as an engineering material in construction. Whereas the Foundation Engineering branch of science is concerned with the application of soil mechanics and rock mechanics in the design of foundation elements of structures.

All structures built on earth transfer the superimposed loads to the ground (soil/rock) underneath, through the appropriate foundation. Soils are complex geological materials that are expected to receive the loads transferred to them safely without causing damage to the structure. The soils are physico-chemically active materials, and their engineering behaviour depends upon their water content. This subject encompasses

- A detailed study of soils – formation, composition, properties, and their determination.
- A detailed study of rocks – types, properties, strength, and deformation characteristics and their determination.
- Different types of foundations, their relative merits and limitations, suitability, and design aspects.
- Design and analysis of various earth structures such as embankments, dams, retaining walls, etc.
- Site investigation, sub-soil exploration, and field tests.
- Ground improvement techniques.

Geotechnical earthquake engineering is a specialized field of geotechnical engineering, which deals with earthquakes, their effects on foundation soil, different types of seismic hazards, the study of dynamic soil properties, seismic design of earth structures, soil improvement to withstand/minimize seismic hazards, etc.

Transportation Engineering:

The social and economic development of any country is a function of transportation facilities available in that country. Transportation engineering is concerned with moving people and goods efficiently, and safely through roadways, railways, airways, and waterways. This involves specifying, designing, constructing, and maintaining transportation infrastructure which includes streets, canals, highways, rail systems, airports, ports, and mass transit. It includes areas such as transportation design, transportation planning, traffic engineering, some aspects of urban engineering, queueing theory, pavement engineering, Intelligent Transportation Systems (ITS), and infrastructure management.

Hydraulics and Water Resource Engineering:

Hydraulics engineering is the application of the principles of fluid mechanics to problems dealing with the collection, storage, control, transport, regulation, measurement, and use of water. Water is integral to human life and almost all construction activities. This subject deals with:

- Basic properties of water
- Study of water at rest as well as in motion
- Flow through pipes
- Open channel flows
- Flow measurements
- Different analytical, computational, and experimental approaches to analyse the flow problems.

Water resources engineering is concerned with the collection and management of water (as a natural resource). As a discipline, it therefore combines hydrology, environmental science, meteorology, geology, conservation, and resource management. This area of civil engineering relates to the prediction and management of both the quality and the quantity of water in both underground (aquifers) and above-ground (lakes, rivers, and streams) resources. Water resource engineers analyse and model very small to very large areas of the earth to predict the amount and content of water as it flows into, though, or out of a facility. Although the actual design of the facility may be left to other engineers.

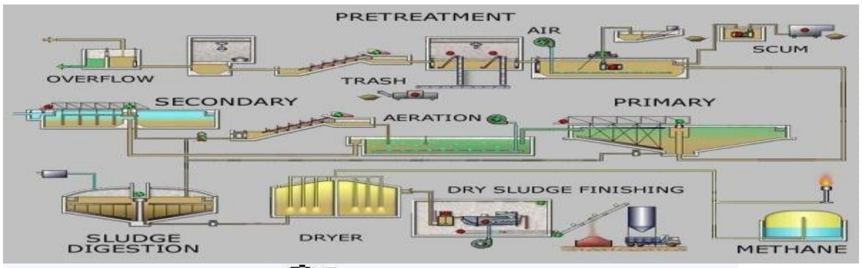
Environmental Engineering:

Environmental engineering is the contemporary term for sanitary engineering, though sanitary engineering traditionally had not included much of the hazardous waste management and environmental remediation work covered by environmental engineering. Public health engineering and environmental health engineering are other terms being used.

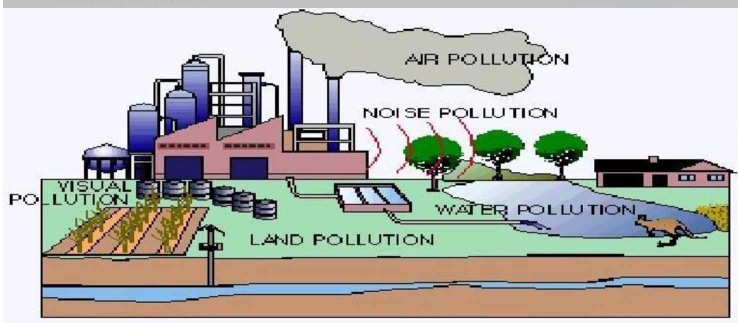
Environmental engineering deals with the treatment of chemical, biological, or thermal wastes, purification of water and air, and remediation of contaminated sites after waste disposal or accidental contamination. In detail, this subject deals with the following:

- Study of available water quality and checking against the standards.
- Water collection and water purification through various treatment processes.
- Supply and distribution of quality for urban and rural areas, for domestic and industrial usage.
- Study of domestic water supply system and sanitary system.
- Wastewater collection, treatment, and safe disposal.
- Study of waste and waste management.
- Study of different kinds of pollution and pollution control measures.
- Study of environmental safety.

Among the topics covered by environmental engineering are pollutant transport, water purification, wastewater treatment, air pollution, solid waste treatment, and hazardous waste management. Environmental engineers administer pollution reduction, green engineering, and industrial ecology. Environmental engineers also compile information on the environmental consequences of proposed actions.



EN VIRONME NT ENGINEERING



Building Construction and Planning:

Building construction and planning are essential components of the construction industry. Building construction involves the physical construction of a building while building planning involves the process of designing and coordinating the construction of a building.

Building construction typically involves the following steps:

1. Site preparation: This includes clearing the land, removing any debris, and preparing the site for construction.
2. Foundation: The foundation is the base of the building, and it is typically made of concrete or masonry. The foundation must be strong enough to support the weight of the building.
3. Framing: The framing stage involves constructing the basic structure of the building, including the walls, floors, and roof.
4. Exterior finishing: This includes installing siding, windows, and doors.
5. Interior finishing: This includes installing drywall, flooring, and fixtures such as lighting and plumbing.
6. Electrical and mechanical systems: This includes installing electrical wiring, plumbing, and HVAC (Heating, Ventilation, and Air conditioning) systems.
7. Final inspections and occupancy: Before the building is occupied, it must pass a series of inspections to ensure that it meets building codes and safety standards.

Building planning involves the following steps:

1. Project initiation: This includes identifying the need for a new building and defining the project's goals and objectives.
2. Feasibility study: This includes assessing the practicality of the project, including the availability of resources and the potential impact on the community.
3. Concept design: This includes developing initial designs for the building, including the layout, exterior, and interior design.
4. Graphic design or Plan: This includes creating detailed designs for the building, including the electrical, mechanical, and plumbing systems.
5. Construction documents: This includes creating detailed construction documents, including plans, specifications, and drawings.
6. Bidding and contract administration: This includes soliciting bids from contractors and administering the contract between the owner and the contractor.
7. Project management: This includes overseeing the construction process, including managing the budget, schedule, and quality of the work.

Overall, building construction and planning are critical components of the construction industry, and they require careful planning, coordination, and execution to ensure that the building is safe, functional, and meets the needs of its occupants.

Construction Materials:

Shelter is the basic need of civilized society. Construction materials are the materials used in the construction of buildings, structures, and other physical infrastructure. Stones, bricks, timber, and lime concrete are the traditional materials used for the construction of houses and other buildings. Improved versions of many building materials keep on appearing in the market regularly. These materials can include:

1. Concrete: a composite material made from cement, water, and aggregate (such as gravel or crushed stone).
2. Steel: a metal alloy used for structural elements such as beams, columns, and framing.
3. Wood: a natural material used for framing, decking, and other structural elements.
4. Brick: a type of building material made from clay and shale, often used for exterior walls and facades.
5. Glass: a non-metallic, non-porous material used for windows and other transparent elements.
6. Plastic: a synthetic material used for a variety of applications, including piping, roofing, and siding.
7. Roofing materials: such as asphalt shingles, metal roofing, and clay or concrete tiles.
8. Insulation materials: such as fiberglass, cellulose, and foam board, are used to reduce heat transfer and energy consumption.
9. Drywall: a type of wallboard used for interior walls and ceilings.
10. Paint: a material used to protect and decorate surfaces.
11. Flooring materials: such as hardwood, carpet, tile, and laminate.
12. Cabinets and countertops: made from materials such as wood, laminate, and quartz.
13. Doors and windows: made from materials such as wood, metal, and vinyl.
14. Plumbing materials: such as pipes, fittings, and fixtures.
15. Electrical materials: such as wiring, switches, and outlets.

These are just a few examples of the many different types of construction materials that can be used in building design and construction. The specific materials used will depend on the project's requirements, budget, and local building codes.

Cement:

Cement is a commonly used binding material in construction. The cement is obtained by burning a mixture of calcareous (calcium) and argillaceous (clay) material at a very high temperature and then grinding the clinker so produced to a fine powder. It was first produced by a mason Joseph Aspdin in England in 1924. He patented it as portland cement.

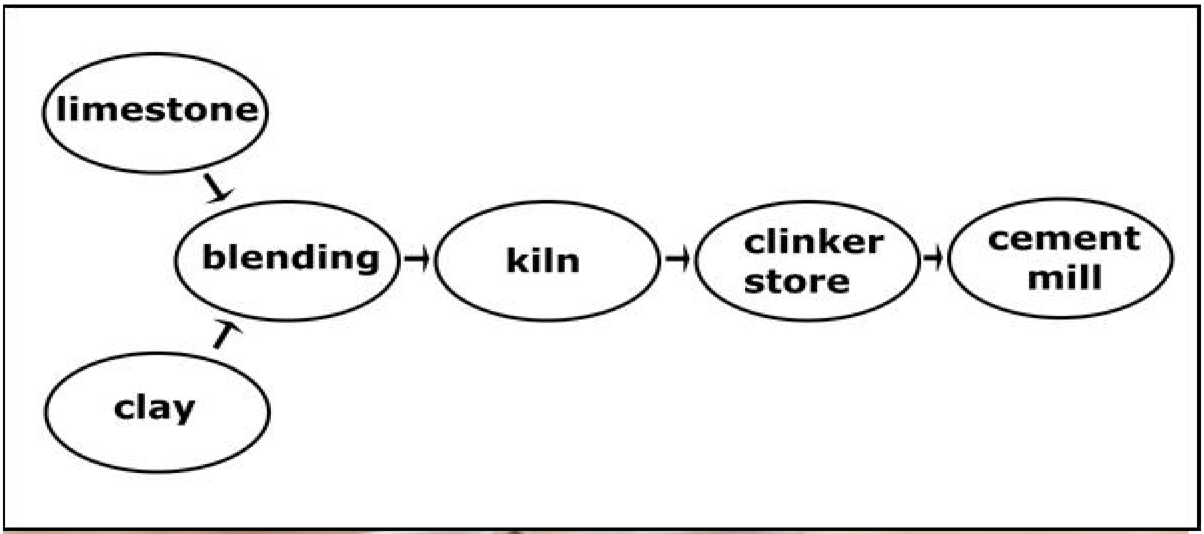
The cement experiences exothermic chemical reactions when comes in contact with water. The cement is assumed to have a specific gravity of 3.15 with a density of 1440 kg/m^3. Cement can be manufactured either from natural cement stones or artificially by using calcareous and argillaceous materials.

Argillaceous	Calcareous
▪ Shale and Caly ▪ Blast furnace slag ▪ Slate	▪ Cement rock ▪ Limestone ▪ Chalk ▪ Marine shells ▪ Marl

Manufacturing of Cement:

- The first-time manufacturing of cement is named ordinary Portland cement (OPC) because when the cement comes in contact with water it becomes a hard mass after a certain period and this hard mass resembles the stone found in the Portland area of England.
- India is 2nd largest manufacturing hub after China.
- The cement is manufactured by integrating the calcareous component and argillaceous component in a ratio of 3:1.
- The calcareous components can be limestone chalk, marine shells, and marl whereas the argillaceous component is composed of silica, alumina, iron oxide, and other impurities.

- Cement can be manufactured either by dry process or wet process.



Types of Cement:

There are different types of cement as classified by the Bureau of Indian Standards (BIS):

1. Ordinary Portland Cement
    a. 33 grade – IS: 269-1989
    b. 43 grade – IS: 8112-1989
    c. 53 grade – IS: 12269-1987
2. Portland Pozzolana Cement – IS: 1489-1991 (Part 1 and 2)
3. Portland Blast Furnace Slag Cement – IS: 455-1989
4. White Portland Cement – IS: 8042-1989
5. Rapid Hardening Cement – IS: 8041-1990
6. Extra Rapid Hardening Cement
7. Sulphate Resisting Portland Cement – IS: 12330-1988
8. Low Heat Portland Cement – IS: 12600-1989
9. Coloured Portland Cement – IS: 8042-1989

10. Hydrophobic Cement – IS: 8043-1991
11. High Alumina Cement – IS: 6452-1989
12. Super Sulphated Cement – IS: 6909-1990
13. Special Cements

1. Ordinary Portland Cement (OPC):

- It is obtained by pulverizing argillaceous material in the correct proportion.
- Portland cement is a most common variety of artificial cement and is most commonly known as OPC (Ordinary Portland Cement).
- It is available in 3 grades:
  - OPC-33 grade (IS: 269-989)
  - OPC-43 grade (IS: 8112-1989)
  - OPC-53 grade (IS: 12269-1987)
- The numbers 33, 43, and 53 correspond to 28 days of characteristic compressive strength of cement as obtained from standard tests on cement sand mortar (1:3) specimens.
- The OPC 33 is recommended for concrete mix having strength up to 20 N/mm^2 i.e. M20.
- These are most commonly used in general concrete construction, where there is no exposure to sulphates.

2. Portland Pozzolana Cement (PPC):

- It can be produced either by grinding together portland cement clinker and pozzolana with the addition of gypsum or by blending uniformly portland cement and fine pozzolana.
- As per the latest amendment, the proportion of pozzolana may vary from 15 to 35% by weight of cement clinker. Earlier, it was 10 to 25%.
- A pozzolanic material is essentially a silicious or aluminous material that in itself possesses no cementitious properties, which in finely divided form and in the presence of water reacts with calcium hydroxide, liberated in the hydration process at ordinary temperature to produce compounds possessing cementitious properties. This is known as pozzolanic action i.e.

$$Ca(OH)_2 + \text{Pozzolana} + \text{Water} \rightarrow \text{C-S-H (gel)}$$

- The pozzolanic materials generally used for manufacturing of portland pozzolanic cement are calcined clay (IS: 1489 part 2 of 1991) or fly ash (IS: 1489 part 1 of 1991).
- Fly ash is a waste material generated in a thermal power station, when powdered coal is used as a fuel.
- PPC produces less heat of hydration and offers greater resistance to the attack of impurities in water than OPC.

3. Portland Blast Furnace Slag Cement (PBFSC):

- This cement is made by integrating portland cement clinker and granulated blast furnace slag.

- The proportion of the slag is not less than 25% or not more than 65% by weight of cement.
- The slag should be granulated blast furnace slag of high lime content, which is produced by rapid quenching of molten slag obtained during the manufacturing of pig iron in a blast furnace.
- In general blast furnace slag cement is found to gain strength more slowly than ordinary portland cement.
- The heat of hydration of portland blast furnace slag cement is lower than that of OPC. So this cement can be used for mass concreting but is suitable for cold weather.

Testing of Cement:

Field Tests for Cement:

- **Colour:** Grey colour with a light greenish shade
- **Physical Properties:** Cement should feel smooth when rubbed in between the fingers.
- If the hand is inserted in a bag of cement, it should feel cool.
- If a small quantity of cement is thrown in a bucket of water, it should sink and should not float on the surface.
- **Presence of lumps:** Cement should be free from lumps.

Physical Tests on Cement:

The following physical properties should be checked before selecting a protland cement for the civil engineering works. IS: 269-1967 specifies the method of testing and prescribes the limits:

a. Fineness
b. Setting time
c. Soundness
d. Crushing strength

a. Fineness: It is measured in terms of the percentage of weight retained after sieving the cement through a 90-micron sieve or by the surface area of cement in square centimetres per gram of cement. According to IS code specification weight retained on the sieve should not be more than 10 percent. In terms of specific surface should not be less than 2250 cm^2/gm.

b. Setting time: A period of 30 minutes as minimum setting time for initial setting and a maximum period of 600 minutes as maximum setting time is specified by IS code, provided the tests are conducted as per the procedure prescribed by IS 269-1967.

c. Soundness: Once the concrete has hardened it is necessary to ensure that no volumetric changes take place. The cement is said to be unsound if it exhibits volumetric instability after hardening. IS code recommends testing with Le Chatelier mould for testing this property. At the end of the test, the indicator of Le Chatelier mould should not expand by more than 10 mm.

d. Crushing strength: For this mortar cubes are made with standard sand and tested in a compression testing machine as per the specification of the IS code. The minimum strength specified is 16 N/mm^2 after 3 days and 22 N/mm^2 after 7 days of curing.

Aggregates:

Aggregates are an essential component of construction materials, and they are used in a wide range of construction projects, from small residential buildings to large commercial and industrial structures. Aggregates are naturally occurring or man-made materials that are used to provide strength and durability to construction projects. Several types of aggregates are commonly used in construction, including:

1. Gravel: Gravels are widely used building materials. Divisions in gravel range in size from pebbles (4-64 mm) in diameter, through cobbles (64-256 mm), to boulders (larger than 256 mm). Gravel is often used as a base layer in construction projects, such as in the foundation or structural elements of a building or in the construction of roads and highways.

2. Crushed stone: Crushed stone is a type of aggregate that is made up of small rocks or stones that have been crushed into smaller pieces. Crushed stone is often used as a base layer in construction projects, and it is also used in the construction of walls, foundations, and other structures.

3. Sand: Sand is a type of aggregate that is made up of small particles of rock or mineral that are finer than gravel. Sand is often used as a base layer in construction projects, and it is also used in the construction of walls, foundations, and other structures. Sand size ranges from 0.05 to 2 mm.

Aggregates are divided into either coarse or fine categories. Coarse aggregates are particulates that are greater than 4.75 mm. The usual range employed is between 9.5 mm to 37.5 mm in diameter. Fine aggregates are usually crushed stone or sand that are less than 9.55 mm in diameter. Both fine aggregate and coarse aggregate are important components of construction materials and are used in a variety of applications, including road construction, building foundations, and concrete production.

Tests on Aggregates:

Several tests can be performed on aggregates to determine their quality and suitability for use in construction. Some of the most common tests include:

Tests on Fine Aggregate:

1. Sieve analysis: This test is used to determine the size distribution of fine aggregate. The aggregate is passed through a series of sieves with different mesh sizes, and the resulting distribution of particles is used to determine the fineness of the aggregate.

2. Density test: This test is used to determine the density of fine aggregate. The aggregate is weighed on a balance and then placed in a container filled with water. The volume of water displaced by the aggregate is measured, and the density is calculated based on the weight and volume of the aggregate.

3. Oven-dry density test: This test is used to determine the oven-dry density of fine aggregate. The aggregate is dried in an oven at a high temperature, and the resulting density is measured. The oven-dry density is used to determine the moisture content of the aggregate.

These tests can help determine the quality and suitability of aggregates for use in construction and can help ensure that the final product is strong, durable, and safe.

4. Water absorption test: This test is used to determine the water absorption properties of fine aggregate. The aggregate is placed in a water absorption chamber, and the amount of water that is absorbed by the aggregate is measured over time. The water absorption rate is expressed as a percentage of the weight of the aggregate.

5. Specific Gravity test: The specific gravity test is a laboratory test used to determine the density of a material, such as fine aggregate. The test involves measuring the weight of a sample of the material and then calculating the specific gravity, which is the ratio of the weight of the material to the weight of an equal volume of water.

6. Porosity test: This test is used to determine the porosity of fine aggregate. The aggregate is placed in a porosity meter, which is a device that measures the amount of air or water that can pass through the aggregate. The porosity is expressed as a percentage of the volume of the aggregate that is filled with air or water.

Tests on Coarse Aggregate:

1. Sieve analysis: Sieve analysis of coarse aggregate is a laboratory test used to determine the size distribution of the aggregate. The test involves passing the aggregate through a series of sieves with different mesh sizes and measuring the amount of material that passes through each sieve. The resulting data is then used to determine the percentage of the aggregate that falls within each size fraction.

The most common sieves used in sieve analysis are 2 mm, 4 mm, 8 mm, 16 mm, and 32 mm. The aggregate is first washed to remove any impurities and then passed through the sieves. The amount of material that passes through each sieve is measured, and the results are typically expressed as a percentage of the total weight of the aggregate.

2. Water Absorption Test: The water absorption test is used to determine the ability of the aggregate to absorb water. The test is important because it helps to determine the aggregate's potential for shrinkage and swelling during the curing process, which can affect its strength and durability.

The test is performed by weighing a known quantity of the aggregate and then exposing it to a controlled amount of water. The weight of the aggregate is measured at regular intervals to determine the rate of water absorption. The test is typically performed at a temperature of 20°C (68°F) and a relative humidity of 50%.

3. Specific Gravity Test: The specific gravity test is used to determine the density of the aggregate. The test is important because it helps to determine the aggregate's potential for settling and segregation during placement, which can affect its strength and durability.

The test is performed by measuring the weight of a known quantity of the aggregate and then dividing it by the volume of the aggregate. The specific gravity is calculated by dividing the weight by the volume and then multiplying by 100. The test is typically performed at a temperature of 20°C (68°F) and a relative humidity of 50%.

In concrete technology, the specific gravity of aggregates is made use of in design calculations of concrete mixes. The specific gravity of aggregate is also required in calculating the compacting factor in connection with the workability measurements. The average specific gravity of the rocks varies from 2.6 to 2.8.

4. Aggregate Crushing Value Test: Aggregates used in road construction should be strong enough to resist crushing under traffic wheel loads. If the aggregates are weak, the stability of the pavement structure is likely to be adversely affected. The strength of coarse aggregate is assessed by the aggregates crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of pavement, aggregate possessing low aggregate crushing value should be preferred.

The aggregate crushing value is defined as a ratio of the weight of the fine passing the specified IS sieve to the total weight of the sample expressed as a percentage. As per the IS code, the aggregate crushing value for cement concrete pavement shall not exceed 30%. Whereas, the aggregate crushing value for wearing surfaces shall not exceed 45%.

$$\textbf{Aggregate Crushing Value} = \frac{W2}{W1} \times 100$$

Where, W_1 = Total weight of dry sample

W_2 = Weight of the portion of crushed material passing 2.36 mm IS sieve.

5. Impact Strength Test: Impact strength is a measure of the resistance of a material to deformation or failure when subjected to a sudden and forceful impact, such as a blow from a hammer or a drop from a height. In the case of coarse aggregate, impact strength is an important property to consider, as it can affect the overall durability and performance of the material in construction applications.

The resistance of stones to impact is found by conducting tests in impacting testing machines. It consists of a frame with guides in which a metal hammer weighing 13.5 to 15 kg can freely fall from a height of 380 mm. Aggregates of size 10 mm to 12.5 mm are filled in cylinders in 3 equal layers; each layer being tamped 25 times. The same is then transferred to the cup and again tamped 25 times. The hammer is then allowed to fall freely on the specimen 15 times. The specimen is then sieved through a 2.36 mm sieve.

The aggregate impact value is defined as a ratio of the weight of the fine passing the specified IS sieve to the total weight of the sample expressed as a percentage. As per the IS code, the aggregate impact value for cement concrete pavement shall not exceed 30%. Whereas, the aggregate impact value for wearing surfaces shall not exceed 45%.

$$\textbf{Aggregate Impact Value} = \frac{W2}{W1} \times 100$$

Where, W_1 = Total weight of dry sample

W_2 = Weight of the portion of crushed material passing 2.36 mm IS sieve.

6. Acid Test: This test is normally carried out on sandstones to check the presence of calcium carbonate, which weakens the weather-resistant quality. In this test, a sample of stone weighing about 50 to 100 gm is taken and kept in a solution of one percent hydrochloric acid for seven days. The solution is agitated at intervals. A good building stone maintains its sharp edges and keeps its surface intact. If edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate. Such stones will have poor weather resistance.

Bricks:

Bricks are a type of building material that is made from a mixture of clay, water, and other substances, and then baked in a kiln. They are commonly used in construction to build walls, houses, and other structures. Bricks are known for their durability and resistance to weathering, and they can be used to create a wide range of architectural styles. The standard size of masonry brick is 190 mm × 90 mm × 90 mm. With mortar joints, the size of these bricks is taken as 200 mm × 100 mm × 100 mm.

Classification of Bricks Based on their Quality:

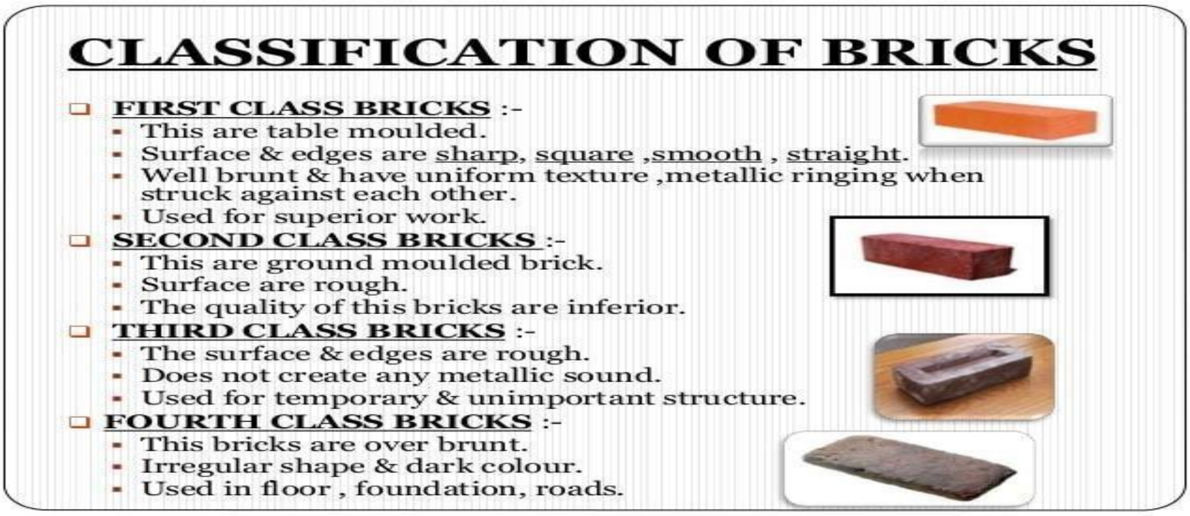
The bricks used in construction are classified as follows:

(i) **First Class Bricks:** These bricks are of standard shape and size. They are burnt in kilns. They fulfill all desirable properties of bricks.

(ii) **Second Class Bricks:** These bricks are ground moulded and burnt in kilns. The edges may not be sharp and uniform. The surface may be somewhat rough. Such bricks are commonly used for the construction of walls that are going to be plastered.

(iii) **Third Class Bricks:** These bricks are ground moulded and burnt in clamps. Their edges are somewhat distorted. They produce dull sounds when struck together. They are used for temporary and unimportant structures.

(iv) **Fourth Class Bricks:** These are the over-burnt bricks. They are dark in colour. The shape is irregular. They are used as aggregates for concrete in foundations, floors, and roads.



Properties of Bricks:

The following are the required properties of good bricks:

(i) **Colour:** Colour should be uniform and bright.

(ii) **Shape:** Bricks should have plane faces. They should have sharp and true right-angled corners.

(iii) **Size:** Bricks should be of standard sizes as prescribed by codes.

(iv) **Texture:** They should possess fine, dense, and uniform texture. They should not possess fissures, cavities, loose grit, or unburnt lime.

(v) **Soundness:** When struck with a hammer or with another brick, it should produce a metallic sound.

(vi) **Hardness:** Finger scratching should not produce any impression on the brick.

(vii) **Strength:** The crushing strength of the brick should not be less than 3.5 N/mm^2. A field test for strength is that when dropped from a height of 3 to 4 feet on hard ground, the brick should not break into pieces.

(viii) **Water Absorption:** After immersing the brick in water for 24 hours, water absorption should not be more than 20 percent by weight. For class-I works this limit is 15 percent.

(ix) **Efflorescence:** Bricks should not show white patches when soaked in water for 24 hours and then allowed to dry in the shade. White patches are due to the presence of sulphate of calcium, magnesium, and potassium. They keep the masonry permanently in damp and wet conditions.

(x) **Thermal Conductivity:** Bricks should have low thermal conductivity so that buildings built with them are cool in summer and warm in winter.

(xi) **Sound Insulation:** Heavier bricks are poor insulators of sound while lightweight and hollow bricks provide good sound insulation.

(xii) **Fire Resistance:** The fire resistance of bricks is usually good. In fact, bricks are used to encase steel columns to protect them from fire.

Tests on Bricks:

The following *laboratory tests* may be conducted on the bricks to find their suitability:

i. Crushing strength
ii. Absorption
iii. Shape and size and
iv. Efflorescence

(i) **Crushing Strength:** The brick specimen is immersed in water for 24 hours. The frog of the brick is filled flush with 1:3 cement mortar and the specimen is stored in a damp jute bag for 24 hours and then immersed in clean water for 3 days. The specimen is placed in a compression testing machine with 6 mm plywood on top and bottom to get a uniform load on the specimen. Then load is applied axially at a uniform rate of 14 N/mm^2. The crushing load is noted. Then the crushing strength is the ratio of the crushing load to the brick-loaded area. An average of five specimens is taken as the crushing strength. The minimum crushing strength of brick is 3.5 N/mm^2. If it is less than 3.5 N/mm^2, then it is not useful for construction purposes.

(ii) **Absorption Test:** Brick specimens are weighed dry. Then they are immersed in water for a period of 24 hours. The specimen is taken out and wiped with a cloth. The weight of each specimen in wet conditions is determined. The difference in weight indicates the water absorbed. Then the percentage absorption is the ratio of water absorbed to dry weight multiplied by 100. An average of five specimens is taken. For quality brick, the absorption value should not exceed 20 percent. For first-class bricks, the absorption value should not exceed 15 percent

(iii) **Shape and Size:** Bricks should be of standard size and edges should be truly rectangular with sharp edges. To check it, 20 bricks are selected at random and they are stacked along the length, along the width, and then along the height. For the standard bricks of size 190 mm × 90 mm × 90 mm. IS code permits the following limits:

- Lengthwise: 3680 to 3920 mm
- Width wise: 1740 to 1860 mm
- Height wise: 1740 to 1860 mm

(iv) **Efflorescence:** The presence of alkalies in brick is not desirable because they form patches of gray powder by absorbing moisture. Hence to determine the presence of alkalies this test is performed as explained below:

Place the brick specimen in a glass dish containing water to a depth of 25 mm in a well-ventilated room. After all the water is absorbed or evaporated again add water for a depth of 25 mm. After the second evaporation observe the bricks for white/grey patches. The observation is reported as 'nil', 'slight', 'moderate', 'heavy', or serious to mean

(a) Nil: No patches
(b) Slight: 10% of the area covered with deposits
(c) Moderate: 10 to 50% area covered with deposit but unaccompanied by flaking of the surface.
(d) Heavy: More than 50 percent area is covered with deposits but unaccompanied by flaking of the surface.
(e) Serious: Heavy deposits of salt accompanied by flaking of the surface.

Cement Concrete:

Cement concrete is a building material made from a mixture of cement, water, and aggregate (such as gravel or crushed stone). It is a common material used for constructing buildings, roads, and other structures. The process of making cement concrete typically involves the following steps:

1. Mixing the ingredients: The ingredients for cement concrete are mixed together in a specific ratio. This typically includes cement, water, and aggregate.
2. Placing the mixture: The mixed ingredients are then placed in a mould or form, which is the shape that the concrete will take.
3. Compacting the mixture: The mixture is then compacted using a machine or by hand to remove any air pockets.
4. Curing the concrete: The concrete is then left to cure, which is a process that allows it to harden and become stronger. This can take anywhere from a few hours to several days, depending on the type of concrete and the environmental conditions.

Cement concrete is a durable and versatile material that can be used for a wide range of applications, including building foundations, walls, floors, and roofs. It is also used for making concrete slabs, which are used for driveways, sidewalks, and other outdoor surfaces. There are different types of cement concrete, including:

- **Ready-mix concrete:** This is a pre-mixed concrete that is delivered to the job site in a truck.
- **Premixed concrete:** This is concrete that is mixed on-site, but the ingredients are pre-mixed in a plant.
- **Fresh concrete:** This is concrete that is mixed on-site and is not pre-mixed.

Cement concrete has several advantages, including:

- **Durability:** Cement concrete is a durable material that can last for many years with proper maintenance.
- **Strength:** Cement concrete is a strong material that can support heavy loads.
- **Versatility:** Cement concrete can be used for a wide range of applications, including building foundations, walls, floors, and roofs.

However, cement concrete also has some disadvantages, including:

- **High energy consumption:** The production of cement concrete requires a significant amount of energy, which can contribute to greenhouse gas emissions.
- **Environmental impact:** The production of cement concrete can also have negative environmental impacts, such as the release of pollutants into the air and water.
- **Cost:** Cement concrete can be expensive, especially for large-scale projects.

Tests on Cement Concrete:

Several tests can be performed to evaluate the quality and resistance of cement concrete which is suitable for the proposed application. Some of the most common hardened and durability properties include.

1. Compressive Strength test: This test determines the maximum amount of pressure that a concrete sample can withstand before it fails. The compression test is usually conducted on cubes or cylinders. The cube molds that are usually used for compression tests are 150x150x150mm or 100x100x100mm. The concrete cylinder used for the compression test has a length twice that of its diameter. The cylinders usually used for compression tests are 150mm in diameter and 300mm in length. The strength of the cylinder is found to be 0.8 times the strength of the cube. The cylinders are tested in the same direction as it was casted whereas the cube is casted in one direction and tested in another direction.

In this experimental investigation, 3 cubes of size 150x150x150mm were cast for each 7-day and 28-day test. The average of the compressive strength of these cubes was taken as the final result. The loading was done at a rate of 2.5 kN/sec. The compression testing machine can apply a maximum load of 2000 kN. The unit for compressive strength is megapascal or MPa. The compression strength was calculated using the formula.

$$\textbf{Compression Strength = Load in N / Area in mm}^2$$

2. Tensile Strength Test: This test determines the maximum tensile strength of cement concrete. It was difficult to determine the direct tensile strength of concrete due to the presence of eccentricity of axial loading. Therefore, the indirect tension test or splitting tensile test was developed in which a concrete cylinder was placed horizontally between the loading plates of the compression testing machine as shown in Fig. When the load is applied as shown in the figure the element on the vertical axis of the concrete cylinder experiences vertical compressive stress and horizontal stress. The tensile test was done for 3 cylindrical concrete specimens and the average of these was taken. The unit of the tensile strength test is MPa. The tensile strength was obtained by using the formula.

$$\textbf{Tensile Strength} = 2P / \pi LD$$

3. Flexural Strength Test: This test determines the maximum amount of bending stress that a concrete sample can withstand before it fails. It is done by applying a specified load to the sample and measuring the resulting deformation. This test can be done using a three-point loading test setup and expressed as N/mm^2 or MPa.

4. Shear Strength Test: This test determines the maximum shear strength of cement concrete. A specimen is subjected to a controlled amount of shear force, and the force required to break the specimen is measured. The shear strength of cement concrete is usually expressed as N/mm^2 or MPa.

5. Modulus of elasticity test: This test determines the stiffness of a concrete sample. It is done by applying a specified load to the sample and measuring the resulting deformation.

6. Density test: This test determines the mass of a concrete sample per unit volume. It is done by measuring the volume of the sample and dividing it by its weight.

7. Water absorption test: This test determines the amount of water that a concrete sample can absorb. It is done by placing the sample in a controlled environment and measuring the weight of the sample before and after exposure to water.

8. Shrinkage test: This test determines the amount of shrinkage that a concrete sample experiences as it cures. It is done by measuring the dimensions of the sample before and after curing.

9. Thermal conductivity test: This test determines the ability of a concrete sample to conduct heat. It is done by measuring the temperature of the sample before and after exposure to a heat source.

10. Acid resistance test: This test determines the ability of a concrete sample to withstand exposure to acid. It is done by applying a specified amount of acid to the sample and measuring the resulting degradation.

Steel:

Steel is a metal that is commonly used in construction, manufacturing, and transportation. It is made by heating iron in the presence of oxygen and carbon, which causes it to become malleable and ductile. Steel is known for its strength, durability, and resistance to corrosion, making it a popular choice for a variety of applications. It is often used in the construction of beams, columns, and other structural elements in buildings. The following three varieties of steel are extensively used:

(a) Mild steel

(b) High-carbon steel and

(c) High tensile steel

To ensure the safety and durability of steel structures, a variety of tests are conducted to evaluate their strength and resistance to corrosion. Tests are typically conducted by certified testing laboratories and are required by building codes and regulations to ensure the safety and durability of steel structures. Some common tests include:

1. Tensile testing: This test measures the strength of steel by pulling it apart at a constant rate.

2. Compressive testing: This test measures the strength of steel by pushing it together at a constant rate.

3. Bending testing: This test measures the strength of steel by bending it at a constant rate.

4. Corrosion testing: This test measures the resistance of steel to corrosion by exposing it to a corrosive environment and measuring the amount of corrosion that occurs.

5. Fatigue testing: This test measures the ability of steel to withstand repeated loading and unloading without failing.

Factors to be Considered in Building Planning:

There are many factors to consider when planning a building project, including:

1. Location: The location of the building should be considered in terms of its proximity to transportation, utilities, and other amenities.

2. Functionality: The building should be designed to meet the needs of its intended occupants, including the number of rooms, the size of each room, and the layout of the building.

3. Cost: The cost of the building project should be carefully considered, including the cost of materials, labor, and any other expenses associated with the project.

4. Safety: The building should be designed to meet safety standards, including fire safety, earthquake safety, and other potential hazards.

5. Sustainability: The building should be designed to be sustainable, including the use of energy-efficient materials and systems, and the incorporation of green building practices.

6. Aesthetics: The building should be designed to be visually appealing and in line with the surrounding architecture.

7. Zoning and building codes: The building should be designed to meet local zoning and building codes, which may include restrictions on height, size, and other aspects of the building.

8. Environmental impact: The building should be designed to minimize its environmental impact, including the use of sustainable materials and the incorporation of green building practices.

9. Accessibility: The building should be designed to be accessible to people with disabilities, including the provision of ramps, elevators, and other accommodations.

10. Maintenance and upkeep: The building should be designed to be easy to maintain and upkeep, including the use of durable materials and the incorporation of easy-to-clean features.

Nature of building:

Buildings are structures that are designed and constructed to provide shelter, protection, and other functions for people and goods. They can be used for a variety of purposes, including residential, industrial, and commercial uses.

Typical layouts of residential buildings:

The typical layout of a residential building can vary depending on the size and style of the building, as well as the needs and preferences of the occupants. However, some common layouts are commonly found in residential buildings.

1. Single-family home: A single-family home is a standalone residential building that is designed for one family to live in. It typically consists of a living room, bedrooms, a kitchen, and bathrooms.

2. Multi-family home: A multi-family home is a residential building that is designed to house multiple families. It can be an apartment building, a condominium, or a townhouse. These buildings typically consist of multiple units, each with its own living room, bedrooms, kitchen, and bathrooms.

3. Townhouse: A townhouse is a residential building that is designed to be a single-family home, but is built in a row or cluster of similar buildings. It typically consists of a living room, bedrooms, a kitchen, and bathrooms, and may also have a garage or other outdoor living space.

4. Apartment building: An apartment building is a residential building that is designed to house multiple families in separate units. It typically consists of multiple floors, with each floor containing multiple units. The units may be one-bedroom, two-bedroom, or three-bedroom, and may also have a balcony or other outdoor living space.

Overall, the typical layout of a residential building is designed to provide a comfortable and functional living space for the occupants, while also being aesthetically pleasing and in line with local building codes and regulations.

Typical layouts of industrial buildings:

The typical layout of an industrial building can vary depending on the type of industry and the specific needs of the business. However, some common layouts are commonly found in industrial buildings.

1. Warehouse: A warehouse is a large, open space that is used for the storage and distribution of goods. It typically consists of a main storage area, with smaller offices and other support spaces located throughout the building.

2. Manufacturing plant: A manufacturing plant is a facility where goods are produced through the use of machinery and other manufacturing processes. It typically consists of a production floor, with offices and other support spaces located throughout the building.

3. Distribution centre: A distribution centre is a facility where goods are sorted, packaged, and shipped to their final destination. It typically consists of a main storage area, with smaller offices and other support spaces located throughout the building.

4. Research and development facility: A research and development facility is a facility where new products and processes are developed and tested. It typically consists of laboratories, offices, and other support spaces located throughout the building.

Overall, the typical layout of an industrial building is designed to provide a functional and efficient space for the business to operate, while also being aesthetically pleasing and in line with local building codes and regulations.

Typical layout of a commercial building:

The typical layout of a commercial building can vary depending on the type of business and the specific needs of the business. However, some common layouts are commonly found in commercial buildings.

1. Supermarket: A supermarket is a retail store that sells food and other household items. It typically consists of a main sales area, with smaller offices and other support spaces located throughout the building. The sales area may be divided into different sections, such as produce, dairy, meat, and bakery.

2. Hotel: A hotel is a facility that provides temporary lodging for people. It typically consists of multiple rooms or suites, each with its own bathroom and other amenities. The hotel may also have a lobby, restaurant, and other support spaces.

3. Theatre: A theatre is a performance space where live performances, such as plays and concerts, are held. It typically consists of a main stage, with smaller rehearsal and dressing rooms located throughout the building. The theatre may also have a lobby and other support spaces.

4. Office building: An office building is a facility that houses businesses and other organizations. It typically consists of multiple floors, with offices and other support spaces located throughout the building. The offices may be arranged in a variety of ways, such as open plan or individual offices.

5. Retail store: A retail store is a facility that sells goods to the public. It typically consists of a main sales area, with smaller offices and other support spaces located throughout the building. The sales area may be divided into different sections, such as clothing, electronics, and home goods.

6. Restaurant: A restaurant is a facility that serves food and drinks to the public. It typically consists of a main dining area, with a kitchen and other support spaces located in the back of the building. The dining area may be arranged in a variety of ways, such as tables and booths.

7. Warehouse: A warehouse is a large, open space that is used for the storage and distribution of goods. It typically consists of a main storage area, with smaller offices and other support spaces located throughout the building.

PART A: BASIC CIVIL ENGINEERING

UNIT II:

Surveying:

Surveying is "taking a general view by observation and measurement determining the boundaries, size, position, quantity, condition, value, etc. of land, estates, building, farms mines, etc. and finally presenting the survey data in a suitable form".

(OR)

Surveying is defined as the science of making measurements of the earth, especially the surface of the earth. This is carried out by finding the spatial location (relative/absolute) of points on or near the earth's surface.

(OR)

Surveying is the art of science of determining the relative positions of various points or stations on the surface of the earth by measuring the horizontal and vertical distances, angles and taking the details of these points, and preparing a map or plan to any suitable scale.

The process of surveying is therefore in three stages namely:

(i). Taking a general view: This part of the definition is important as it indicates the need to obtain an overall picture of what is required before any type of survey work is undertaken. In land surveying, this is achieved during the reconnaissance study.

(ii). Observation and Measurement: This part of the definition denotes the next stage of any survey, which in land surveying constitutes the measurement to determine the relative position and sizes of natural and artificial features on the land.

(iii). Presentation of Data: The data collected in any survey must be presented in a form that allows the information to be interpreted and understood by others. This presentation may take the form of written reports, bills of quantities, datasheets, drawings, and land surveying maps and plans showing the features of the land.

The primary aims of field surveying are:

- To measure the horizontal distance between points
- To measure the vertical elevation between points
- To find out the relative direction of lines by measuring horizontal angles regarding any arbitrary direction
- To find out absolute direction by measuring horizontal angles regarding a fixed direction

Importance of Surveying to Civil Engineers:

- The planning and design of all civil engineering projects such as the construction of highways, bridges, tunnels, dams, etc., are based upon surveying measurements.
- Moreover, during execution, a project of any magnitude is considered along the lines and points established by surveying
- Thus, surveying is the basic requirement for all civil engineering projects
- Other principles in which surveying is primarily utilized are:
  - To fix the national and state boundaries
  - To chart coastlines, navigable streams and lakes
  - To establish a control point (control point is stations having known positions)
  - To execute hydrographic and oceanographic charting and mapping and
  - To prepare a topographic map of the land surface of the earth

Objectives of Surveying:

- To collect field data
- To prepare a plan or map of the area surveyed
- To analyse and calculate the field parameters for setting out the operation of actual engineering works
- To set out field parameters at the site for further engineering works

Primary Division of Surveying:

- The primary division is based on whether the earth's curvature is considered or not.
- The approximate shape of the earth can be defined as an oblate or spheroid.
- Based upon the consideration of the shape of the earth, surveying is broadly divided into two types:
  1. Geodetic Surveying
  2. Plane Surveying

1. **Geodetic Surveying:**
   - In this branch of surveying, the true shape of the earth, i.e., the curvature of the earth is taken into account.
   - This type of surveying is being carried out for highly precise work and is adopted for surveying of largest area.
   - All lines lying on the surface are curved lines and triangles are spherical triangles.
   - The directions of plumb lines at various points cover towards centre of the earth.
   - A geodetic survey is needed to fix the widely spaced control points that are later used as necessary control points for fixing the minor control points.
   - The geodetic survey is carried out by the Department of National Survey of India.

2. **Plane Surveying:**
    - In this branch of surveying curvature of earth is neglected and is assumed to be a flat surface.
    - In plane surveying, relatively small areas are under consideration (less than 200 square kilometres).
    - The vertical line is indicated by the direction of a freely suspended plumb bob. A single horizontal plane of reference is selected. There the plumb bob lines at all points of the area are assumed to be parallel. The curved line on the earth's surface is considered as straight.
    - In the plane survey difference in length between the arc and its subtended chord on the earth's surface for a distance of 18.2 km, is only 10 mm.
    - Also, the difference between the sum of angles in a plane triangle and a spherical triangle is only one second (1”) for a triangle at the earth's surface having an area of 195 square kilometres.

No.	Plain Surveying	Geodetic Surveying
1	The earth surface is considered as plain Surface.	The earth surface is considered as Curved Surface.
2.	The Curvature of the earth is ignored	The curvature of earth is taken into account.
3	Line joining any two stations is considered to be straight	The line joining any two stations is considered as spherical.
4.	The triangle formed by any three points is considered as plain	The Triangle formed by any three points is considered as spherical.
5.	The angles of triangle are considered as plain angles.	The angles of the triangle are considered as spherical angles.
6.	Carried out for a small area < 250 km^2	Carried out for a small area > 250 km^2

Classification of Surveys:

According to the use and the purpose of the final maps, surveys may be classified, under the following different heads:

I. Classification based on the nature of the field/purpose:

1. Topographical survey: These surveys are used to obtain maps that show details of natural and man-made features on the earth's surface including elevation.
Scale = (1:25000 to 1:10 lakh)

2. Engineering survey: These are surveys used for engineering works like railways, highways, canals, bridges, etc.
Building: 1:50 to 1:200
Bridge and other civil engineering works: 1:500 to 1:2500
Highway: 1:1250 to 1:50000

3. Cadastral survey: These surveys are generally plotted on a larger scale than topographical surveys and are carried out for fixing the property lines.
Scale: 1:1000 to 1:5000

4. Hydrographic survey: The survey that deals with the mapping of large water bodies for navigation, construction of harbor works, prediction of tides, and determination of mean sea level are called hydrographic surveys.

The hydrographic survey consists of the preparation of topographical maps of the shores and banks, by taking soundings and determining the depth of water at several places and ultimately surveying bathymetric contours under water.

5. Astronomical survey: With the help of this survey, we can determine latitude, longitude, and LMT at any place on the earth's surface.

6. Geological survey: This is done to determine information about various strata of the earth's surface.

II. Classification based on the instrument:

1. Chain Surveying: It's the simplest type of surveying in which only linear measurements are done with the help of chain or tape and no angular measurements are done.

2. Compass Surveying: It is a branch of surveying in which horizontal angles and direction of lines are measured with a compass and length of lines are measured with chain and tape.

3. Theodolite Surveying: In this surveying, horizontal and vertical angles are measured with theodolite, and distances are measured with chain or tape.

4. Levelling: In this type of surveying elevations of various points are measured with a levelling instrument and vertical staff.

5. Plane table Surveying: In plane table surveying plan or map is produced by determining the direction of various points and taking linear measurements with chain or tape.

6. Tacheometric Surveying: In this surveying horizontal and vertical distances are measured with an instrument called tacheometer.

7. Photogrammetric Surveying: In this survey, photographs are taken for an area that is inaccessible or time available is less and area to be survey is large.

Principal of Surveying:

The fundamental principles upon which different methods of surveying are based; are stated below.

(i). Working from the whole to the part:

- The main principle of surveying whether plane or geodetic is to work from the whole to the part.
- To achieve this in actual practice, a sufficient number of primary control points are established with higher precision in and around the area to the detail surveyed.
- Minor control points in between the primary control points, are then established with the less precise method.
- The main idea of working from whole to part is to prevent the accumulation of errors and to localize minor errors within the framework of control points.

(ii). Location of a point by measurement of two control points:

- Let P and Q be two given control points. Any other point say, R can be located about these points, by any one of the following methods:

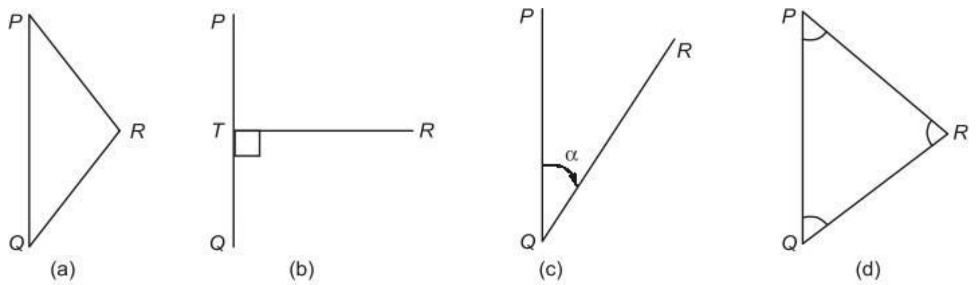


Fig. *Shows location of points*

- Principles (a) and (b) are usually used in the method of chain survey.
- Principle (C) is used in the method of theodolite traversing.
- Principle (d) is used in the method of triangulation.

The following terms are generally used in surveying:

1. Plan:

A plan is the graphical representation of the features on the earth's surface or below the earth's surface as projected on a horizontal plane.

2. Map:

- The representation of the earth's surface on a small scale, is called a map.
- The map shows its geographical position on the globe.
- On a map, the topography of the terrain, is depicted generally by contours, hachures, and spot levels.

Horizontal Measurements:

In surveying, horizontal measurements refer to the distance between two points measured along a straight line, regardless of the relative elevation of the two points. Horizontal measurements are essential in various types of surveying, such as chain surveying and traverse surveying. Some common methods for measuring horizontal distances include:

1. Pacing: This is a rapid means of approximately checking more precise measurements of distance. Pacing over rough country may be done with a precision of one in one hundred.

(**[**]Pacing** is the process of walking the distance and counting the number of steps "paces" to cover the distance)

2. Measuring Wheel: A measuring wheel is a device used to measure horizontal distances by rolling it along the ground.

3. Tape: A tape measure can be used to measure horizontal distances by laying it out along the ground and marking the desired distance.

4. Electronic Distance Measurement (EDM): Modern surveying equipment, such as total stations or theodolites, can be used to measure horizontal distances with greater precision.

When measuring horizontal distances on sloping ground, it is essential to account for the slope's gradient, as this can affect the accuracy of the measurements. Slope corrections in surveying refer to adjustments made to measured horizontal distances to account for the slope of the ground.

Vertical Measurements:

Vertical measurements in surveying refer to the process of measuring vertical distances, such as heights or elevations, relative to a reference surface like mean sea level, a geoid, or an ellipsoid. Some key aspects of vertical measurements in surveying include:

1. Levelling: This is the operation of measuring vertical distances, either directly or indirectly, to determine differences in elevation. Levelling is still a cost-effective way to produce elevation data with sub-meter accuracy.

2. Vertical Angles and Slopes: Vertical angles are angles formed by two connected lines in the vertical plane, between a low point and two higher points. The slope of a line is called the gradient and can be expressed in various ways, such as percentages or degrees.

3. Vertical Datums: Vertical datums are essential for land surveying, as they provide a reference point for measuring heights and elevations. They can be based on a physical phenomenon, such as sea level or gravity, or on a mathematical model, such as an ellipsoid or a geoid.

4. Technologies and Methods: Surveying involves various technologies and methods to measure vertical distances, such as GPS, precise levelling, and adhering to established standards like those set by the National Geodetic Survey (NGS).

5. Benchmark Establishment: Ensuring the accuracy and reliability of vertical datums in land surveying involves several key steps, including benchmark establishment, which involves placing a physical object or point at a specific location to serve as a reference for future measurements.

Vertical measurements in surveying are crucial for various applications, such as determining the elevation of points, the difference in elevation between points, and the slope of lines. These measurements are essential for accurate land surveying and can be affected by factors like ground slope, which is important to consider when designing structures like fish farms, canals, and ponds.

Angular Measurements:

Angular measurements in surveying are essential for determining the relative positions of points or objects on or near the Earth's surface. These measurements are crucial in various aspects of civil engineering and construction. There are several types of angular measurements used in surveying, including horizontal and vertical angles, azimuths, and bearings. Some common instruments used for measuring angles and elevations in surveying are:

1. Hand level: A simple level held in the hands of the operator, used for estimating elevation and slope. It employs a spirit level and a single cross-hair.

2. Abney level: A level similar to a hand level but with a more sophisticated mechanism, including stadia hairs for measuring horizontal and vertical angles.

3. Dumpy level: A more advanced level that uses a telescope and two measurement wheels for reading horizontal and vertical angles.

4. Automatic level: An electronic device that measures angles and elevations with greater accuracy and speed than traditional levels.

5. Laser level: A modern instrument that uses lasers to measure angles and elevations with high precision.

6. Transit: A theodolite with a telescope for sighting distant target objects, two measurement wheels for reading horizontal and vertical angles, and bubble levels to ensure accuracy.

7. Theodolite: An electronic equivalent of a transit, which uses electronic components to measure angles with high precision.

Surveyors use these instruments to measure angles in various ways, such as bearings (angles less than 90° within a quadrant defined by the cardinal directions) and azimuths (angles between 0° and 360° measured clockwise from North). In plane surveying, the forward and back azimuth of a line always differ by exactly 180°. Surveyors also use deflection angles in their computations, which are the angles between two lines of sight or between two legs of a traverse.

Levelling Instruments used for Levelling:

Levelling instruments are used to establish or verify points in the same horizontal plane, and they play a crucial role in surveying and construction. Some of the commonly used levelling instruments include:

1. Dumpy Level: Also known as an automatic level, this instrument is an optical device that can establish or verify points located on the same horizontal plane. It consists of a telescope fitted with a spirit level and, generally, mounted on a tripod.

2. Digital Level: A digital level is a precise instrument used for precise levelling. It operates on the principle of digital processing of video indications of a coded staff, and it can automatically record heights and distances.

3. Tilting Level: This instrument is used to measure the height of distant points about a benchmark. It consists of a telescope with crosshairs and stadia marks, which allow for range-finding and height measurements.

4. Level Rods: These are used in conjunction with levelling instruments to establish the relative height or levels of objects or marks.

5. Level Vials: Small vials filled with a liquid that are used to establish a level line when placed on a surface.

6. Telescopes: These can be used in conjunction with levelling instruments to measure distance and angles.

7. Theodolite: A surveying instrument used to measure angles, particularly in the vertical plane. It can also be used for levelling purposes.

8. Total Station: An electronic theodolite integrated with an electronic distance measurement (EDM) system, which is used to read slope distances from the equipment itself to a designated point. The integrated computer then collects the data and performs the necessary calculations.

These instruments are used to measure height differences, transfer and measure heights of known objects or marks, and ensure accurate measurements in various applications, such as land surveying, construction, and civil engineering.

Introduction to Bearings:

Bearings and azimuths are two fundamental concepts used to describe directions or angles on the Earth's surface in surveying. They both serve the purpose of providing directional information, but they differ in their definition and application.

- Bearings are angles measured clockwise or counter clockwise from a reference direction, which is often a line along a surveying traverse or a meridian. They are usually expressed in degrees, minutes, and seconds, such as N 45°30'W or S 30°15'E. Bearings are commonly employed in land surveying and construction, as they are more practical for describing angles between specific points on a site or property.
- Azimuths are horizontal angles measured clockwise from the north direction. They are expressed in degrees, typically ranging from 0° (north) to 360° (back to north). Azimuths are commonly used in geodetic and celestial navigation, providing a clear and continuous reference to cardinal directions. For example, an azimuth of 90° corresponds to due east, and 180° is due south.

To convert between bearings and azimuths, you can use the following formulas:

- **Azimuth to Bearing:** Add or subtract 90° or 180° depending on the quadrant. For example, if the azimuth is 30°, the bearing would be S 30°15'E.
- **Bearing to Azimuth:** Add or subtract 90° or 180° depending on the quadrant. For example, if the bearing is S 30°15'E, the azimuth would be 15°.

In summary, bearings and azimuths are essential tools in land surveying for establishing boundaries, locating points, and defining shapes on the Earth's surface. They can be used interchangeably, but it is crucial to know the context and the specific application of each concept.

Contour Mapping:

Contour mapping, also known as contour surveying, is a technique used in cartography and geography to represent the three-dimensional shape and elevation of the Earth's surface on a two-dimensional map. Contour maps display lines called "contour lines" that connect points of equal elevation above a reference datum, typically mean sea level. These lines help visualize the topography and relief of a region, making it easier to understand the landforms and changes in elevation. There are two methods of contour surveying:

1. Direct Method: This method involves finding vertical and horizontal controls of the points directly traced out in the ground by locating and making several points on each contour. The direct method of contouring is the most accurate but can be slow and tedious.

2. Indirect Method: In this method, levels are taken at some selected points, and their levels are reduced. Horizontal control is established by comparing the reduced levels with the known elevation of the points. This method is suitable for large areas and where less accuracy is required.

Contour maps are useful for various purposes, such as identifying noticeable differences in elevation, land property development, and engineering projects like roads, railways, canals, dams, and buildings. They provide valuable information about the land, helping engineers and architects understand the topography and relief of a region.

Simple Problem:

Q: The staff readings taken at stations A and B are 2.750 and 0.725 m respectively. Find the RL of B if the RL of A is 50.000 and the difference in level between A and B.

A: Given data:

R.L (Reduced level) of A = 50.000;

B.S (Back sight) = 2.750

F.S (Fore sight) = 0.725

Height of the instrument (H.I) = R.L + B.S = 50.000+2.750 = 52.750

R.L of B = H.I – F.S = 52.750 – 0.725 = 52.025 m

Therefore, Difference in level between A & B = R.L of B – R.L of A

= 52.025 – 50.000 = 2.025 m

(OR)

Difference in level between A & B = B.S on A – F.S on B

= 2.750 – 0.725 = 2.025 m

PART A: BASIC CIVIL ENGINEERING

UNIT III:

Importance of Transportation in Nation's Economic Development:

Transport: Derived from Latin words = trans + portare (across) + (to carry)

Transportation: Transportation refers to the activity that facilitates the physical movement of goods as well as individuals from one place to another. The transport sector contributes to 6% of Indian GDP. In that 6% alone road transport contributes around 75% share.

Transportation engineering plays a crucial role in a nation's economic development by contributing to the efficient movement of people, goods, and services. Here are some key points highlighting the importance of transportation engineering in economic development:

1. Infrastructure Development: Transportation engineering involves planning, designing, and constructing transport infrastructure such as roads, highways, railways, airports, and ports. Developing and maintaining this infrastructure enhances connectivity and accessibility, enabling trade and commerce across regions and stimulating economic activities.

2. Efficient Supply Chain: Efficient transportation systems optimize the movement of goods, reducing costs and delays in supply chains. Well-designed transportation networks enable businesses to efficiently transport raw materials and finished products, leading to increased competitiveness, improved productivity, and economic growth.

3. Trade Facilitation: Transportation engineering enables the efficient movement of goods across national and international borders. Efficient trade routes, customs processes, and logistics networks ensure smooth international trade, attracting investments, boosting exports, and driving economic development.

4. Job Creation: The planning, construction, and maintenance of transportation infrastructure create employment opportunities, directly in the engineering and construction sectors, as well as indirectly through supporting industries. This job creation contributes to economic growth, reduces unemployment, and improves living standards.

5. Urban Development: Transportation engineering plays a vital role in urban development by providing efficient transportation options within cities. Well-planned road networks, public transit systems, and pedestrian infrastructures enhance mobility, reduce congestion, and improve overall livability, attracting businesses, investments, and talent.

6. Regional Connectivity: Transportation engineering connects different regions and promotes balanced regional development. Improved connectivity between urban and rural areas ensures access to markets, education, healthcare, and other essential services, reducing regional disparities and fostering inclusive economic growth.

7. Sustainable development: Transportation infrastructure has an enormous impact on sustainable development, promoting industrialization, urban aggregation, and economic growth while reducing travel costs and promoting resource reallocation and manufacturing productivity.

Overall, transportation engineering is crucial for economic development as it enhances connectivity, facilitates efficient supply chains, promotes trade, creates jobs, supports urban development, and fosters regional integration.

Pavements:

Pavements are surfaces made from various materials, such as cement, concrete, bitumen, and limestone, used for roadways, runways, and other infrastructure. They serve as the foundation for transportation systems, providing a durable and comfortable driving experience. The choice of pavement type depends on factors like load distribution, material availability, and environmental conditions. Some common **types of pavements** include:

1. Rigid Pavements: These pavements consist of a single layer and are constructed from cement concrete or reinforced concrete slabs. They have a high modulus of elasticity and can distribute loads effectively, making them suitable for heavy traffic loads. Some common types of rigid pavements include:

- Jointed plain concrete pavement (JPCP)
- Jointed reinforced concrete pavement (JRCP)
- Continuous reinforced concrete pavement (CRCP)
- Pre-stressed concrete pavement (PCP)

2. Flexible Pavements: These pavements are made up of multiple layers and are typically constructed from bituminous materials. They are designed to distribute loads through the layers of the pavement, reducing the stress on the subgrade. Some common types of flexible pavements include:

- Conventional layered flexible pavement
- Full-depth asphalt pavement
- Contained rock asphalt mat (CRAM)

3. Composite Pavements: A composite pavement structure combines the elements of both asphalt and concrete pavement systems, acting as one composite structure. Typically, composite pavements are asphalt overlays on top of concrete pavements.

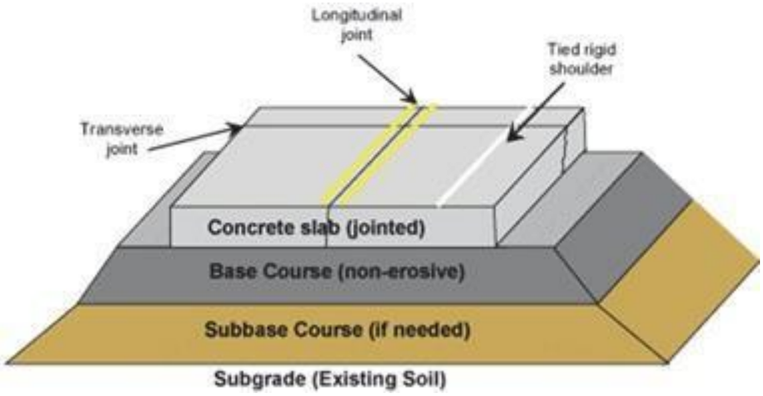
4. Airfield Pavements: These are the surfaces used for runways and other aircraft infrastructure, and can be made from flexible or rigid materials.

1. Flexible Pavements:

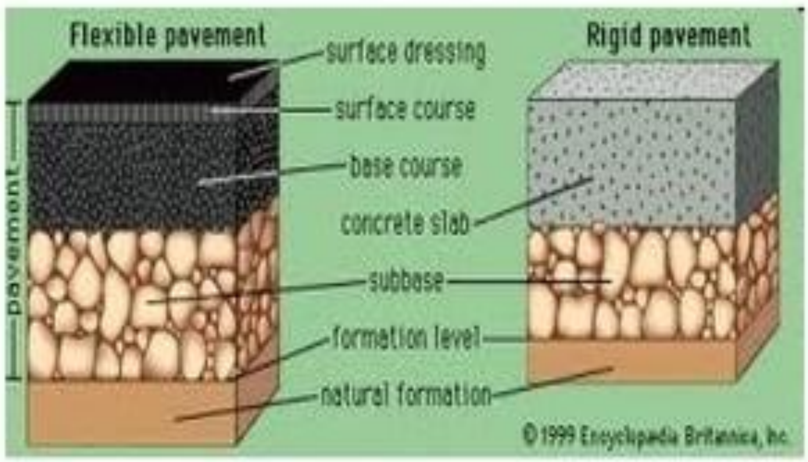
A flexible pavement can be defined as a pavement layer comprising a mixture of aggregates and bitumen, heated and mixed properly and then laid and compacted on a bed of granular layer. A typical flexible pavement consists of a bituminous surface course over the base course and sub-base course. The surface course may consist of one or more bituminous or Hot Mix Asphalt (HMA) layers. These pavements have negligible flexure strength and hence undergo deformation under the action of loads. The structural capacity of flexible pavements is attained by the combined action of the different layers of the pavement. The load from trucks is directly applied on the wearing course, and it gets dispersed (in the form of a truncated cone) with depth in the base, sub-base, and subgrade courses, and then ultimately to the ground. Since the stress induced by traffic loading is highest at the top, the surface layer has maximum stiffness (measured by resilient modulus) and contributes the most to pavement strength. The layers below have lesser stiffness but are equally important in the pavement composition. The subgrade layer is responsible for transferring the load from the above layers to the ground. Flexible pavements are designed in such a way that the load that reaches the subgrade does not exceed the bearing capacity of the subgrade soil. Consequently, the thicknesses of the layers above the subgrade vary depending upon the strength of soil affecting the cost of a pavement to be constructed.

2. Rigid Pavements:

Rigid pavements can be defined as pavement layers made from cement concrete or reinforced concrete slabs, laid over a low-strength concrete layer (Dry lean concrete, DLC) on a well-compacted layer of aggregates or both. Rigid pavements are named so because of the high flexural rigidity of the concrete slab and hence the pavement structure deflects very little underloading due to the high modulus of elasticity of their surface course. The concrete slab is capable of distributing the traffic load into a large area with a small depth which minimizes the need for several layers to help reduce the stress. The most common type of rigid pavement consists of dowel bars and tie bars. Dowel bars are short steel bars that provide a mechanical connection between slabs without restricting horizontal joint movement. Tie bars, on the other hand, are either deformed steel bars or connectors used to hold the faces of abutting slabs in contact. Although they may provide some minimal amount of load transfer, they are not designed to act as load transfer devices and are simply used to ‘tie’ the two concrete slabs together.



Types of Pavements



Difference between Flexible Pavements and Rigid Pavements:

	Flexible Pavement	Rigid Pavement
1.	It consists of a series of layers with the highest quality materials at or near the surface of pavement.	It consists of one layer Portland cement concrete slab or relatively high flexural strength.
2.	It reflects the deformations of subgrade and subsequent layers on the surface.	It is able to bridge over localized failures and area of inadequate support.
3.	Its stability depends upon the aggregate interlock, particle friction and cohesion.	Its structural strength is provided by the pavement slab itself by its beam action.
4.	Pavement design is greatly influenced by the subgrade strength.	Flexural strength of concrete is a major factor for design.
5.	It functions by a way of load distribution through the component layers	It distributes load over a wide area of subgrade because of its rigidity and high modulus of elasticity.
6.	Temperature variations due to change in atmospheric conditions do not produce stresses in flexible pavements.	Temperature changes induce heavy stresses in rigid pavements.
7.	Flexible pavements have self healing properties due to heavier wheel loads are recoverable due to some extent.	Any excessive deformations occurring due to heavier wheel loads are not recoverable, i.e. settlements are permanent

Basic Geometric design elements of Highways:

The geometric design of highways is a crucial aspect of highway engineering, as it affects the efficiency, safety, and environmental impact of roadways. The basic geometric design elements of highways include:

1. Cross-section elements: These elements consist of pavement surface characteristics, width of pavement or carriageway, and cross slope or camber.

2. Horizontal alignment: This refers to the route of the road, defined as a series of horizontal tangents and curves.

3. Vertical alignment: This includes the vertical aspect of the road, such as crest and sag curves, and the straight grade lines connecting them.

4. Intersection design: This element focuses on the layout and features of intersections, such as stop signs, traffic signals, and road signs.

5. Sight distance consideration: This aspect deals with the visibility of the road users and the surrounding environment, ensuring that drivers have enough time to respond to any situation that arises while driving.

6. Design speed: The design speed is the selected rate of travel used to determine various geometric design parameters, such as the length of vertical curves, horizontal curves, and sight distances.

7. Topography factors: The terrain and gradient of the land affect the geometric design, as steeper gradients and sharper curves may increase construction costs and require different design standards.

These geometric design elements are essential for ensuring the safety, efficiency, and environmental impact of highways. A well-designed highway should consider factors such as traffic volume, traffic speed, road terrain, and user characteristics, as well as the interaction between drivers, vehicles, and the road environment.

Camber:

Camber is found on the highways. The slope from the diagonal direction is called camber. Cambers mainly drain out the rainwater from the road surface. Camber provides the road surface by draining the rainwater out of the road. It is also called a cross slope of the road.

The rate of camber is normally indicated by 1 : n (1 in n) (1 vertical to n horizontal) or in proportions as n % (for instance, 1 in 50 or 2 %). The design values of the camber are mainly based on pavement type and the amount of rainfall in the area.

Cambers are very useful in eliminating surface water. But these are not recommended for wearing down the surface. Cambers of slope 2 to 3% are arranged.

Types of Camber:

1. **Composite Camber**

Composite camber is a combination of partly parabola and partly straight lines which have different slopes. The central part of the road is made of parabolic and it is provided with straight slopes near the edges. By increasing the contact area of the wheel camber helps to decrease the intensity of pressure.

2. **Sloped or Straight Camber**

This type of camber is made by meeting two straight surfaces in the crown. The Crown is the central point on the surface of the road. The shape of the edges makes it difficult for the traffic. That is why it is not used frequently.

3. **Two Straight Line Cambers**

This type of camber is made of straight lines steeper near the edges. This type of camber is best for Indian roads.

4. **Barrel Camber**

This type of camber consists of a continuous curve. The curve is either parabolic or elliptical. This type of camber is mainly used for those roads where fast-moving vehicles pass frequently.

Purpose of Camber

1. It is used to prevent surface water from subgrade soil through the pavement.
2. It is used to prevent the water to the bituminous pavement layers.
3. It is used for removing the rainwater from the pavement surface very quickly and allows the pavement to get dry after the rain.

Advantages of Camber

1. It prevents rainwater from piling up at local shrinkages and forms water pools around the road surface. However, it is not acceptable to the public and the road structure.
2. Camber quickly drains the rainwater. It also saves the foundation course of this road structure from the percolation of rainwater it through the road surface.

Stopping sight distance:

Stopping sight distance (SSD) is the distance needed for drivers to see an object on the roadway, such as a pedestrian, stopped vehicle, or road debris, to have enough time and space to stop the vehicle safely. It is a crucial factor in road design and plays an essential role in geometric highway design. SSD is influenced by both vertical and horizontal alignment. There are several types of sight distances, including:

- Stopping Sight Distance

- Overtaking Sight Distance

- Intermediate Sight Distance

- Head Light Sight Distance

- Sight Distance at Intersections

SSD is calculated using the following components:

1. Perception-Reaction Time (PRT): The time it takes for a driver to see an object and react to it. For design purposes, a conservative distance is needed, allowing a vehicle traveling at the design speed to stop before reaching the object.

2. Brake Distance: The distance traveled by the vehicle during the braking process. This can be calculated using the vehicle's speed, deceleration, and friction coefficient.

The total stopping sight distance (SSD) is the sum of these two components. SSD values are derived for various design speeds based on assumptions for driver reaction time, the braking ability of most vehicles under wet pavement conditions, and the friction provided by most pavement surfaces, assuming good tires. Design sight distance should be provided at all points on all highways and on all intersects unless a design analysis is deemed appropriate.

Super Elevation:

Superelevation is a road design feature that banks the roadway to keep vehicles from skidding or tipping while navigating into and through horizontal curves. It is the transverse slope provided to counteract the effect of centrifugal force and reduce the tendency of vehicles to overturn. Superelevation is expressed as a decimal, representing the ratio of the pavement slope to width, ranging from 0 to 0.12 foot/feet.

The need for superelevation is determined by several factors, such as:

- Friction, inertia, weight, and velocity or speed

- Climate, terrain, highway location (urban vs. rural), and frequency of very slow-moving vehicles

Superelevation provides several benefits, including:

- Maintaining a constant speed while remaining comfortable on a curved path

- Reducing the number of accidents

- Assisting in the drainage of rainwater towards the inner side of the road

- Keeping vehicles on the correct side of the road, preventing them from veering off course

Superelevation is an essential safety feature in roadway design, as it helps drivers maintain speed and control while navigating curves, especially in wet or cold weather or at full speed.

Water Resources and Environmental Engineering:

Sources of Water:

There are several sources of water, which can be categorized into natural and artificial sources.
Natural sources of water include:

1. Surface water: This type of water is found in rivers, lakes, and freshwater wetlands. It is naturally replenished by precipitation and lost through discharge to evaporation, evapotranspiration, and groundwater recharge.

2. Groundwater: Located below the surface of the earth in spaces between rock and soil, groundwater is naturally filtered and can contain germs and chemicals depending on its depth and the area's local conditions.

3. Rainwater: Collected rainwater can be used as a drinking water source in some areas, especially in rural locations where access to public water systems is limited.

Artificial sources of water include:

1. Treated wastewater: Reused or recycled water can be treated to meet drinking water standards.

2. Desalinated water: This type of water is obtained by removing salt from seawater, making it suitable for human consumption.

Water sources can also be categorized based on their use, such as drinking water, irrigation water, and industrial water. The majority of household wells are found in rural areas, while rivers, lakes, ponds, and tanks are the primary surface water sources. Protecting source water is crucial to ensure its quality and quantity, and it can help reduce treatment costs and prevent potential health risks.

Quality of water-Specifications and Tests:

Water quality specifications and tests are essential for ensuring the safety and quality of water for various purposes, such as drinking, recreation, and industrial use. Water quality is typically divided into three categories: physical, chemical, and biological parameters. Some key water quality testing parameters include:

1. Physical parameters: These parameters indicate properties detectable by the senses, such as temperature, pH, turbidity, salinity, nitrates, and phosphates.

2. Chemical parameters: These parameters measure the presence and levels of various chemicals, such as dissolved minerals like calcium and magnesium (water hardness), and the acidity or alkalinity of water, which should fall within the 6.5-8.5 range.

3. Biological parameters: These parameters include the presence and levels of microorganisms, such as bacteria and viruses, which can indicate the water's sanitary quality.

Water quality standards are set by national or regional authorities, such as the United States Environmental Protection Agency (EPA) and the World Health Organization (WHO). These standards provide guidelines for the maximum or minimum levels of key physical, chemical, and biological components found in water.

Some key aspects to consider when testing water quality include:

1. Test Strips: These are small, single-use strips that change color to indicate the concentration of a specific chemical. They are affordable and easy to use.

2. Portable Field Test Methods: These methods include colorimetric comparison tests, photometric test kits, or spectrophotometers to measure contaminants in water.

3. Professional Lab Tests: For a more thorough analysis, it's recommended to have your water sent to a professional water testing lab. These labs can provide accurate results and interpret them for you.

It's essential to test your water regularly, especially if you notice any changes in taste, odor, color, or clarity. The frequency of testing depends on your local water conditions and personal preferences. If you suspect contamination, it's crucial to contact your local health or environmental department for guidance in interpreting the test results.

Introduction to Hydrology:

Hydrology is the science that studies the occurrence, distribution, movement, and properties of water on Earth, as well as their relationship with the environment within each phase of the hydrologic cycle. It is a crucial field of study due to the importance of water resources for life on Earth and the need to understand and manage water systems effectively. Hydrology deals with various aspects of water, such as:

- Water resources and their management

- Hydro climatology (study of precipitation and its distribution)

- Surface water hydrology (study of water flow in surface water systems)

- Soil hydrology (study of water movement and storage in soil)

- Glacier hydrology (study of water movement and storage in glaciers)

- Watershed and river basin modeling (study of water flow and its interaction with the landscape)

- Risk and uncertainty analysis (assessment of potential water-related hazards and uncertainties)

- Data acquisition and information systems (collection and analysis of hydrological data)

Hydrologists play a vital role in finding solutions to water problems and addressing various challenges related to water resources, such as water supply, wastewater treatment, irrigation, drainage, hydropower generation, flood control, navigation, erosion and sediment control, salinity control, pollution abatement, recreational use of water, and fish and wildlife protection. They use their knowledge of hydrological processes and spatial and temporal patterns of precipitation, evaporation, and runoff to develop effective strategies for water resources management.

Hydrograph:

A hydrograph is a graph that shows the rate of flow (discharge) versus time past a specific point in a river, channel, or conduit carrying flow. The rate of flow is typically expressed in cubic meters or cubic feet per second (cms or cfs). Hydrographs are commonly used in various fields, such as hydrology, hydrogeology, and sewerage design. They can display different hydrologic variables over time, such as stage, streamflow, and water temperature.

Some key aspects of hydrographs include:

- **Precipitation:** Hydrographs often relate changes in precipitation to changes in discharge over time.

- **Discharge:** Discharge hydrographs depict the volume of the discharge itself, showing how surface water flow responds to fluxes in precipitation.

- **Stage:** Stage hydrographs show fluctuations in the height of water about a certain point.

- **Water Temperature:** Water temperature hydrographs show how the temperature of the stream's water has changed over time.

- **Frequency:** Hydrographs can be made from either natural or synthetic hydrographs, showing results from exactly one unit (inch, cm, etc.) of constant rainfall.

Hydrographs can be obtained from various sources, such as the United States Geological Survey (USGS), which maintains over 9,000 stream-gaging stations across the country. These gaging stations transmit their data to USGS continuously, and the data is published on the web. Hydrographs are useful tools for monitoring water levels, forecasting flood risks, and understanding the impact of precipitation on streamflow.

Rainwater Harvesting:

Rainwater harvesting is the practice of collecting and storing rainwater for reuse, reducing the demand for existing water supplies and promoting sustainability. It is an innovative alternative water supply approach that can be implemented in various settings, including urban and rural areas. The main components of a rainwater harvesting system include a catchment surface, conveyance system, storage, distribution, and treatment.

Benefits of rainwater harvesting include:

- Reducing demand on existing water supplies

- Reducing run-off, erosion, and contamination of surface water

- Saving money on water bills

- Contributing to sustainability goals and reducing environmental impact

Rainwater harvesting systems can be used for various purposes, such as:

- Landscaping and irrigation

- Car washing

- Laundry

- Toilet flushing

- Washing walkways and driveways

There are different types of rainwater collection systems, including:

1. Roof catchment: This method involves locating collection pipes underground to connect multiple downspouts from different gutters.

2. Ground residential rainwater collection systems: These systems collect water via drain pipes or earthen dams and store it above or below ground in tanks.

Rainwater harvesting is considered a viable technology in urban settings, and it can be as simple as collecting rain in a rain barrel or as elaborate as installing a complex system with pumps and filtration devices. The cost of rainwater systems varies depending on the complexity and components used, ranging from inexpensive DIY systems to more advanced and expensive options.

Rainwater Runoff:

Rainwater runoff is generated from rain and snowmelt that flows over land or impervious surfaces, such as paved streets, parking lots, and building rooftops and does not soak into the ground. This runoff can pick up and deposit various pollutants, including trash, chemicals, and dirt/sediment, into streams, lakes, and groundwater. Some of the negative effects of rainwater runoff include:

- Pollution: Runoff can contaminate waters, close local businesses, and harm or kill fish and other wildlife.

- Flooding: High volumes of runoff can cause flooding in urban and suburban areas, leading to property damage, dampness and mold in basements, and street flooding.

- Erosion: Runoff can contribute to soil erosion and stream bank erosion, damaging habitats for critters that live in streams.

To reduce the impact of rainwater runoff, communities can employ various management practices, such as:

- Low Impact Development (LID) and green infrastructure: These systems and practices preserve or use detain, or filter contaminants from stormwater, including bioretention facilities, rain gardens, vegetated rooftops, buffer strips, forested areas, grassed waterways, constructed wetlands, rain barrels, and permeable pavements.

- Reducing impervious areas: Encouraging homeowners to reduce the number of impervious surfaces, such as paved driveways and rooftops, can help rainwater soak into the ground.

- Planting native trees and plants: These can help infiltrate stormwater and increase evaporation.

- Proper lawn care practices: Maintaining healthy lawns can help absorb water and reduce runoff.

- Managing stormwater on-site: Using rain gardens, rain barrels, and other practices to manage stormwater at the source.

Water Storage Structures (Introduction to Dams and Reservoirs):

There are various types of water storage structures available, each designed to serve specific purposes and store different types of water. Dams and reservoirs are essential structures that play a crucial role in various aspects of human life, including water supply, flood control, energy generation, and recreation. Dams are man-made barriers constructed across a stream or river channel to impound water, while reservoirs are artificial lakes formed behind the dams that store the water.

The primary purposes of dams and reservoirs include:

1. Water storage: Dams create reservoirs that supply water for various uses, such as irrigation, drinking water, and flood control.

2. Flood control: Dams help regulate the flow of water, reducing the risk of flooding and protecting downstream areas.

3. Hydroelectric power: Dams can generate electricity by harnessing the power of flowing water, making them an essential source of renewable energy.

4. Recreation: Reservoirs can be used for recreational activities like boating, fishing, and swimming, providing opportunities for public enjoyment.

Dams can be constructed from various materials, such as timber, rock, concrete, earth, steel, or a combination of these materials. Some of the most common materials used in modern dams are concrete and rock, which are often used in combination with non-erosive materials like concrete or rock for spillways.

There are numerous benefits of dams and reservoirs, but they can also have environmental impacts. Some of the environmental concerns associated with dams include the potential for habitat loss, alteration of natural water flow, and the release of greenhouse gases. To minimize these impacts, dams should be built at sites with the least environmental impacts and consider the rarity of species in the area.

In conclusion, dams and reservoirs are vital structures that provide essential services to human society, including water storage, flood control, and energy generation. However, it is crucial to consider the environmental impacts of these structures and strive to minimize their negative effects on the natural environment.

ROLE OF MECHANICAL ENGINEERING IN INDUSTRIES AND THE SOCIETY

Mechanical engineers play a key role in virtually ever human existence. Their expertise extends to machines, automobiles, aircraft, power generation, automotive components, manufacturing plants and more. The Mechanical ~~eg~~ Engineer's responsibility encompasses the conception, development and rigorous testing of machinery and thermal devices.

* In our society, the contributions of mechanical engineers are multi-faceted:

1. Power Generation: Mechanical engineers are at the fore front of designing and crafting power-generating machinery, spanning internal combustion engines, gas turbines.

2. Heating and Cooling Systems: Their expertise extends to the design and development, refrigeration and air conditioning systems.

3. Transportation: Mechanical engineers are instrumental in automobiles, trains, aircraft, steamships and boats, revolutionizing how we traverse the world.

4. Industrial Equipment: They contribute significantly to

the design, development and maintainance of industrial machinery and equipment, including machine tools, robotic and conveyor systems, optimizing manufacturing processes.

5. Product Design: Their creative prowess extends to conceiving diverse products.

6. Research and Development: Mechanical engineers are at the vagnguard of research, continuously exploring innovative and ideas and solutions that meet society's evolving needs and enhancing or advancing exisisting concepts.

7. Energy: They play a pivotal role in energy planning, distribution of power in industries involving natural gas, oil and alternative energy sources.

Technologies in Different Sectors

Energy Sector :-

1. Renewable Energy: Renewable energy sources such as solar, wind and geothermal power and being hamessed to mitigate environmental impact by reducing harmful emissions.

2. Internet of Energy (IOE): Traditional electric power systems often employ a centralized architecture during

constructions, posing challenges to the industry. The IOE addresses optimized designs for energy systems.

3. Energy storage: Energy storage system encompass a range of technologies including batteries, thermal, mechanical, pumped hydro and hydrogen storage. These system enhance the power supply reliability, promote resilient energy infrastructure and provide cost-saving benefits for utilities and consumers.

4. Block chain: Blockchains or distributed ledgers, have garnered significant interest from energy supply companies, start ups, financial institutions, governments, technology developers and academia.

5. AI and Machine learning: Artificial Intelligence (AI) and machine learning are revolutionizing the energy sector by leveraging vast amounts of data to optimise operations, enhance efficiency and reduce costs.

Manufacturing sector :-

1. Internet of Things (IoT) in Manufacturing:
Industrial IoT (IIoT) incorporates a multitude of sensors, RFID tags, software and electronics into industrial machinery and systems, enabling real-time data collection.

2. Big Data in Manufacturing: Industry 4.0 addresses

data integration challenges through big data, enabling pattern recognition and efficient problem-solving by harnessing insights from across the manufacturing floor.

3. Automation and Artificial Intelligence (AI) in Manufacturing:

AI powers demand planning, inventory management, logistics and production scheduling within automated systems. Advanced robots, driven by AI and machine learning, possess enhanced capabilities, including memory, agility and collaborative skills with humans.

4. Additive Manufacturing (3D Printing):

This technology minimizes material usage, reduces product development costs, optimizes space and enables flexible prototyping. Additive manufacturing also supports distributed manufacturing reducing transportation distances and costs and simplifying inventory management through the digital file storage.

5. Augmented Reality (AR):

AR and VR technologies empower maintainance technicians to perform maintainance tasks remotely, increasing efficiency. They provide valuable insights and enhanced visibility into various manufacturing processes, further improving efficiency.

Automotive Sector :-

1. Connectivity and Data Transmission:

As autonomous driving emerges, connectivity and transmission play a pivotal role in monitoring traffic, parking, object detection and engine control.

2. Surge in Demand for Electric Vehicles:

Electric vehicles (EVs) are gaining immense popularity and are projected to reach a marks value of USD 1,559.84 billion by 2030, with a CAGR of 21.9% from 2020 to 2030. Innovation in automotive software and unique designs are driving the growth of the EV industry.

3. Advent of 3D Printing Technology:

Automakers are embracing 3D printing to create robust vehicle exteriors capable of withstanding collisions. Solid-state chassis development is among the innovate applications of 3D printing in the automotive sector.

4. Autonomous Driving:

AI, machine learning and the global deployment of 5G technology are paving the way for autonomous vehicles and self driving capabilities. The reality of autonomous driving is on the horizon, promising safer and more efficient transportation.

5. Internet of Things (IoT):

IoT Technology enables vehicles to connect to the internet and exchange data with other devices, facilitating remote vehicle monitoring, predective maintainance and real-time traffic updates.

6. Autonomous Vehicles (AVs):

AVs reduce the dependence on human drivers, promising enhanced safety, convienience and efficiency. Advanced technologies such as AI-enhanced computer vision enable AVs to detect obstacles, minimizing accidents due to human error or fatigue.

Aerospace sector :-

1. Sustainability:

Biofuels and electric flight technology reduce dependence on fossil fuels, lowering carbon emissions. Energy-efficient integrations and novel designs enhance fuel efficiency, reducing emmisions and fuel costs.

2. Artificial Intelligence:

AI automates processes and reduces human errors, with machine learning and computer vision uncovering new insights from data. Optimization of routes, asset utilization and fuel efficiency is manned and unmanned flight operations benefit from AI.

3. Digitization: Digital technologies and smart factories drive

efficient production and faster design-to-delivery cycles. Process digitization streamlines supply chain operations and improve communication among stakeholders.

4. Additive Manufacturing:

Lower launch costs and Metal 3D printing expands additive manufacturing to critical aeroscape parts, enabling cost effective low-volume production. Smart materials offer stronger and lighter alternatives to traditional materials.

5. Blockchains:

Blockchain enhances data security and supply chain visibility in the aeroscape industry is automates access rights and entitlement management, improving traceability and efficiency.

6. Aerial Mobility:

Advancements include air taxis, drones for deliveries and emergency services and faster things technologies like super sonic and hypersonic flights. Electrical vertical Take-off and Landing (eVTOL) technology reduces carbon footprint and enables diverse applications.

Marine Sector :-

1. Artificial Intelligence (AI):

AI is used for predictive maintenance, autonomous navigation and route optimization. AI processes data from sensors, publi information systems and assest tracking to generate actionable insights.

2. Clean Energy:

Transitioning to low carbon, renewable energy sources is essential for decarbonizing marine operations. The industry explores electric propulsion, biofuels, wind and solar power and hydrogen fuel.

3. Maritime Robotics:

Maritime robots, equipped with AI and advanced hardware, address workface shortages and safety concerns. These robots assist in logistics, maintainance, cleaning, rescue and inspection including underwater tasks.

4. Maritime IoT:

Continuous tracking and monitoring of ships locations enhance navigation and saftey. IoT integration enables realtime data acquisition, including emissions, machine conditions and structural integrity.

5. Blockchain Technology:

Blockchain-based solutions improve transparency in maritime operations, offering free data flow. Applications include electronic documentation, payment processing and smart contracts tailored for maritime use.

6. 5G Technology:

Integration of IoT into offshore communication networks relies on high-speed, real-time information. 5G technology enhances search and rescue, acquaculture management, renewable asset monitoring and smart ports.

1. Role of Mechanical Engineering in Industries and Society

1. Mechanical engineer create and develop mechanical system for all of the humankind concern with principles of force, energy and motion. (or)

A mechanical engineer plays vital role in design, development, testing the machines and thermal devices.

2. Elemination of excessive usage of resource by the optimizing and improving efficiency.

3. To build things that make the world a better living place.

4. Reduce the human effort and makes works easy. It plays a key role in all the ways of like transportation, Medical, Agriculture defence and power generation.

5. Some of the upcoming projects were made by the mechanical engineers that is self-driving cars, hyper loop trains, Asteroid Re-direct missels by using there skills to improve safety, security and the efficiency.

6. Mechanical engineer has also played a key role in development of modern health care, Medical devices like Artificial joints, Pace makers and diayalsis

machines have all been designed and manufactured by mechanical engineer. Improving the lives of million of people around the world.

7. Another important impact of mechanical engineers on society is its contribution to manufacturing and industry have helped to design and build the machines that are used to manufacturing the products from textiles to electronics. This has helped to make manufactured more efficient and cost effective and has enabled companies to produced more products at a lower cost.

8. Mechanical engineering also helped to advance renewable engineering and energy technologys such as wind turbines and solar planes, and it reducing the fossil fuels usage. There are essentially to reduce the impact of climate change.

9. New challenges such as a need for environmental protection and security. Mechanical engineers provides innovetion design, construction, installation

and repair solutions for all the kinds of marine chemicals as off shore installation.

Applications:

1. Manufacturing of industrial equipments such as machine tools, belts, conveyors etc....

2. For the robotic field like welding, painting, Assemble lines, picking and placings for printed circut boats, packing, production, inspection, testing for increasing speed and precession.

3. Heating and cooling systems that is air conditioning, refrigrators, washing machines.

4. For the application of roads, buildings and bridges.

2. Ferrous and Non-Ferrous:—

classification of materials:-

Metallic materials are divided into two types

1. Ferrous materials

2. Non-ferrous materials

1. Non-ferrous materials:—

The bulk of non-ferrous materials are made up of alloys of copper, Aluminium, Magnesium materials, Nickel, Tin, lead, zinc. Other non-ferrous materials and alloys are used to lesser extent include cadmium, cobalt, zirconium, Berillyum, Titanium and the gold, silver and platinum.

1. Copper:

Properties of copper:-

1. High electrical and Thermal conductivity.
2. Good corrision resistance
3. Good machine ability
4. Good strength and easy fabrication
5. It is having pleasing colour and used in welded, brazing, soldering.

Applications of copper:

1. Most of the copper is used for electrical conductors contains 99.9% copper is identifyed.
2. It is also used for Roofing, gutters, Automobiles, radiators, pressure vessels etc.
3. Oxygen free copper is used in electronics tubes (or) similar appliances Because it makes a prefect seal to glass.
4. Arsenic copper contains 0.3% of Arsenic has improved

resistance to special corrosive conditions and used for heat exchangers.

5. For the applications of welding tips, switch gears by and other electrical equipments.

Copper base alloys:-

In most important commercial copper alloys may be classified as follows

1. Brasses
2. Bronze
3. Gun metal
4. German silver

1. Brasses:

* These alloys consists of copper and zinc and containing more than 5% zinc.
* It having 5-20% zinc are called has red brass.
* Having zinc content between 20-36% are called yellow brass.

Appliances:

1. Rivits
2. Screws
3. Jewellery

2. Bronze:

1. copper with other alloys except zinc is called as bronze.

2. It consists copper, silicon, Aluminium, Tin

Properties:

1. It has high strength

2. Toughness

3. It has good corrosive resistance

Applications:

1. springs

2. Taps

3. Bushes

3. German silver:

1. It consists of copper(cu), Ni, zn is called as German silver.

2. The percentage of silver is 0% in German silver

3. It has good corrision resistance

Applications:

1. Jewellery

2. Name plates

3. utensils

Alluminium and Aluminium alloys:

Properties of Aluminium:

1. It is good ductile and malleable in nature

2. It is light in weight.

3. It has very good thermal and electrical conductivity.

4. It has excellent corrisive resistance.

5. It carries more electricity than copper.

6. Aluminium is used for photographic reflectors.

7. Aluminium is non-toxic, non-magnetic and non-sparkling.

8. These are extensively used for cooking utensils, food and chemical handle etc.

Titanium Alloy:

1. It contains Titanium 87%, Al (6%), V (4%), fe (0.4%), cr (0.1)%.

2. Titanium is one of the allotropic material that is it can be exibits into two different crystal structure.

3. At room temperature it has a closed packed Hexagonal structure,

4. At raund 885°C, Titanium transfroms to body centred cubic structure.

5. which is stable upto a melting point around 1680°C

6. Titanium alloy can be classified into 3 groups that is α, β, $\alpha+\beta$.

7. It is light in weight than the steel and heavier than Aluminium.

8. It has high strength.

9. It has good corrosive resistance. It provides excellent

resistance to atmosphere and see environments as well as wide ranges of chemical including chlorine and containing chlorides, Titanium performs function of Global metal.

10. It has good electrical resistance.

Applications:

1. Surgical implants
2. Marine appliances.
3. Compressors and valved body's.

Ferrous metals:-

1. Ferrous materials may be defined as those metals whose main constituent is iron such as pig iron, wrought iron, steel and their alloys.
2. Ferrous materials are usually stronger and harder and used in daily life products.
3. Ferrous materials posses special property due to their characteristics can be altered by heat treatment process.
4. Ferrous metals has different physical properties according to their carbon components.

Wrought iron:

1. The meaning of wrought iron is metal which posses sufficient ductility in order to hot and cold working.

2. wrought iron is the purest iron with a small amount of slag.

3. It contains 99% of iron and remaining carbon, phosporous, Manganese, silicon, sulphur etc.

4. It has good corrosive resistance and helps to reducing shocks and vibrations.

5. It is tough, malleable and ductile

6. Good tensile strength

7. The melting point of wrought iron is 1530°C.

8. The wrought iron can be reheated to form bars, plates, railway coupling, bolds and nuts, chains and cooling towers.

Cast iron:

1. It consists of iron and carbon. The carbon content varies from 1.5 to 4%.

2. carbon present in the cast iron is graphite-state. Melting point of cast iron is lower than steel

3. Most of the castings produced by the cast iron poundry are grey cast iron.

characteristics:

1. very good casting characteristic.
2. Low cost
3. High compressive strength
4. Good wear resistance
5. Excellent machanability
6. It has limitation of Brittleness and low tensile strength.

Types of cast iron:

1. Grey cast iron
2. white cast iron
3. Malleable cast iron
4. Nodullar cast iron
5. chilled cast iron

1. Grey cast iron:

1. It is the iron which is most commonly used in foundary work.
2. If this iron is broken shows the greyish colour. Hence the name grey cast iron.
3. The grey colour is due to the fact that carbon is

present in the form of free graphite. Hence, structure act as a lubricant.

4. Good mechaniability.

5. High compressive strength.

6. Low Tensile strength and Ductility.

7. Manufacturing of steel, automobile cylinder Blocks and fly wheel.

White cast iron:

1. It is also called due to the whitish colour shown by its fracture. White cast iron contains carbon exessily in the form of cemintite.

2. It has poor mechanability and poor mechanical properties.

Nodullar castiron:

It is also known as spheroidal graphite iron.

It is obtained by adding magnesium to the molten cast iron.

It has good mechanical properties and less brittleness.

It appliances hydralic cylinder, pipes, walls, cylinder head, diesel engine.

Stainless Steel:

1. It is iron base alloy contains 1 to 20% chromium as there alloying element for improving corrosion resistance.
2. It has good thermal conductivity and also mechaineability.
3. It has high ductile in nature.
4. good surface finish
5. Do not rust easily in most of environment and media.
6. Medical equipments as easily stabilized and resistance to carrosion, cutting rods tools, food processing equipments.
7. containers to transportation of chemicals and liquids.
8. It is also used for to make common house hold items.

Steel:

Steel is it is defined as combination of Iron and low amount of carbon (0.15% to 1.5%)

Low carbon steels:-

The carbon percentage is 0.15% to 0.3% is called as low carbon steel

It has good ductility and softer

Applications of building and bridges, plates for biolers, tubes, Rivits.

Median carbon steel:

The carbon content 0.3 - 0.6% is called as medium carbon steel.

strong and less ductility.

Applications of pressure vessels, boiler drums hammers.

High carbon steel:

The carbon content 0.6 - 1.3% is called has high carbon steel

at has high wear resistance

less machineability

Manufactuing of springs, lathe tools, screw ~~driving~~ drivers etc.

3. Ceramics:—

ceramic materials are defined as the containing compound of metallic and non metallic elements.

1. The science of ceramics is the processing of earth materials by heat.
2. The crued cooking utensils of early man were the first application of materials now used in jet engines and atomic reactors.
3. All the ceramic products were made from clay. Because, they were easily formed. It was dried and fired to develop the permanent structure.

classification of ceramics:

1. Functional classifications:-

1. Abrassives :- Alumina, carbondem
2. Pure oxide ceramics :- MgO_2, SiO_2
3. Fine clay products:- Bricks, Tiles etc
4. Inorganic glasses:- window glass, lead glass.
5. cement materials:- portland cement, Lime, rocks, granites, sand stone etc.

6. Minerals :- Quartz

7. Refactories :- silica bricks.

b. structural classification

1. crystalline ceramics

2. None crystalline ceramics

3. Glass bonded ceramics

4. cements

c. classification of ceramic products :-

1. white wears

2. chemical stone weares

3. Abrassives (Al_2O_3)

4. Bricks & Tiles

5. cement & concrete

6. Glass

7. Electrical porcelain.

Advantages of ceramic materials:

1. The ceramics are hard & strong.

2. They have high resistance to action of chemicals

3. High compressive strength than the Tensile.

4. They offer excellent dielectric property.

5. They are good Thermal insulators.

6. Availability is good.
7. Good sanitation
8. Better economy

Applications:

1. Manufacturing of Piles
2. low & high voltage of insulators.
3. High frequency applications
4. chemical industry as crucible & Jars.
5. Industrial furnaces.
6. Electrical & Electronic industries
7. optical applications
8. Internal combustion engines
9. Electronic packaging.

Properties of ceramic materials:

Mechanical properties

1. The compressive strength is several times more than the tensile strength
2. Non ductility
3. As compared to pure metals more force is required to cause slip.

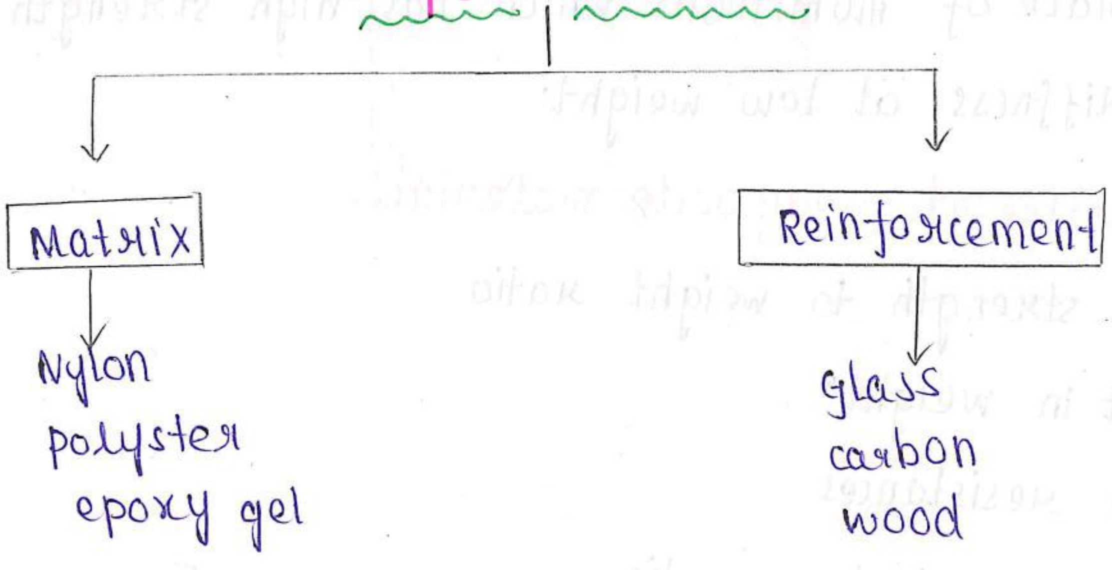
Electrical properties:

1. It has good dielectric constant.
2. The dielectric constant for porcelins various between 4.130 to 11
3. It has good dielectric strength.

Thermal properties:

1. It has good thermal capacity.
2. It has good thermal conductivity.
3. Thermal shock & vibrations.

4. Composite Materials



A composite materials is a material combination of two (or) more engineered material & donot dissolved into one another. (or)

The composite material is a material that consists of one (or) more discontinuous components (fibers) or Reinforcement) that are placed in a medium (matrix) wood composities are commonly seen example of composite materials.

Features:-

Mechanical properties:

1. combination of two (or) more materials that are used in combination to retify a weakness in one material by a strength in another.

2. Fibre Reinforced composite where first developed to replace of Aluminium which has high strength and stiffness at low weight.

Properties of composite materials:

1. High strength to weight ratio
2. Light in weight
3. Fire resistances
4. Good electrical properties
5. chemical & weathering resistances.
6. Fine colour
7. Design Flexibility.
8. It has less thermal conductivity.

Advantages:

1. low density.
2. High mechanical properties four times greater than steel and Al.
3. High toughness than ceramics.
4. good corrisive resistance.
5. versatile design

Applications:

1. Airospace Applications
2. Automotive & road transportation.
3. construction of buildings & bridges.
6. Design of furnitures and home.
7. Electronics industries
8. Marino transportation and ship buildings.
9. Bath tubs
10. swimming pool pannels
11. Boat hull bodies etc..

classification of composite materials:

1. organic matrix composites (OMC)
2. Polymer matrix composites (PMC)

3. carbon-carbon matrix composites (C-CMC)
4. ceramic matrix composites (CMC)
5. Metal matrix composites (MMC)

1. Polymer matrix composites:-

on the basis of polymer region is used to made the (PMC)

These can be classifyed into two types:-

1. Thermo plastic composites
2. Thermo setting composites

1. Thermoplastic composites:-

1. This type of composite materials consits thermo plastic resin like "polyster & Nylon".
2. These can be recycled.
3. It as loss the strength during at high temperature, so that less toughness, rigidity.
4. If temperature raises above the melting points become easily converts the shapes. Due to high viscocity causes problem during penetration into reinforcement.
5. Manufacturing of automobile control panels,

electronic products, pens, carry bags etc.

2. Thermo setting composites:-

1. These are cannot be recycled.
2. In this composites epoxy is used.
3. These are permenantly used plastic composites.
4. They are most commonly used type of composites in automobiles, Aeroscope, switch boards and flying plan.

Smart materials:—

Smart materials, also known as intelligent materials, are substances endowed with the capacity to alter their physical properties in specific ways in response to stimuli. These stimuli can encompass factors such as pressure, temprerature, stress, moisture, pH, light, electric and magnetic fields, chemicals and nuclear radiation, among others. The adaptable physical properties that smart materials can exhibit include changes in shape, stiffness, viscosity and damping among others.

Types of Smart Materials:

1. Piezoelectric Materials.
2. Shape Memory Alloys.
3. Magnestostrictive Materials.
4. Electro-Rheological Materials.
5. Magneto-Rheological Materials.

Advantages of smart Materials:

1. High Energy Density.
2. Excellent Bandwidth
3. Simplified Packaging
4. Unique Functions, such as the significant volume change exhibited by smart gels in response to temperature

variations.

Disadvantages of smart Materials:

1. Complex Thermo-Mechanical Behaviour.
2. Lack of Biodegradability.
3. Potential for Environmental Pollution.
4. High production costs
5. Uncertain long-Term Effects
6. Possible Global Impact

Applications of smart Materials:

1. Accelerometers (eg: stabilizing quadrotors)
2. strain sensors.
3. Emitters and Receivers of stress waves
4. Active Vibration control in stationary and Moving structures (eg; helipcopter blades)
5. smart skins for submarines
6. Piezoelectric Materials with skin like properties for sensing Temperature and pressure. thermochromic paper polymers and inks.
7. Utilization in Thermochromic Technologies, including liquid crystals, leuco dye, thermochromic paper, polymers and inks.
8. Implementation in photochromic Lens Technology.

Metal Casting

2:1 Introdution:

Casting is one of the oldest manufacturing processes, and even today is the first step in manufacturing most products. In this process, the material is first liquefied by properly heating it in a suitable furnace. Then, the liquid is poured into a previously prepared mould cavity where it is allowed to solidify subsequently, the product is taken out of the mould cavity, trimmed and cleaned to shape.

2.2 :Steps Involved In Making Castings.

i) Preparation of moulds and patterns [used to make the mould]

ii) Melting and pouring of the liquefied metal.

iii) Solidification and further cooling to room temperature.

iv) Defects and inspection.

2.3: Advantages of Metal Casting:

Metal castings have the following advantages.

1) It is one of the most versatile manufacturing processes.

2) Casting provide uniform directional properties and better damping capacity to cast parts.

3) Intricate shaped components that are difficult to produce by other methods can be produced by casting.

4) Very complicated components can be cast in one piece. It eliminates many joining processes.

5) Metals like cast iron that are difficult to shape by other processes can be cast.

6) The casting process can be modernized by suitable mechanism for mass production of components.

7) Very heavy and bulky parts that are difficult to form by other process can be cast.

8) Casting provide greatest freedom of producting components in terms of design, shape, size and quality.

9) The overall cost of the components is low.

2.4: Applications of Metal Castings:

Great advances have taken place in foundry engineering due to lower cost and the above-mentioned advantages. There is hardly any product in engineering. Which doesn't have one or more cast components casting find the following applications in engineering.

i) Road transportation and vehicles – more than 90% automobile engine components more than 35% of car truck, bus components and more than 50% tractor components by weight are made by casting.

ii) Aeroplanes – more than 30% components used by weight in aeoplanes are cast components.

iii) Machine tool structures – beds of machines like planer, shaper, milling, lathes etc. are cast in cast iron.

iv) Paper mill stock breaker parts are castings of steel.

v) Defence – more than 50% components used in defence are cast.

vi) Cast components are used in communication, construction and atomic energy.

vii) Aircraft jet engine blades.

viii) Agricultural parts.

ix) Turbine vanes.

x) Sanitery fittings.

xi) Fish plates used in railways.

xii) Super charger castings.

xiii) Mill housings.

2.5: Disadvantages of Castings:

1) Casting is a very high energy consuming process. For example, about 2000Kwh of power is required to produce a ton of finished steel casting.

2) Casting process is a highly labour-intensive compared to the other processes.

3) The quantum of raw materials required for producing casting is quite high and needs large buildings, handling systems, large space, and inventory costs. For example, for producing one ton of steel castings about 2.2 tons of metal, 0.3 ton of parting sand and 4tons of moulding sand are needed apart from fuel and many other materials.

4) Time involved for manufacturing is more when compared to the machining processes.

5) The environmental pollution is high.

Imp
1 MARK

Pattern Making Materials

1. wood
2. Metals
3. Rubber
4. wax
5. plastics.

Principles of Gating

4.1 Gating System: V.V Imp

The term gating system refers to all the passageways through which the molten metal passes enter the mould cavity. Since the way in which the liquid metal enters the mould has a decided influence upon the quality and soundness of the casting, the different components of a gating system should be carefully designed and produce. Different components of a gating system of shown in Fig: 4.1.

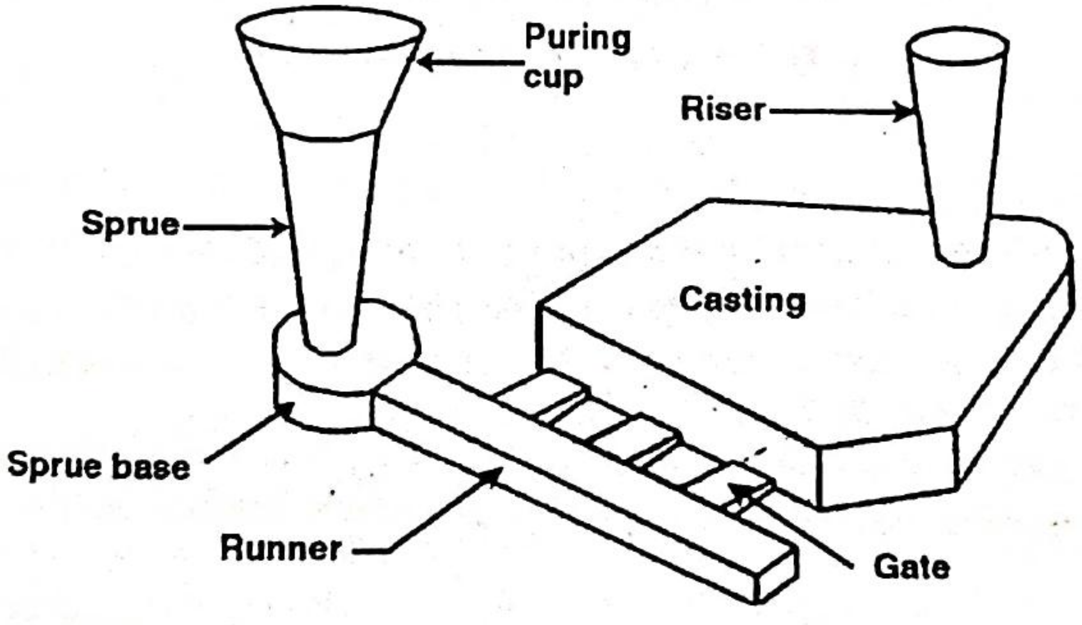


Fig. 4.1: Components Of Gating System

4.1.1 Pouring Cup

The molten metal is not directly poured into the mould cavity because it may cause mould erosion. Molten metal is poured into a pouring cup or basin, which acts as a reservoir from which it flows smoothly into the sprue.

4.1.2 Sprue

Sprue helps in feeding metal to the runner, which in turn reaches the cavity through the gates. The sprue may have either straight or taper shape.

4.1.3 Spruebase

This is a reservoir for the metal at the bottom of the momentum of the falling molten metal. The molten metal, as it moves down the sprue, gains in velocity, some of which is lost in the sprue base well, and the mould erosion is reduced. This molten metal changes direction in the spruce base and flows into the runner in a more uniform way.

4.1.4 Runner

Runner is used to take the molten metal from the sprue base and distribute it to several single gate, the runner may not be required.

4.1.5: Gate

The gate is a channel, which connects runner with the mould cavity and through which molten metal flows to fill the mould cavity.

4.1.6: Riser

A riser is a hole cut or moulded in the cope to permit the molten metal to rise above the highest point in the casting. The riser serves as a feeder to feed the molten metal into the main casting to compensate for its shrinkage during solidification. If the metal does not appear in the riser, it indicates that either the metal is insufficient to fill the mould cavity or there is some obstruction to the metal flow between the sprue and the riser.

tions.

7.2 Centrifugal Casting Methods :-

Several Centrifugal casting techniques are in common use and are usually classified as,

1. True centrifugal casting
2. Semi – centrifugal casting
3. Centrifuge casting

a. Metal molds prove to be economical when larger quantities of castings are required to be produced

b. De lavaud process makes use of metal molds.

c. Figure 7.8 shows the essentials of de Lavaud casting process.

d. The de lavaud casting machine contains an accurately machined metal mold (die), entirely surrounded by cooling water

e. The machine is mounted on wheels and it can be moved length wise on a slightly inclined track.

f. At one and of the track there is a ladle containing proper quantity of liquid metal which flows though a long pouring spout initially inserted to the for extremity of the mold.

g. As pouring proceeds the rotating mold i.e., the casting machine is moved slowly down the track so that the metal is laid progressively along the length of the mold wall following a helical path; control being achieved by synchronising the rate of pouring, mold travel and speed of mold rotation.

h. After completion of the pouring, the machine will be at the lower end of its track with the mold rotating continuously till the pipe has solidified

i. The pipe, after it has solidified, is extracted from the metal mold by inserting a pipe puller which expands as it is pulled.

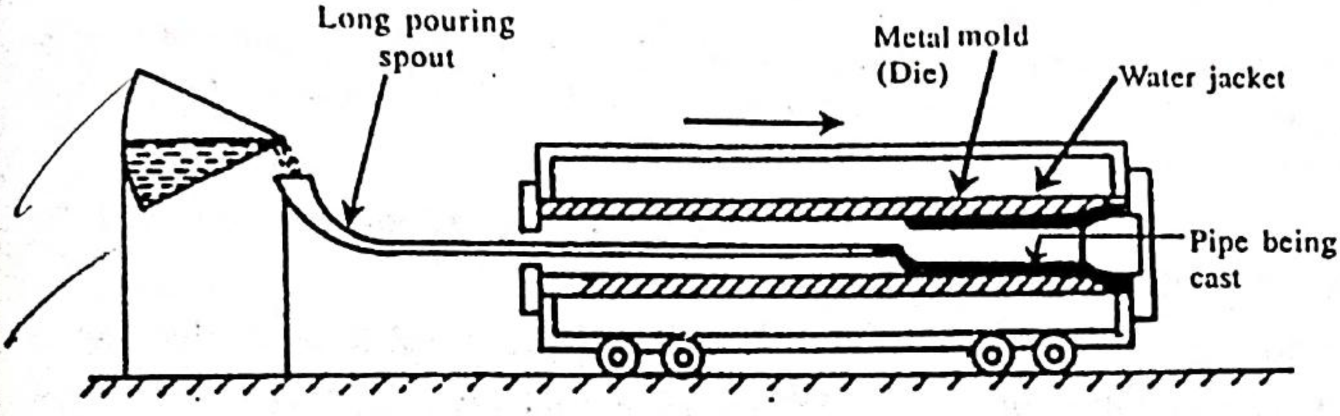


Fig : 7.8 De Lavaud casting machine.

7.2.1.2 Advantages of true centrifugal Casting :

1. Relatively lighter impurities within the liquid metal such as sand, slag, oxides and gas float more quickly towards the centre of rotation from where they can be easily machined out thereby giving clean metal casting.
2. Dense and fine grained metal castings are produced by true centrifugal casting technique (for the reasons explained under introduction).
3. Except with castings having greater wall thickness, there is proper directional solidification from outside (surface) towards inwards of the casting.
4. There is no need of a central core to make a pipe or tube.
5. Gating system is not required; this raises casting yield as high as 100% in certain cases
6. True centrifugal casting may be adopted for mass production.

7.2.1.3 Disadvantages

1. True centrifugal casting is limited to certain shapes
2. Equipment costs are high.
3. Skilled workers are required for operation and maintenance

7.2.1.4 Applications :

1. Bearings for electric motors and industrial machinery
2. Cast iron pipes, alloy steel pipes and tubings.
3. Liners for I.C. Engines
4. Rings, short or long pots and other annular components.

7.3 Die casting

Die casting machines perform the following functions:

1. Holding two die halves firmly together
2. Closing the die
3. In jecting molten metal into die
4. Opening the die
5. Ejecting the casting out of the die

Die casting machines are of two types

a. Hot chamber die casting machines

b. Cold chamber die casting machines.

7.3.2. Cold Chamber Die Casting :-

In these machines, the metal is melted separately in a furnace and transferred to these by means of small hand ladle. After closing the die, the molten metal is forced into the die cavity by a hydraulically operated plunger and pressure is mainted till solidification. These machines can either have vertical plunger or horizontal plunger for forcing molten metal into die. These machines are widely used for casting a good number of aluminium alloys and brasses

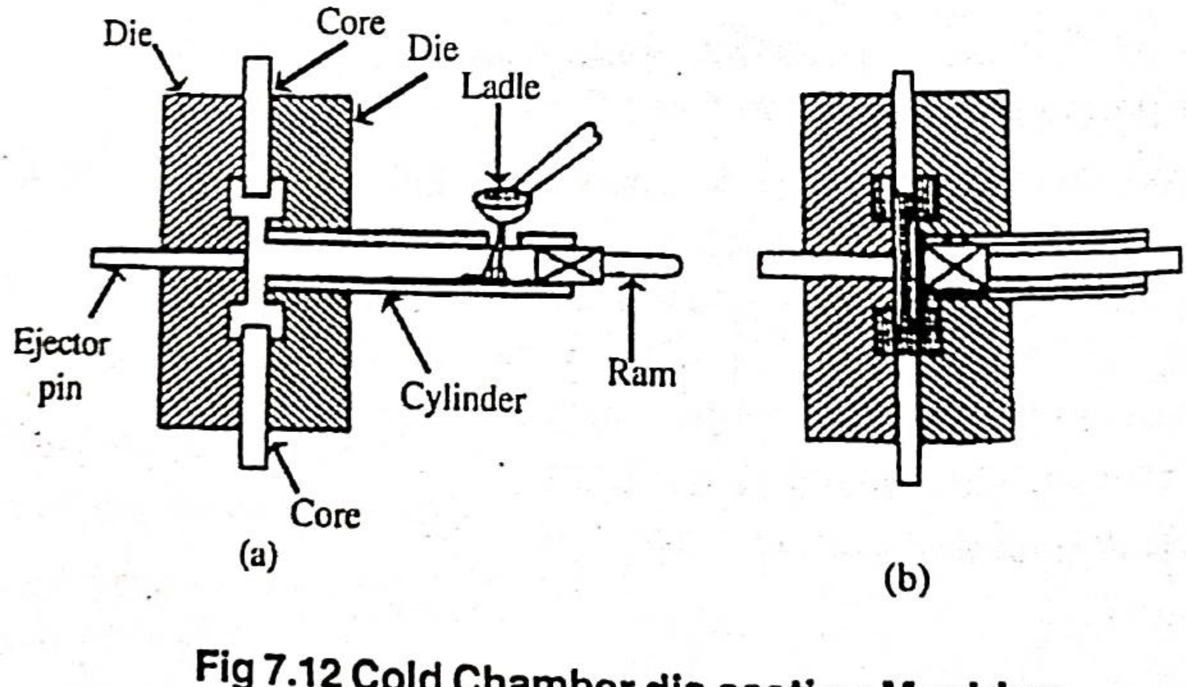


Fig 7.12 Cold Chamber die casting Machine

7.3.3 Advantages of Die Casting :

1. It requires less floor space
2. Die casting provides for precision manufacture with a subsequent reduction in machining cost.
3. Thin sections of the complex shape are possible
4. High production rate
5. Greater surface finish
6. Inserts can be easily cast in place
7. Die castings are less defective than sand casting
8. The increased soundness and reduction of defects provides increased yield.
9. The labour cast involved is less
10. Threads and other fine surface details can be easily obtained
11. A number of nonferrous alloys can be die cast
12. The die has a long life. It is possible to produce 1,00.000 castings in case of zinc base alloys and 75,000 castings in case of copper base alloys.

7.3.4. Limitations of Die Casting :-

1. The cost of die and equipment is high
2. The life of die decreases rapidly it metal temperature is high
3. Ferrous alloys are not cast and moreover a limited number of nonferrous alloys can be economically die-cast.
4. The size of the casting is limited.
5. The air in the die cavity gets trapped inside the casting and creates porosity.
6. Special skill is required for maintenance and supervision of die
7. The minimum economic quantity for die casting is around 20,000
8. Die casting technique requires comparatively a longer period of time for going into production (Set up time, preparation time)
9. In certain cases, dies may produce an undesirable chilling effect on the die casting.

7.3.5 Applications of Die Casting :

1. Die casting process has been used for many non-ferrous metals and alloys such as zinc, Aluminium, copper, magnesium, lead and tin.
2. Automobile parts
3. Marine uses
4. Domestic appliances
5. Instruments
6. Parts of the refrigerators, washing machines, television, typewriters, Projectors, Radio, Binocular, Camera
7. Lead base alloys are used in radiation shielding, battery parts, light duty bearings etc.

Welding

9.1. Introduction :-

Welding process can be defined as the process of metallurgically joining two pieces of metals by fusing to produce essentially a single piece of the metal. Welding technology is more than 2500 years old with the advancements that have taken place in the welding technology, almost all metals are weldable provided that the proper process and techniques are used. By using proper techniques, it is possible to weld even plastics and glasses.

The welding process joins two pieces of metals by alloying intense heat or pressure or both to melt the edges of the metal so that they fuse permanently. The joint formed is a permanent joint. In welding, filler material may also be used. The heat required for the process of welding can be obtained by using an electric arc, electric current, gas flame or chemical reaction. The process of welding can be done with or without the application of pressure.

9.3. Advantages of Welding :-

Welding has the following advantages.

1. It produces a permanent joint.
2. The overall cost of welding equipment is generally low.
3. Many portable welding instruments are available.
4. A large number of metals can be welded.
5. A good weld is as strong as the base metal.
6. Welding can be employed from limited portion to any length.
7. Welding operations can be mechanised for production.

9.4. Disadvantages of welding :-

1. Welding creates residual stresses and distortion in workpieces
2. Edge preparation is generally required before welding.
3. A skilled welder is essential for performing a good welding operation.
4. Since welding produces internal stresses, the work piece often requires annealing or stress - relieving.
5. Welding produces structural, physical and chemical changes.
6. Jigs and fixtures are needed to hold parts in position
7. Welding gives off harmful radiations like light, fumes and spatters.

9.5. Applications of Welding :-

The economics and improvements brought about by the welding process have made it an outstanding tool for manufacturing, construction, maintenance, etc. Some of the broad fields of application have been listed here :

a. Aircraft industries
b. Boilers, pressure vessels, drums, tanks etc.
c. Construction of bridges,
d. Building construction
e. Cutting tools and dies
f. Earth moving equipments
g. General maintenance and repairs
h. Pipe manufacturing
i. Nuclear power plants, etc.

Welded Joints

10.1. Types of Welding Joints :-

The type of joint defines the relative positions of joining and welding of two pieces. The basic types of joints are : butt joint, lap joint, corner joint, and T - joint that are shown in Fig 10.1. The position of welding is marked with a cross (×) in each case.

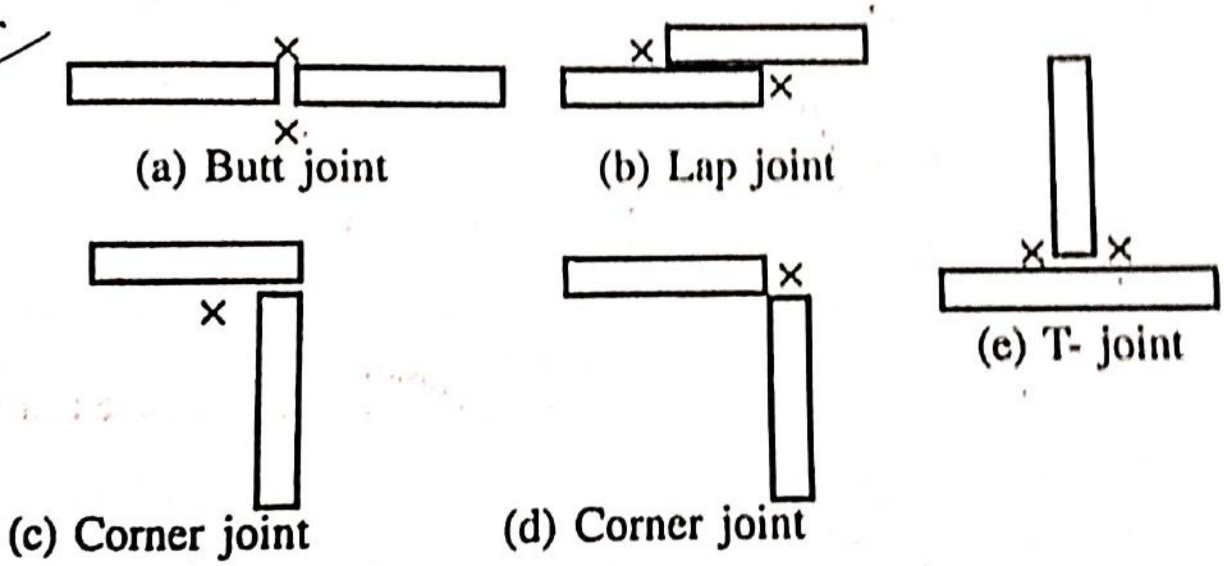


Fig : 10.1 Different types of joints :

10.2. Types of Welds :-

Fig 10.2 shows the various types of welds used in making a joint. A 'bead' weld is one in which the filler metal is deposited at a joint where the two surfaces adjoining the joint are in the same plane. A 'bead' is defined as a single run of weld metal. A "fillet" weld is one in which the filled metal is deposited at the corner of two intersecting surfaces, such as a T or Lap joint. A "groove" weld is one in which the filler material is deposited in a groove formed by edge preparation of one member or of the both the members. A "plug" or "slot" weld is one in which a hole is formed through one of the pieces to be welded and the filler material is then deposited into this hole and fused with the mating part.

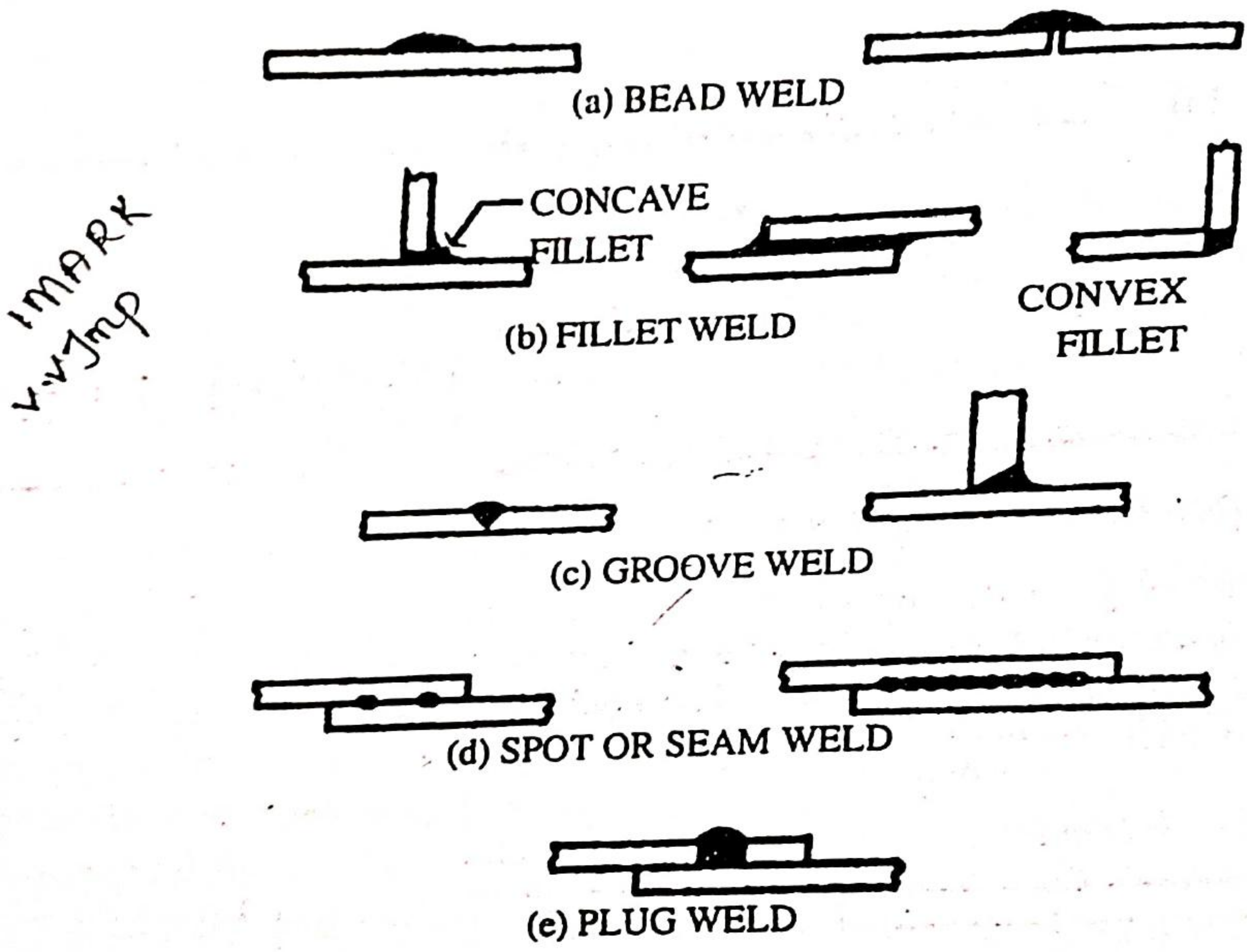


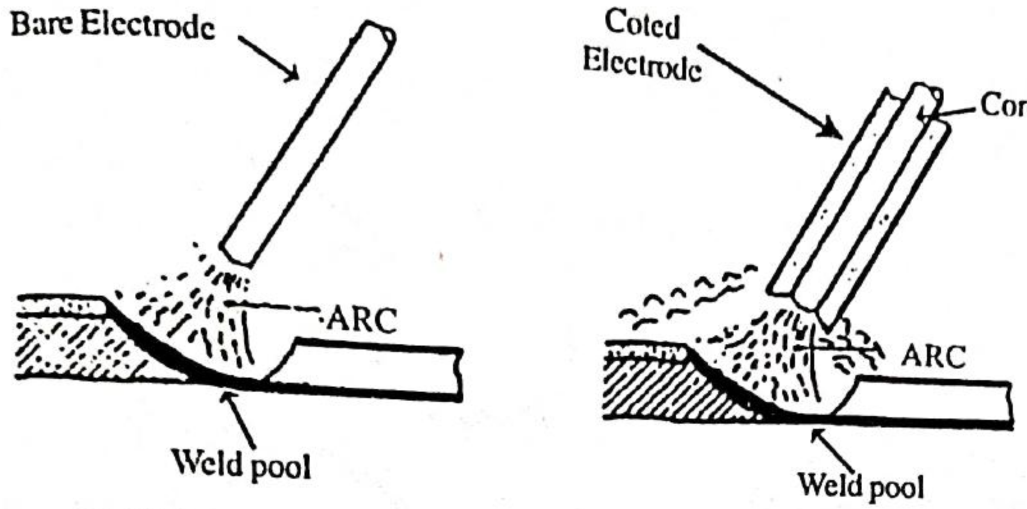
Fig : 10.2 : Types of Welds

1.3. Arc Welding :-

1.3.1 Principle of Arc Welding :-

The source of heat in this process is an electric arc. The electric are evelops when current flows across the air gap between the end of metal lectrode and the work surface. Thus are is strong stable electric discharge ccuring in the air gap between the end of metal electrode and the work urface. This arc is strong stable electric discharge occuring in the air gap etween an electrode and the work. The temperature of this arc is about 3600°C which can melt and fuse the metal very quickly to produce joint. The emperature of the arc at the centre is around 6500°C only 60 to 70 percent of he heat is utilised in arc welding to heatup and melt the metal. The remaining 0 to 30 percent is dissipated into surroundings.

The principle of arc welding is based upon the formation of an electric rc between a consumable electrode (bare or coated) and the base metal. The eat of the arc is concentrated at the point of welding; as a result, it melts the lectrode and base metal. When the weld metal solidifies, the slag gets eposited on its surface as it is lighter than metal and weld metal is allowed to ool gradually and slowly. After cooling (Solidification) a sound joint is formed. The slag is removed by chipping hammer. The principle of arc welding is shown in Fig 11.5.



(a) ARC WELDING

(a) SHIELD ARC WELDING

Fig : 11.5 : Principle of arc welding

11.3.2 The sequences of steps involved in arc welding operation :-

1. Preparation of edges
2. Holding the workpiece in a fixture
3. Stricking the arc, and
4. Welding the joint.

11.3.3 Arc welding Equipment and Accessories :-

In arc welding process, the source of heat is electricity. The required electrical energy (high ampere-low voltage) is obtained by an arc welding equipment. The functions of such equipment are.

1. To provide AC or D.C. welding supply for arc welding.
2. To change the high voltage of the main supply (Ac) to low voltage and heavy current (Ac or Dc) suitable for arc welding.
3. To control and adjust the required welding current during arc welding

The equipment and accessories (Fig 11.6) required for electric arc welding usually consists of

1. Equipment to provide the welding current
   a. Transformer (for a.c)
   b. Generator or rectifier (for d.c)

2. Accessories

a) Electrodes

b) Electrode holder

c) Cables

d) Safety devics and

e) Tools

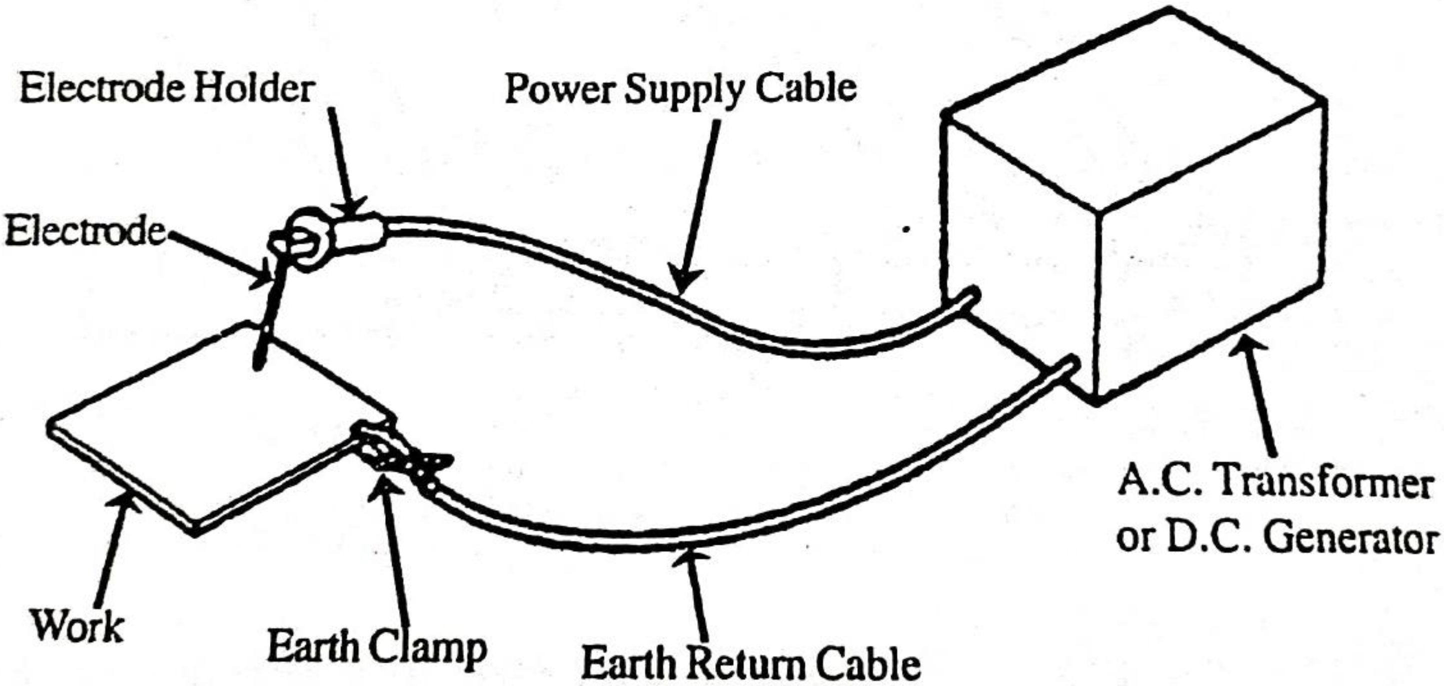


Fig : 11.6 : Manual Metal Arc Welding Equipment

11.3.4 Advantages of Arc Welding

1. Metal arc welding is faster and lower in cost than gas welding.
2. The process is a quite versatile and welds can be made in any position.
3. Suitable for wide range of metals [ferrous and non - ferrous] and their alloys.
4. Less sensitive to weld than other processes.

11.3.5 Disadvantages of arc welding :

1. The process is not suitable for thin sections.
2. The process is not suitable for mechanisation.
3. Electrode replacement is necessary for long joints
4. Not suitable for heavy fabrications because less metal is deposited per hour.
5. Failure to remove the slag when run is interrupted. This will result in slag inclusions in the weld.

11.3.6 Applications of arc welding :

The Manual Metal Arc welding (MMAW) has a wider field of application. It is employed for fabrication of pressure vessels, ships, structural steel work, joints in pipe work, construction and repair of machine parts.

This process can also be used hard facing and repairs of the broken parts.

11.3.4 Advantages of Arc Welding

1. Metal arc welding is faster and lower in cost than gas welding.
2. The process is a quite versatile and welds can be made in any position.
3. Suitable for wide range of metals [ferrous and non - ferrous] and their alloys.
4. Less sensitive to weld than other processes.

11.3.5 Disadvantages of arc welding :

1. The process is not suitable for thin sections.
2. The process is not suitable for mechanisation.
3. Electrode replacement is necessary for long joints
4. Not suitable for heavy fabrications because less metal is deposited per hour.
5. Failure to remove the slag when run is interrupted. This will result in slag inclusions in the weld.

11.3.6 Applications of arc welding :

The Manual Metal Arc welding (MMAW) has a wider field of application. It is employed for fabrication of pressure vessels, ships, structural steel work, joints in pipe work, construction and repair of machine parts.

This process can also be used hard facing and repairs of the broken parts.

11.5 Resistance Welding :-

All of us know that when electric current flows through a wire, it generates heat due to the resistance offered by the metal of the wire to the flow of electrons. In resistance welding, the heat required for welding is produced by means of the electrical resistance between the two members to be joined. This process is also known as electric welding.

11.5.1 Advantages of Resistance Welding :-

1. Fast rate of production
2. No filler rod is needed
3. Semi - automatic equipments
4. Less - skilled workers can do the job.
5. Both similar and dissimilar metals can be welded.
6. High reliability and reproducibility are obtained
7. More general elimination of warping or distortion of parts.

11.5.2 Disadvantages of Resistance Welding :-

1. The initial cost of equipment is high.
2. Skilled persons are needed for the maintenance of equipment and its controls.
3. In some materials, special surface preparation is required
4. Bigger job thickness cannot be welded.

11.5.3 Applications of Resistance Welding :-

Resistance welding is used for

1. Joining sheets, bars, rods and tubes.
2. Making tubes and metal furniture
3. Welding aircraft and automobile parts.
4. Making cutting tools.
5. Making fuel tanks of cars, tractors etc.
6. Making wire fabric grids, grills, mesh weld, containers etc.

11.6. Spot Welding

It is the simplest and most commonly used method of overlap welding of strips, sheets or plates of metal at small areas.

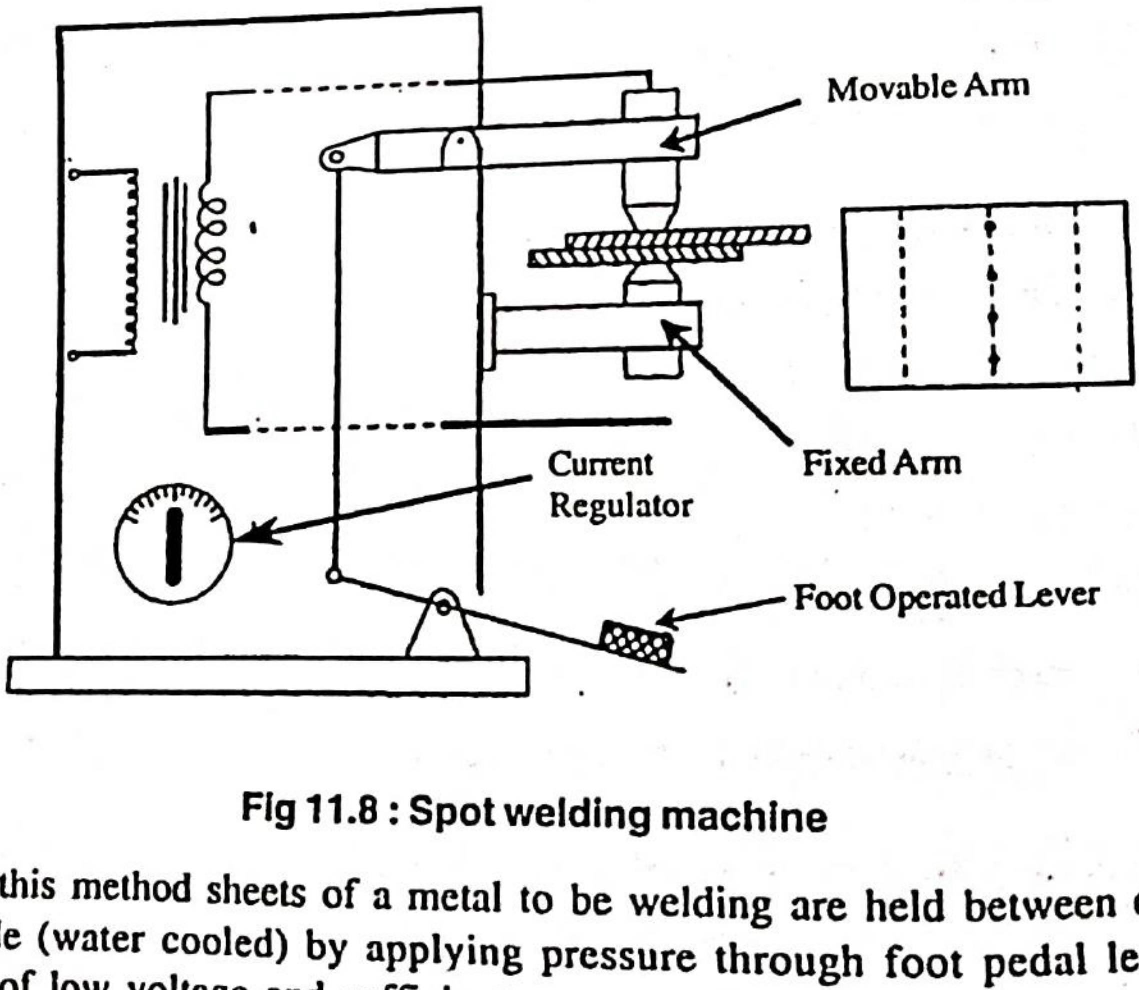


Fig 11.8 : Spot welding machine

In this method sheets of a metal to be welding are held between copper electrode (water cooled) by applying pressure through foot pedal lever. A current of low voltage and sufficient amperage is passed between electrode causing the parts to be brought to welding temperature. The metal under electrode pressure is squeezed and welded. After this the current is turned off while the pressure is still acting. The pressure is applied till the weld cools and produce a solid bond. Now the pressure is released and the work is removed from the machine.

11.6.1 Advantages :

i) No edge preparation is needed.

ii) Low cost.

iii) High speed of welding.

11.6.2 Applications :-

i) This technique is used mostly in thin sheet work like making sheet metal boxes, containers such as receptacles

ii) Thicker metals up to 12.5mm have been successfully spot welded.

iii) It finds application in automobile and air craft industries.

Non-Conventional Machining Process

Non-conventional machining processes, unlike their conventional counterparts, do not necessitate direct contact with the workpiece to remove material. In these processes, machines do not require direct interaction with the cutting material, offering a unique approach to precision machining. Various types of non-conventional machining processes exist.

8. **Electrical Discharge Machining (EDM):** The EDM (Electrical Discharge Machining) process, alternatively referred to as spark machining, die sinking, wire erosion, or wire burning, achieves material removal through erosion. In this method, direct contact between the workpiece and the tool is not necessary, making it particularly well-suited for machining materials that are susceptible to distortion.

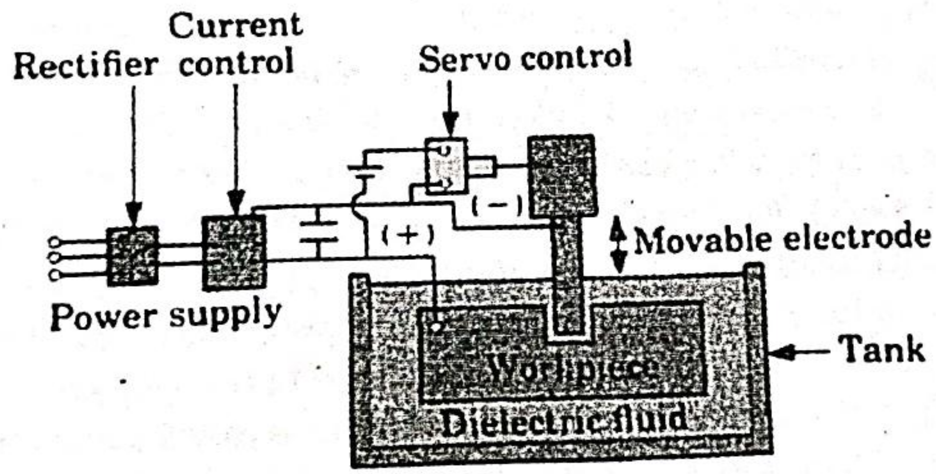


Fig. 2.26: Electrical Discharge Machining

Electrical discharge machining is well-suited for precision cutting of highly durable and demanding exotic materials, achieving exceptionally tight tolerance levels. While EDM may have a relatively slow material removal rate, the resulting products or parts often require minimal or no additional polishing.

ranging from 0.18mm to 0.8mm.

12. Ultrasonic Machining (USM): Ultrasonic machining is a precision machining process that achieves material removal from a workpiece's surface through the application of low-amplitude, high-frequency vibrations. This process takes place while a fine abrasive particle slurry, formed by mixing abrasive particles with water, is present. The abrasive particles vary in grain size, typically ranging from 100 to 1000.

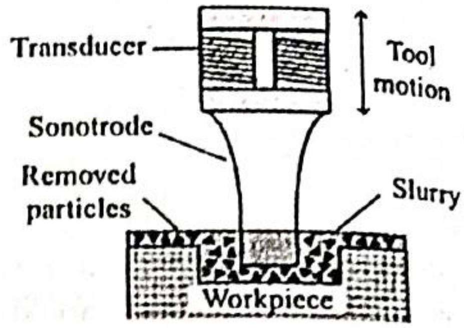


Fig. 2.30: Ultrasonic Machining

Ultrasonic machining distinguishes itself by using smaller grain sizes (higher grain numbers) and generating less heat, resulting in exceptionally smooth surface finishes. This type of machining is particularly well-suited for materials with high hardness or brittleness. Additionally, the vibratory motion involved in ultrasonic machining facilitates the creation of hole-cut shapes with ease.

13. Electronic Beam Machining (EBM): Electronic Beam Machining (EBM) is a machining process that concentrates and focuses electrons onto a specific small spot on a metal material. This method is particularly well-suited for machining extremely hard or brittle materials that are not amenable to conventional machining techniques.

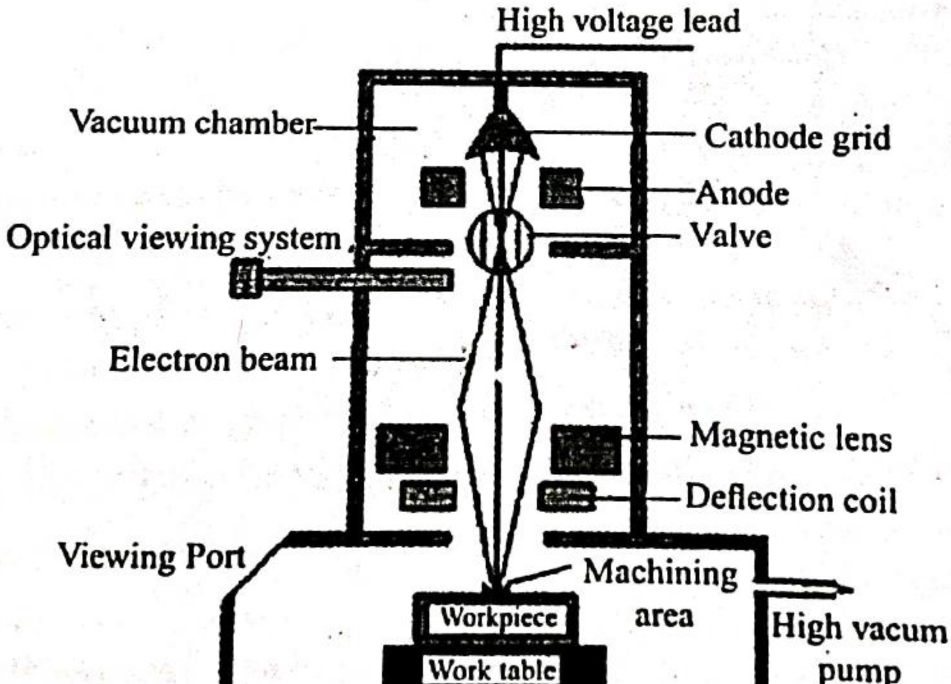


Fig. 2.31: Electronic Beam Machining

Moreover, EBM boasts lower tooling and setup expenses. Furthermore, it imposes no constraints on geometric shapes during machining, enabling the creation of extremely small holes with exceptional precision. Consequently, EBM stands out as an exceptional method for achieving micro-finishing.

14. Laser Beam Machining (LBM): The Laser Beam Machining (LBM) process utilizes a laser beam and heat energy to eliminate materials from a workpiece. This versatile method is well-suited for both drilling and cutting applications, enabling the machining of intricate geometries and the creation of very small holes in hard materials. LBM also excels in partial cutting, engraving, steel metal trimming, resistor trimming and blanking processes.

Furthermore, LBM boasts a high cutting speed and the capability to cut shallow angles effectively. This makes automating intricate cutting patterns a straightforward task. Importantly, LBM is a non-contact process, eliminating concerns about tool wear or breakage during machining.

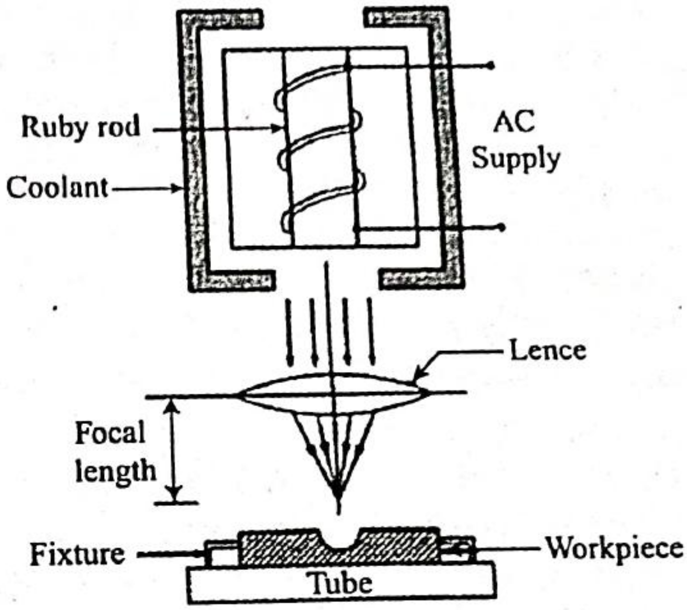


Fig. 2.32: Laser Beam Machining

Advantages:

- Suitable for machining a wide variety of work materials.
- Primarily used for cutting metals.
- Capable of producing parts with diverse shapes and complex geometric features such as screw threads, precise round holes, straight edges and smooth surfaces.
- Offers good dimensional accuracy and surface finish.
- Achieves close dimensional tolerances and desired surface textures/finishes.
- Effective for machining complex-shaped and large-sized components.

Disadvantages:

- Relatively higher process costs.
- Requires skilled operators.
- Generates material wastage in the form of chips.
- May necessitate stress-relieving processes.

Applications: Machining of various engine parts, shafts, holes, grooves, threads, tapers, keyways, gears and typical profiles in a wide range of materials.

2.2.9 Components of Electric Vehicles

Electric vehicles (EVs) rely on electricity as their primary source of power, either as the sole fuel or to enhance the efficiency of traditional vehicle designs. The category of EVs encompasses battery electric vehicles (BEVs), often called all-electric vehicles, as well as plug-in hybrid electric vehicles (PHEVs). These vehicles are commonly referred to as electric cars or simply EVs and they are renowned for their immediate torque delivery and quiet driving experience.

An electric vehicle is an automotive mode of transportation propelled by one or more electric motors, utilizing electrical energy stored in an energy storage device. The fundamental components within electric vehicles consist of the motor, controller, power source and transmission.

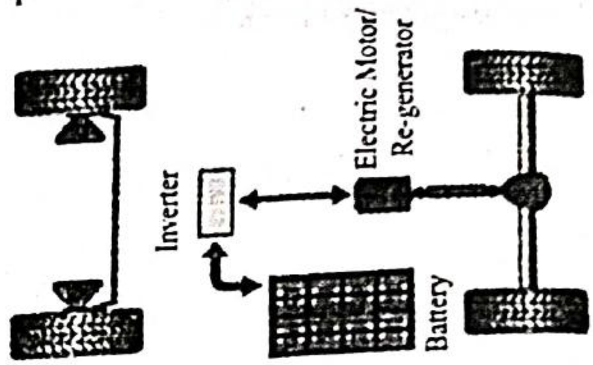


Fig. 2.53: Electric Vehicles

Electric Vehicle Components: Electric vehicles (EVs) consist of several key components:

- **Motor:** The motor is responsible for propelling the vehicle, converting electrical energy into mechanical power for motion.
- **Battery:** The battery serves as the energy storage device, storing electrical power to supply the electric motor and other vehicle components.
- **Transmission:** The transmission is responsible for transmitting the mechanical power generated by the motor to the vehicle's wheels, enabling movement.
- **Motor Controller:** The motor controller manages the distribution of electric power from the battery to the motor, regulating power flow based on data from the accelerator pedal.
- **Vehicle Controller:** This component controls various vehicle functions, including monitoring and managing different systems for safe and efficient operation.
- **Inverter:** The power inverter plays a pivotal role in converting DC power from the batteries into AC power for the motor. It also converts AC current generated during regenerative braking back into DC current for battery recharging.

When the battery is recharged, it stores electric energy, which is subsequently used to power the electric motor and other vehicle components. The controller governs the supply of electric power to the motor, adjusting power flow in response to accelerator pedal input. The transmission transfers mechanical power from the motor to the vehicle's wheels. Some EVs employ regenerative braking to generate energy during braking or deceleration, which is then returned to the battery.

Advantages of Electric Vehicles:

- No need for gasoline, eliminating fuel costs.
- Zero emissions, contributing to environmental sustainability.
- Cost-effective operation with lower maintenance requirements.
- Potential for a shorter payback period in some cases.
- Reduced noise during operation compared to internal combustion engine vehicles.

Disadvantages of Electric Vehicles:

- High initial cost, often exceeding that of conventional vehicles.
- Limited driving range, leading to concerns about range anxiety.
- Longer recharging times compared to refuelling with gasoline.
- Insufficient charging infrastructure in some regions.
- The space and weight of the battery pack can reduce available vehicle space and increase weight, impacting overall vehicle design.

2.2.10 Components of Hybrid Vehicle (HV)

A hybrid vehicle integrates two distinct power sources, with potential combinations encompassing diesel/electric, gasoline/flywheel and fuel cell (FC)/battery. In these combinations, one power source involves energy storage, while the other entails the conversion of fuel into energy.

For instance, a hybrid electric vehicle combines a gasoline engine with an electric motor, while an alternative configuration might feature a diesel engine alongside an electric motor. In the case of a Hybrid Electric Vehicle (HEV), it aligns with the hybrid definition by amalgamating a gasoline engine with an electric motor.

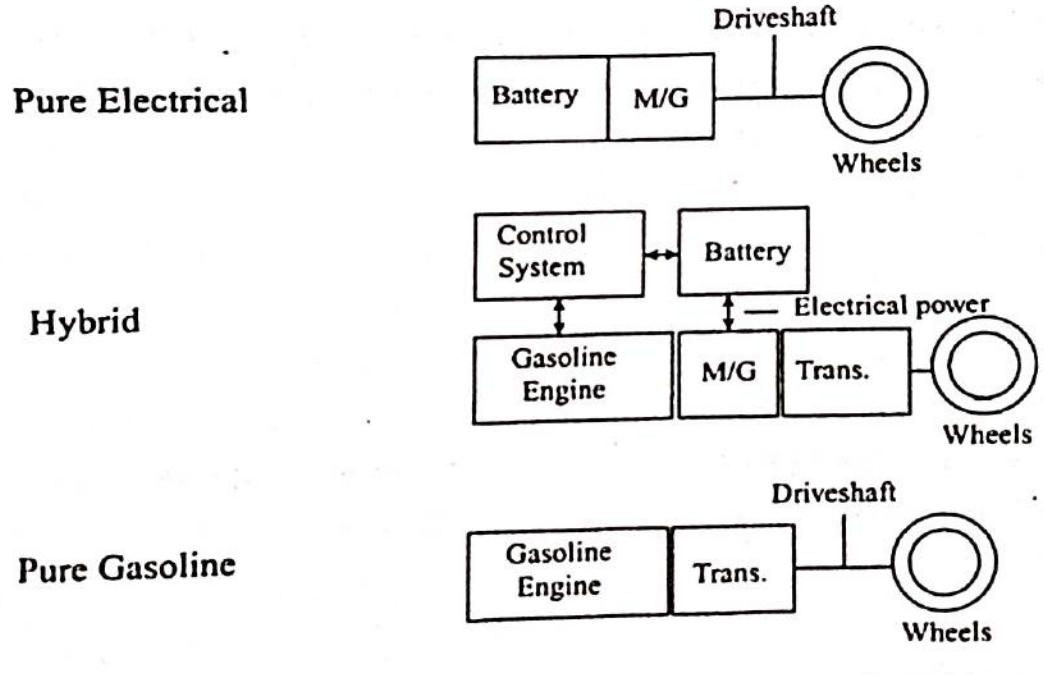


Fig. 2.54: Components of a hybrid vehicle that combines pure gasoline with a pure EV.

As shown in Fig. 2.54, a hybrid electric vehicle (HEV) is a fusion of components derived from both fully electric vehicles and traditional gasoline-powered vehicles. Just as an Electric Vehicle (EV) utilizes a Motor/Generator (M/G) to enable regenerative braking, an HEV also incorporates this M/G to facilitate regenerative braking. In HEVs, the M/G is typically positioned directly behind the internal combustion engine. In the case of Honda hybrids, the M/G is directly connected to the engine.

The battery within these vehicles provides energy to power various electrical components, typically including the inverter. This equipment is designed to accept a wide range of input voltage levels but cannot function with extremely low voltage. There is also a minimum voltage requirement imposed by the battery.

HEVs can be categorized based on the path of energy flow:

- **Mechanical Power Transmission Path (MPTP):** These HEVs rely primarily on mechanical power transmission for energy transfer.
- **Electrical Power Transmission Path (EPTP):** These HEVs predominantly use electrical power transmission for energy transfer.
- **Combination of MPTP and EPTP:** Some HEVs utilize a combination of both mechanical and electrical power transmission paths for energy transfer.

Additionally, HEVs can be classified based on their architectural design:

- **Series:** Series HEV primarily operate with the electric motor, while the internal combustion engine serves as a generator to recharge the battery or provide supplemental power.
- **Parallel:** Parallel HEVs can operate with both the internal combustion engine and the electric motor working in tandem to drive the vehicle.
- **Series-Parallel:** Series-parallel HEVs combine elements of both series and parallel architectures to optimize energy efficiency and performance.

Advantages of Hybrid Vehicles

- The electric motor is far more efficient (70%-85% efficiency) than the heat engine.
- EV's can use regenerative braking (regain 30% of energy used, theoretically).
- HEV's are more environmentally friendly (if electricity if produced from renewable sources)
- Reduction in engine and vehicle weight
- Fuel efficiency is increased
- Emissions are decreased
- Cut emissions of global warming pollutants by 1/3 or 1/2
- Reduce the dependency on fossil fuels
- Approximately 2 times more efficient than conventional engines

Disadvantages of a hybrid vehicle:

- Potential for higher weight
- Electrical losses

Comparison of I.C Engines

TABLE 2.8 *Comparison of Electric Vehicles and Hybrid Electric Vehicles*

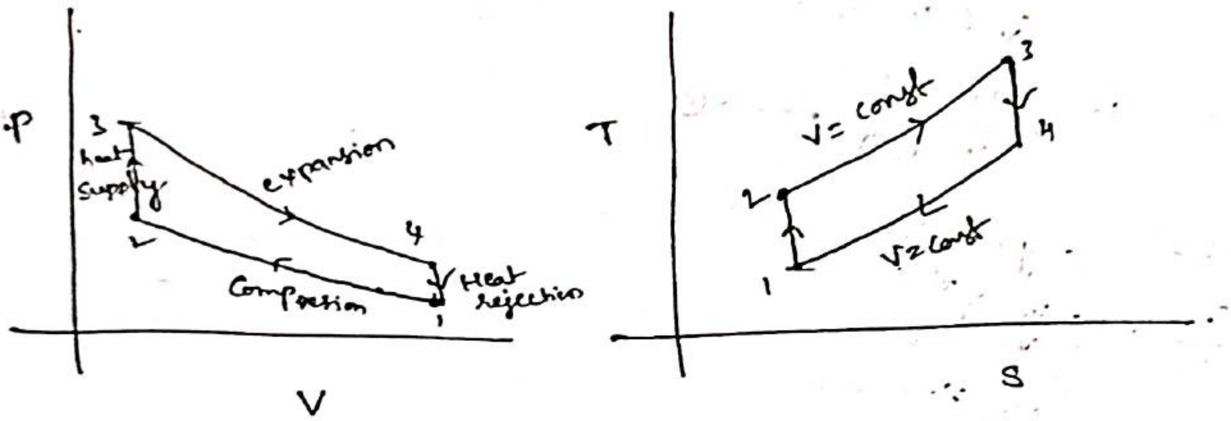
Types of EVs	*Electric Vehicles*	*Hybrid Electric Vehicles*
Propulsion	• Electric motor drives	• Electric motor drives • Internal combustion drives
Energy system	• Battery • Ultracapacitor	• Battery • Ultracapacitor • ICE generating unit
Energy Source and Infrastructure	• Electric grid charging Facilities	• Gasoline stations • Electric grid charging Facilities

v.v.v Imp. Otto cycle :-

→ Its developed by German Scientist named as 'Otto'.

→ This is a constant volume cycle.

→ It consist
2 - Constant volumes.
1 - adiabatic Compression
1 - " expansion.



1-2. adiabatic compression :- At constant volume air is Compressed adiabatically, So, Increases pressure, Temperature (P, T ↑) but entropy constant

2-3 Const volume process :- Heat Supplied to air from hot body, So, T, P increase again.

$$Q_{2-3} = C_V (T_3 - T_2)$$

3-4 adiabatic expansion :- air expands adiabatically. So, P, T decreases.

4-1 Const volume process :- Heat rejection takes place, P, T decreases.

heat supplied (2-3)

$$q_h = C_v (T_3 - T_2)$$

heat rejection (4-1)

$$q_r = C_v (T_4 - T_1)$$

workdone $W = q_h - q_r$

$$W = C_v (T_3 - T_2) - C_v (T_4 - T_1)$$

$$\text{efficiency} = \frac{W}{q_h}$$

$$= \frac{C_v (T_3 - T_2) - C_v (T_4 - T_1)}{C_v (T_3 - T_2)}$$

$$= 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)} \longrightarrow ①$$

adiabatic Compression (1-2)

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1}$$

$$\frac{T_2}{T_1} = (r)^{\gamma - 1}$$

$$\boxed{T_2 = T_1 \, r^{\gamma - 1}} \longrightarrow ②$$

adiabatic expansion (3-4)

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma - 1}$$

$$\frac{T_3}{T_4} = r^{\gamma - 1}$$

$$\boxed{T_3 = T_4 \, r^{\gamma - 1}} \longrightarrow ③$$

Sub eq ② & ③ in ①

$$\eta_0 = 1 - \left[\frac{T_4 - T_1}{T_4 \, r^{\gamma - 1} - T_1 \, r^{\gamma - 1}}\right]$$

$$\boxed{\eta_0 = 1 - \frac{1}{r^{\gamma - 1}}}$$

10.5 DIESEL CYCLE :

This is a constant pressure cycle devised by Rudolph Diesel in 1897. It is named as Diesel cycle, after its inventor and is applied to heavy oil and diesel engines. It is illustrated in Fig. 10.8.

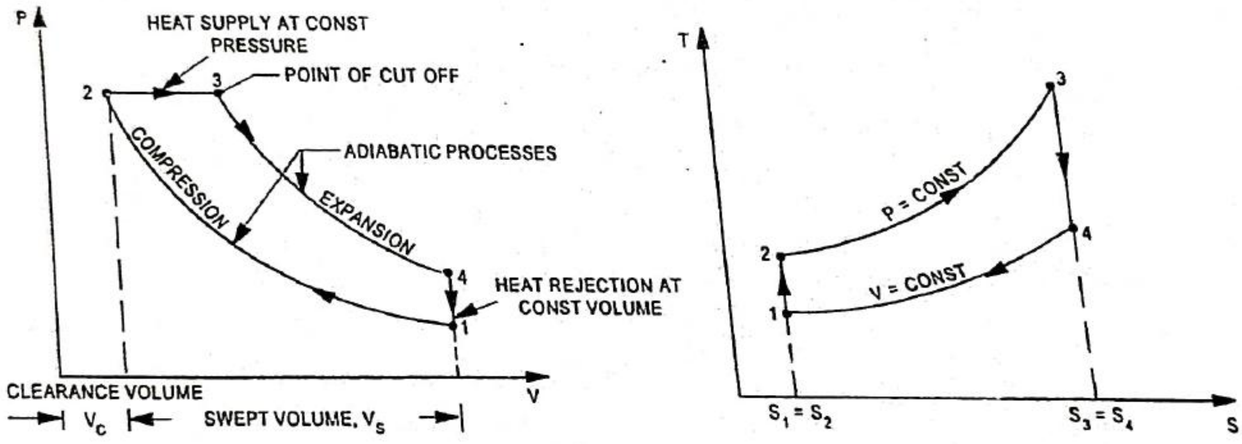


Fig. 10.8 *Diesel Cycle*

The sequence of operations is as follows :

1-2 : Adiabatic compression : Air is compressed adiabatically (i.e., $pV^{\gamma} \doteq$ constant) to a high pressure and temperature. No heat is rejected during adiabatic compression.

2-3 : Constant pressure process : Heat is supplied to air at constant pressure from hot body. The temperature is further increased.

3-4 : Adiabatic expansion : At point (3) the supply of heat is stopped, this point is known as *point of cut-off*. The air expands adiabatically from 3 to 4. The work is done by the gas due to expense of internal energy and there will be no heat transfer.

4-1 : Constant volume process : Heat is rejected to cold body at constant volume. Pressure and temperature decreases to initial state. Thus the cycle is completed.

Air standard efficiency (ASE) :

Consider one kg of air contained in a cyliner. During two adiabatic processes there will be no transfer of heat. Heat is only supplied at constant pressure, and rejected at constant volume. Let p, V and T refer to the pressure, volume and absolute temperature of air, suffixes 1, 2, 3 and 4 refer state points as shown in Fig. 10.8.

Compression ratio, $r = \dfrac{V_1}{V_2}$ Comp ratio :- $\dfrac{\text{volume at begining of Comp.}}{\text{to the V at end of Comp.}}$

Expansion ration, $r_e = \dfrac{V_4}{V_3}$ Exp ratio :- $\dfrac{\text{" " End of "}}{\text{Exp " V " bigining of Exp}}$

Cut-off ratio, $$\rho = \frac{V_3}{V_2} = \frac{V_3}{V_4} \cdot \frac{V_4}{V_2} = \frac{V_3}{V_4} \cdot \frac{V_1}{V_2} \qquad (\because V_1 = V_4)$$

$$\rho = \frac{r}{r_e}$$

$$\therefore \quad \text{Cut-off ratio} = \frac{\text{compression ratio}}{\text{expansion ratio}}$$

Heat supplied, $Q_H = C_p (T_3 - T_2)$

Hear rejected, $Q_L = C_v (T_4 - T_1)$

$$ASE = \frac{\text{work done}}{\text{heat supplied}} = \frac{Q_H - Q_L}{Q_H}$$

$$= \frac{C_p(T_3 - T_2) - C_v(T_4 - T_1)}{C_p(T_3 - T_2)}$$

$$ASE = 1 - \frac{(T_4 - T_1)}{\gamma(T_3 - T_2)} \qquad \text{... (i)}$$

Consider adiabatic compression (1-2)

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1} \text{ or } T_2 = T_1 r^{\gamma - 1} \qquad \text{... (ii)}$$

Consider constant pressure process (2-3)

$$\frac{T_3}{T_2} = \frac{V_3}{V_2} = \rho \text{ or } T_3 = T_2 \cdot \rho$$

Substituting the value of T_2 from equation (ii)

$$T_3 = T_1 r^{\gamma - 1} \rho$$

Consider adiabatic expansion (3-4)

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = r_e^{\gamma - 1} = \left(\frac{r}{\rho}\right)^{\gamma-1}$$

$$T_4 = \frac{T_3 \rho^{\gamma-1}}{r^{\gamma-1}}$$

Substituting the value of T_3 from equation (iii)

$$T_4 = T_1 \rho^{\gamma}$$

Substituting proper values from equations (ii), (iii) and (iv) in equation (i)

$$\eta_D = 1 - \frac{1}{\gamma}\left[\frac{T_1\rho^{\gamma} - T_1}{T_1 r^{\gamma-1}\rho - T_1 r^{\gamma-1}}\right]$$

$$\eta_D = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}\right]$$

Substituting the value of T_2 from equation (ii)

$$T_3 = T_1 r^{\gamma - 1}\rho$$

Consider adiabatic expansion (3-4)

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = r_e^{\gamma - 1} = \left(\frac{r}{\rho}\right)^{\gamma-1}$$

$$T_4 = \frac{T_3\rho^{\gamma-1}}{r^{\gamma-1}}$$

Substituting the value of T_3 from equation (iii)

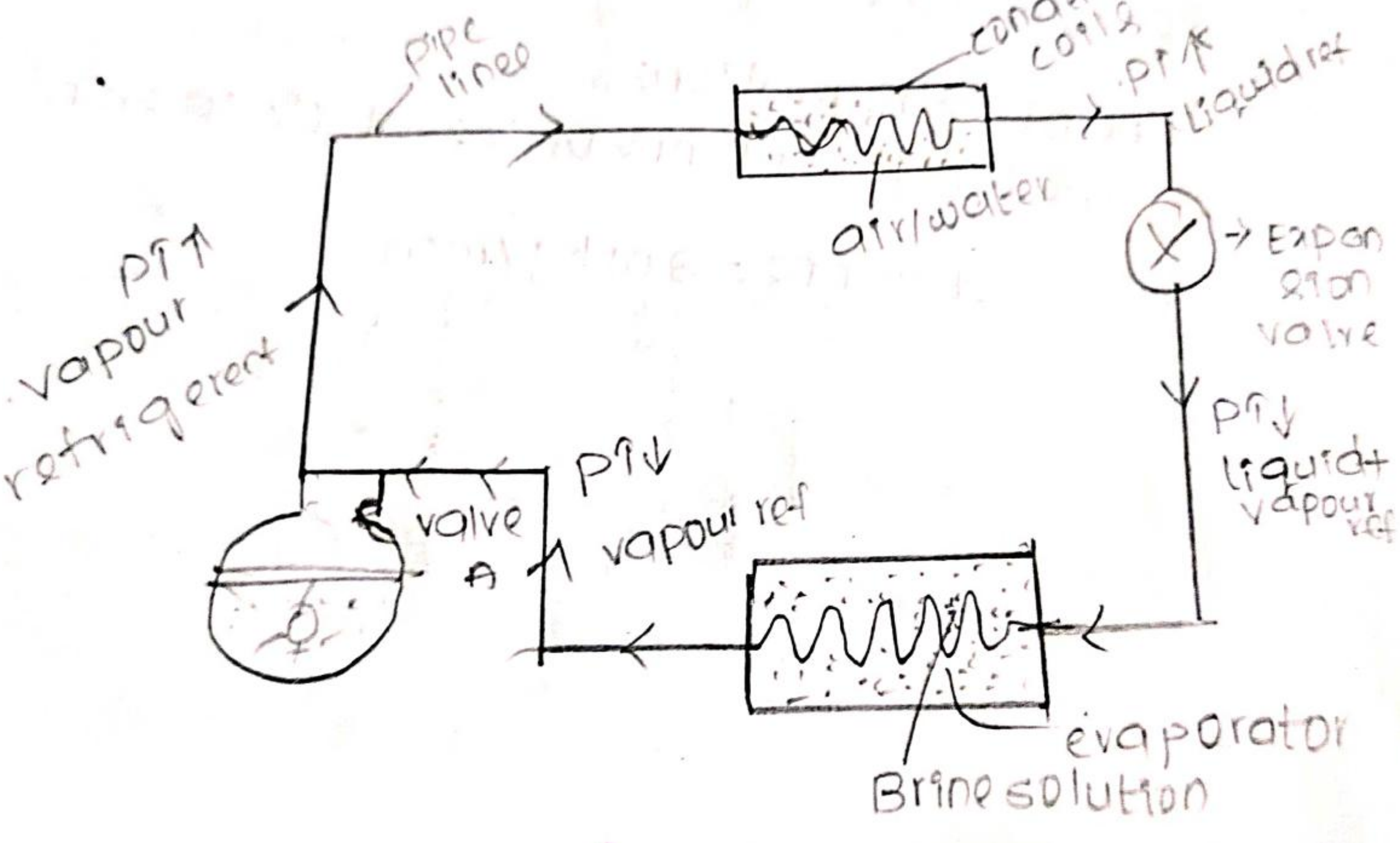
$$T_4 = T_1\rho^{\gamma}$$

Substituting proper values from equations (ii), (iii) and (iv) in equation (i)

$$\eta_D = 1 - \frac{1}{\gamma}\left[\frac{T_1\rho^{\gamma} - T_1}{T_1 r^{\gamma-1}\rho - T_1 r^{\gamma-1}}\right]$$

$$\eta_D = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}\right]$$

(1) vapour compressour refrigration method(VCR):-



The Schematic Diagram of simple vapour compression Refridgeration system as shown in above figure it consist of following parts
(1) compressor
(2) condensor coil
(3) Expansion valve
(4) Evaporator

(A) (1) compressor:- The low pressure temperature vapour refridgrient is converted into high pressure, temperature vapour refrigirent.

$P\downarrow T\downarrow \rightarrow P\uparrow T\uparrow$

(2) condenser coils:- The condensor coils consist of coils of pipe in which high pressure temperature vapour refrigirent cooled. The refrigirent while passing through the condensor gives up latent heat to the surroundings condensing medium which is normally air or water. so that high pressure temperature vapour refrigirent converts high P, T liquid refrigirent

$P, T\uparrow$ vapour $\rightarrow$ $PT\uparrow$ Liquid

(3) Expansion valve:- The function of expansion valve is decreasing the P, T of Liquid refrigirent. Hence Liquid and vapour is formed.

(4) Evaporator:- An evaporator consist of coils in which. liquid vapour refrigirent is evaporated and change into low P, T vapour refrigirent. with help of brine solution.

$\downarrow PT$ (liquid+vapour) $\rightarrow \downarrow PT$ (vapour)

Advantages:-

(1) Less running cost
(2) COP is high than air refrigiration
(3) small in size

Disadvantages:-

(1) Initial cost is high
(2) prevention of leakage of refrigirent of major problem in VCR (vapour compression refrigirent).

2.2.6 IC Engines

1 MARK

An Internal Combustion Engine (I.C. Engine) is a heat engine which converts chemical energy in fuel into heat or thermal energy and then to mechanical energy. To convert chemical energy into heat energy, fuel is to be burnt, that is, it must be subjected to combustion. If this combustion takes place inside the cylinder of a heat engine, then it is called an I.C. engine. On the other hand, if combustion takes place outside the engine (say in a boiler) and the working fluid is conveyed into a cylinder then it is called an external combustion engine.

2.2.7 4-stroke S.I & C.I Engine

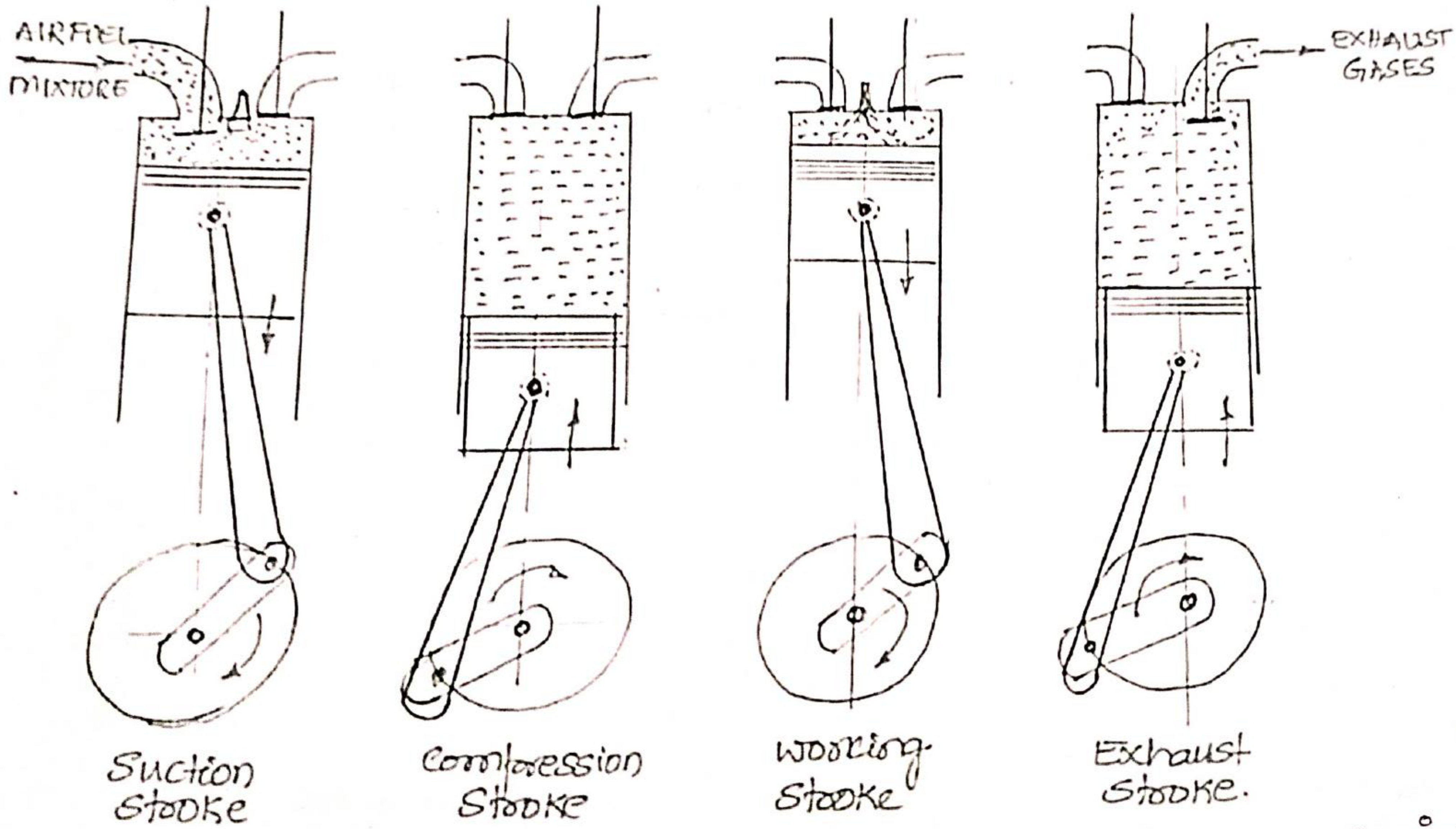
Working Principle of a 4-stroke S.I. Engine:

The essential operations of a cycle are completed as follows in 4-strokes of piston i.e., 2-revolutions of crankshaft of petrol or gas engine as shown in fig.

1st Stroke: Suction Stroke (Induction Stroke): Piston moves down from TDC to BDC. The inlet valve opens. A partial vacuum is created inside the cylinder. Fresh charge of fuel and air is admitted through inlet valve. Exhaust valve remains closed.

2nd Stroke: Compression Stroke: Piston moves up from BDC to TDC. Both the valves remain closed. Charge is compressed inside the cylinder. Its pressure and temperature increase.

At the end of compression, a spark is ejected and ignites the charge.



Four stroke Petrol engine. (or) S.I Engine.

3rd Stroke: Expansion Stroke (Power Stroke): Piston moves down from TDC to BDC, as the power is developed in the form of heat energy. Both the valves remain closed. This is also called the working stroke.

4th Stroke: Exhaust Stroke: Piston moves up from BDC to TDC. The exhaust valve opens. Burnt gases are driven out. The inlet, valve remains closed.

It may be noted that during the first two strokes piston's movement is due to the momentum of the flywheel keyed to the crankshaft. The charge comprising fuel and air mixture comes from a carburettor.

These operations are represented on the p-V diagram.

Ignition

Working Principle of a 4-stroke C.I. Engine:

The 4-stroke cycle of Diesel engines comprises the following operations.

1st Stroke:

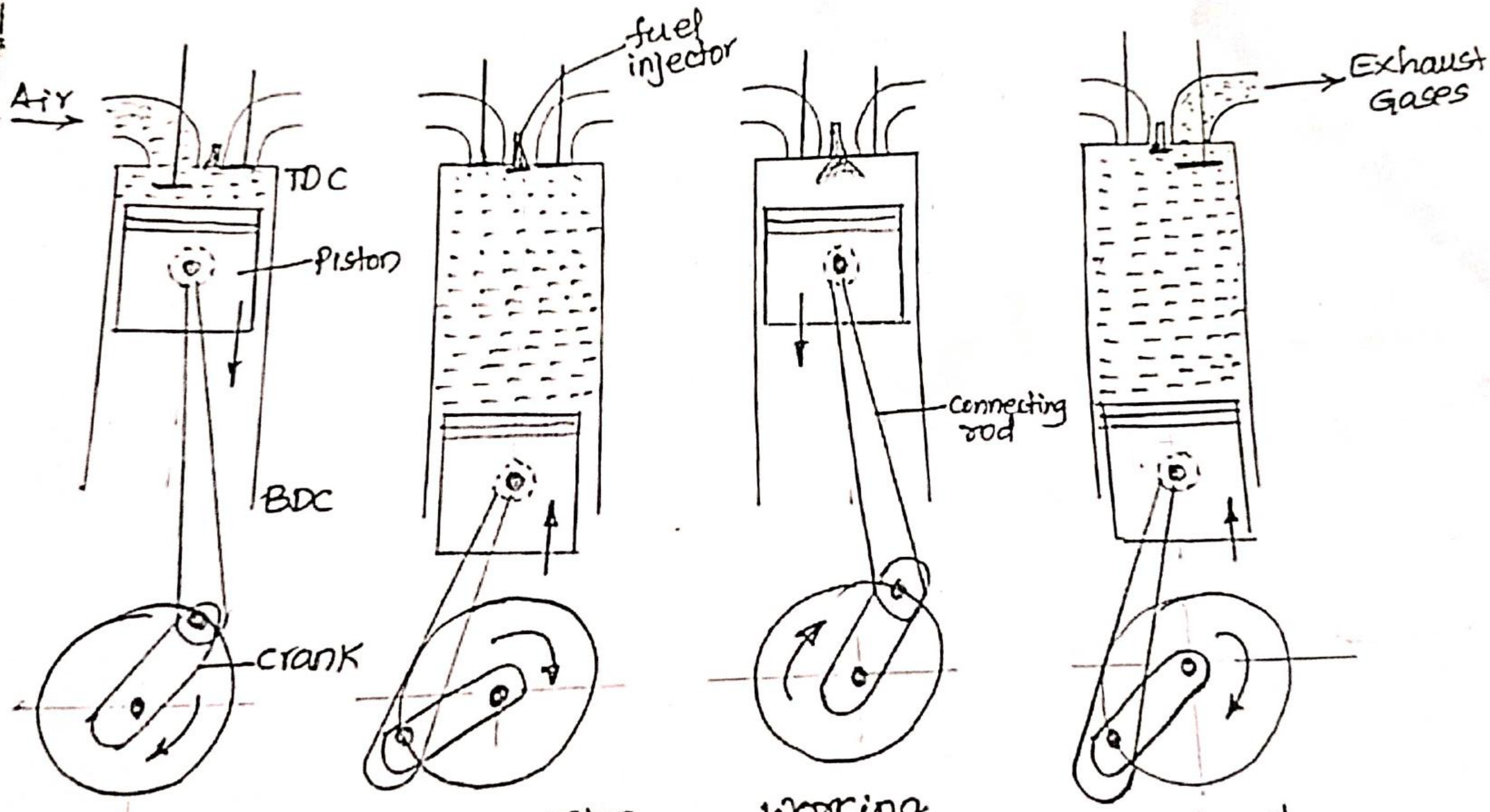
Suction Stroke: The piston moves down from TDC to BDC.

The inlet valve opens, and the Exhaust valve remains closed. Filtered atmospheric air is admitted into the cylinder.

2nd Stroke:

Compression Stroke: The piston moves up from BDC to TDC. Both the valves remain closed. The air is highly compressed. Its pressure and temperature increase. At the end of the compression fuel valve (not shown) opens and fuel is injected into the cylinder through an injector (Fuel oil like Diesel is atomized and sprayed into compressed air). Ignition, subsequently combustion occurs.

Four stroke Diesel Engine (or) C.I Engine.



Suction stroke

Compression stroke

Working stroke

Exhaust stroke

3rd Stroke:

Power Stroke: Power developed inside the cylinder pushes the piston down. Both the valves remain closed. Power is transmitted from the piston through the connecting rod onto the crankshaft.

4th Stroke:

Exhaust Stroke: The piston moves up from BDC to TDC. The exhaust valve opens, and the Inlet valve remains closed. Burnt gases are driven out of the cylinder.

fuel injection and

2.2.8 2-stroke S.I & C.I Engine

Working of Two-Stroke Petrol Engine

In a two-stroke Petrol engine, all four operations of one working cycle i.e., suction, compression, power and exhaust are completed in two strokes of the piston or one revolution of the crankshaft. the two-strokes are:

1. **Upward stroke:** During this stroke both suction and compression will be completed.

2. **Downward stroke:** During this stroke both power and exhaust will be completed.

Ports are used in place of valves for admitting the charge and discharging the exhaust gase The charge is a mixture of air and petrol which is supplied by a carburettor. The working o two-stroke petrol engine is shown in Fig. 2.50.

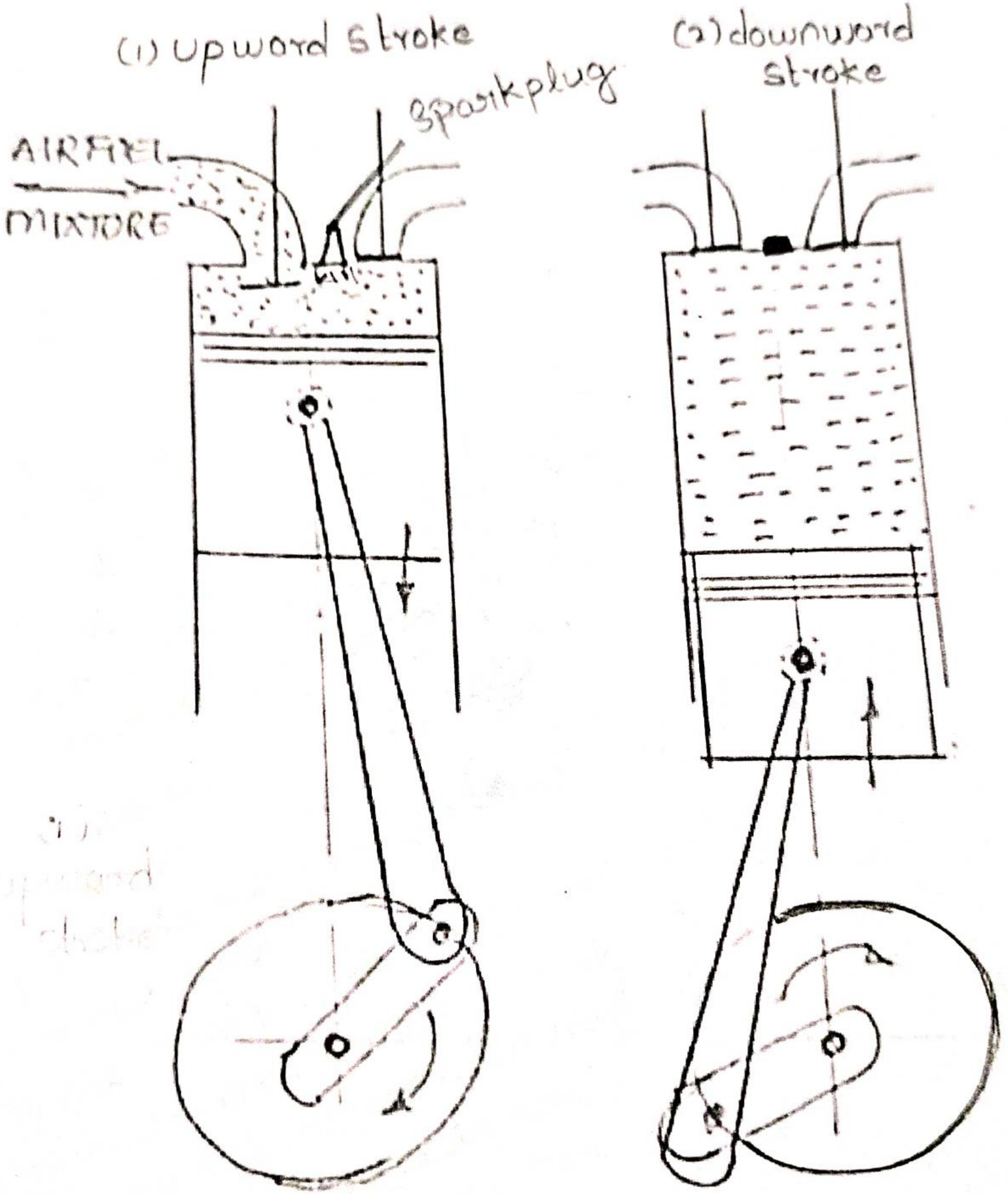

(1) upword stroke
(2) downword stroke
sparkplug
AIR FUEL
MIXTURE

Fig. 2.50: Two-Stroke Petrol Engine

1. Upward Stroke:

During the upward stroke of the piston, both suction and compression strokes are completed.

- The piston moves up from the Bottom Dead Center (BDC) to the Top Dead Center (TDC).
- The pressure in the crankcase becomes lesser than the atmospheric pressure.
- The inlet port is uncovered.
- Fresh charge comprising of air and petrol mixture is admitted into the crankcase.
- The exhaust and transfer ports are covered.
- Compression of previously available charge takes place above the piston inside the cylinder.

At the end of compression stroke, the charge is ignited by a high voltage spark produced from the spark plug.

2. Downward Stroke:

During downward stroke, both power and exhaust strokes are completed.

- The piston moves down from Top Dead Center (TDC) to Bottom
- Dead Center (BDC).
- The hot gases produced on the combustion of charge pushes down the piston from TDC to BDC.
- The expansion of hot gases produces the mechanical power which is obtained at the Crank Shaft.

- The Exhaust port is uncovered, and waste gases are discharged to the atmosphere.
- Inlet port is covered.
- Immediately, the piston uncovers the transfer port and the charge previously available in the Crank Case enters the cylinder through the transfer ports.

Thus, the cycle repeats.

In 2-stroke petrol engines, during downward stroke the exhaust gases are swept out with the fresh charge coming from the crank case. This process is known as scavenging.

Working of 2-Stroke Diesel Engine

In a two-stroke diesel engine, all the four operations of one working cycle i.e., suction, compression, power, and exhaust are completed in two.

Strokes of the piston or one revolution of the crank shaft.

The two-strokes are:

1. Upward stroke:

During this stroke both suction and compression will be completed.

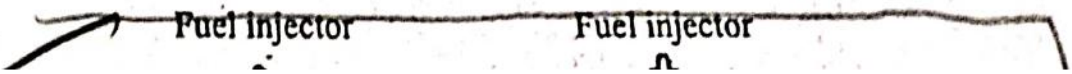
2. Downward stroke:

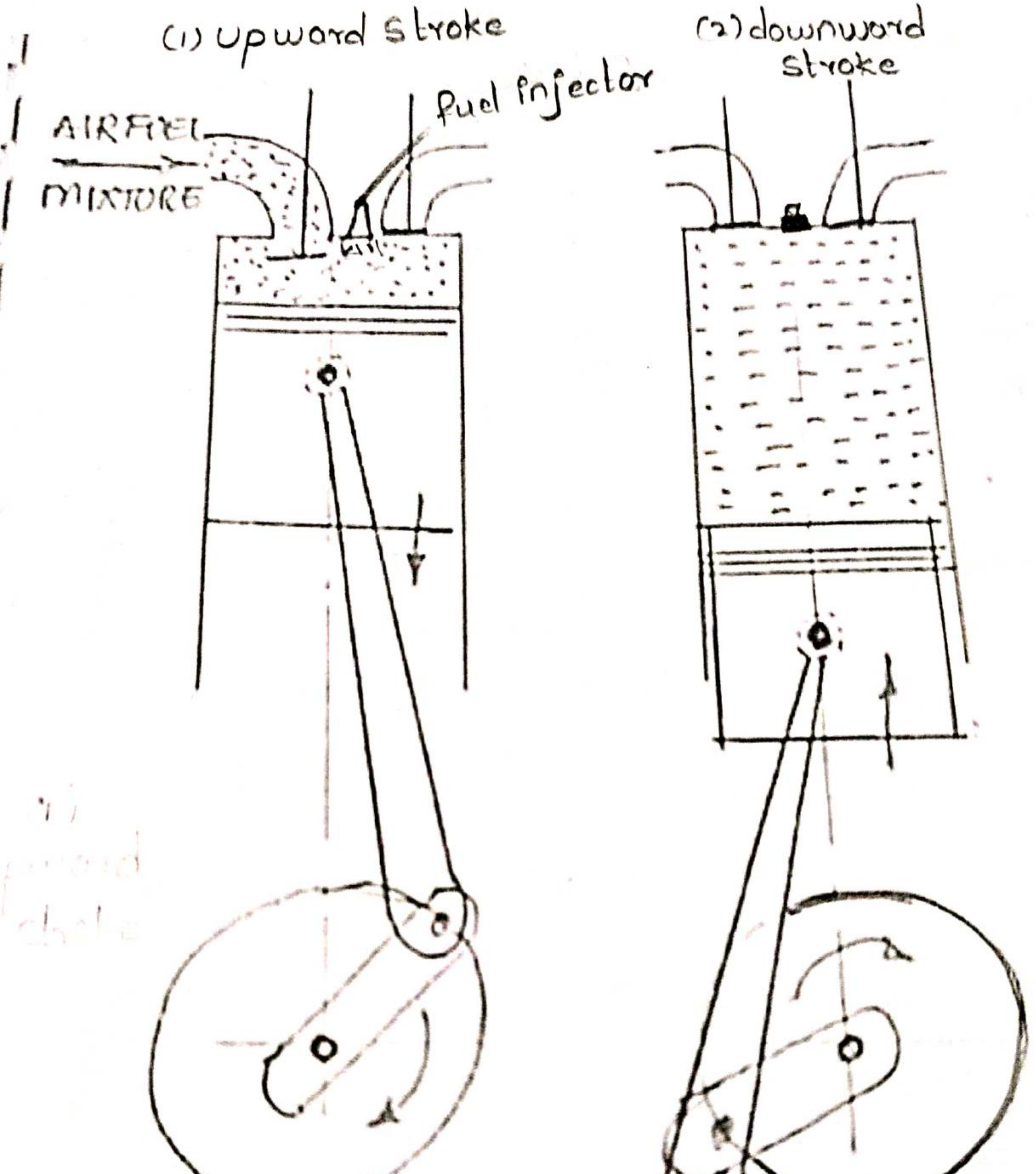
During this stroke both power and exhaust will be completed.

Ports are used in place of valves for admitting the charge and discharging the exhaust gases.

The charge is air only and fuel is supplied by a fuel injector at the end of compression.

The working of a two-stroke diesel engine is shown in Fig. 2.51.





(1) upward stroke
fuel injector
AIRFUEL MIXTURE
(2) downward stroke

Fig. 2.51: 2-Stroke Diesel Engine

1. Upward Stroke:

During the upward stroke of the piston, both suction and compression strokes are completed.

- The piston moves up from the Bottom Dead Center (BDC) to the Top Dead Center (TDC).
- The pressure in the crankcase becomes lesser than the atmospheric pressure.
- The inlet port is uncovered.
- Fresh charge comprising of air is admitted into the crankcase.
- The exhaust and transfer ports are covered.

TABLE 2.6 *Comparison of Petrol Engine and Diesel Engine. (S.I. and C.I. Engines)*

	SI. Engines or Petrol Engine		**C.I. Engines or Diesel Engine**
1.	Charge comprises air and fuel which is admitted into the cylinder during suction stroke	1.	Charge comprises only air
2.	The carburettor is used to supply the charge	2.	Fuel injector injects fuel oi l as a spray into com · pressed air
3.	Sparkplug is used to ignite the charge	3.	Due to extremely high compression of air, fuel gets automatically ignited
4.	Compression ratio varies from 6:1 to 9:1	4.	The compression ratio is high and varies from 12:1 to 22:1
5.	It works on the Otto cycle (constant volume cycle)	5.	It works on the Diesel cycle (modified constant pressure cycle)
6.	Initial cost is less but maintenance is costly	6.	Initial cost is high, and maintenance is cheap
7.	For a given output, it is lighter in weight	7.	Due to the high C.R. engine is heavier
8.	Easy and quick starting	8.	Starting is not so quick
9.	The engine is almost vibration-free at mid- or slow speeds	9.	The engine vibrates considerably
10.	Lighter flywheel is required as fluctuation of speed is minimum	10.	Heavier flywheel is essential
11.	Thermal Efficiency is less (about 26%)	11.	Therma Efficiency is high (about 40%)
12.	Output is controlled by a throttle valve which regulates the mass of the charge	12.	Output is controlled by regulating the supply of oil injected.
13.	Used for light duty such as scooters, motorcycles, sprayers, cars etc.	13.	Used in heavy-duty vehicles such as busses, trucks, tractors etc.

TABLE 2.7 *Comparison of 2-Stroke cycle and Four-Stroke cycle*

	2-Stroke Cycle Engine		**4-Stroke Cycle Engine**
1.	The cycle of operations is completed in 2-strokes of the piston i.e.in revolution of the crankshaft	1.	The cycle of operations is completed in 4-strokes of the piston i.e., in 2-revotution of crankshaft.
2.	There is an overlap in each operation. Example – compression and exhaust	2.	Each operation is distinct and well-defined
3.	Exhaust of burnt gases is assisted by a slightly compressed charge which first transferred into the cylinder	3.	Gases are exhausted by the piston itself
4.	Twice as many working strokes per minute as an engine	4.	Half the number of working strokes per minute of a 2-stroke engine.
5.	Uniform turning moment on the crankshaft and lighter flywheel is required.	5.	The turning moment is more fluctuating, and a larger flywheel is required.
6.	Scavenging of exhaust gases being poor, fuel burnt is less and hence less output.	6.	Exhaust is more effective; more fuel can be burnt and hence higher outputs
7.	More wear and tear, noisier.	7.	less wear and tear; less noisy
8.	Consumes more lubricating oil.	8.	consumes less lubricating oil.
9.	The direction of rotation can be changed.	9.	The direction of rotation cannot be changed.
10.	Thermal Efficiency is less	10.	Thermal efficiency is high
11.	Generally adopted by S.I. engines such as petrol and gas engines.	11.	Generally adopted by C. I engines such as diesel engines.
12.	Generally employed in light vehicles such as scooters and motorcycles. Sprayers, 3-wheelers and 2-stroke Diesel engines are used in marine propulsion.	12.	4-stroke S.I. engines are used in cars, jeeps and airplanes etc. 4-stroke C.I. engines are used in buses, trucks, locomotives, pump sets, earthmovers etc.

2.2.9 Components of Electric Vehicles

Electric vehicles (EVs) rely on electricity as their primary source of power, either as the sole fuel or to enhance the efficiency of traditional vehicle designs. The category of EVs encompasses battery electric vehicles (BEVs), often called all-electric vehicles, as well as plug-in hybrid electric vehicles (PHEVs). These vehicles are commonly referred to as electric cars or simply EVs and they are renowned for their immediate torque delivery and quiet driving experience.

An electric vehicle is an automotive mode of transportation propelled by one or more electric motors, utilizing electrical energy stored in an energy storage device. The fundamental components within electric vehicles consist of the motor, controller, power source and transmission.

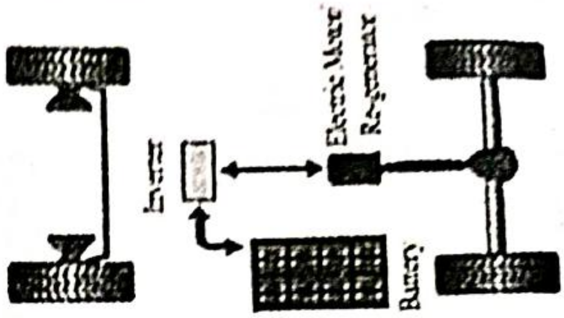


Fig. 2.53: Electric Vehicles

Electric Vehicle Components: Electric vehicles (EVs) consist of several key components:

- **Motor:** The motor is responsible for propelling the vehicle, converting electrical energy into mechanical power for motion.
- **Battery:** The battery serves as the energy storage device, storing electrical power to supply the electric motor and other vehicle components.
- **Transmission:** The transmission is responsible for transmitting the mechanical power generated by the motor to the vehicle's wheels, enabling movement.
- **Motor Controller:** The motor controller manages the distribution of electric power from the battery to the motor, regulating power flow based on data from the accelerator pedal.
- **Vehicle Controller:** This component controls various vehicle functions, including monitoring and managing different systems for safe and efficient operation.
- **Inverter:** The power inverter plays a pivotal role in converting DC power from the batteries into AC power for the motor. It also converts AC current generated during regenerative braking back into DC current for battery recharging.

When the battery is recharged, it stores electric energy, which is subsequently used to power the electric motor and other vehicle components. The controller governs the supply of electric power to the motor, adjusting power flow in response to accelerator pedal input. The transmission transfers mechanical power from the motor to the vehicle's wheels. Some EVs employ regenerative braking to generate energy during braking or deceleration, which is then returned to the battery.

Advantages of Electric Vehicles:

- No need for gasoline, eliminating fuel costs.
- Zero emissions, contributing to environmental sustainability.
- Cost-effective operation with lower maintenance requirements.
- Potential for a shorter payback period in some cases.
- Reduced noise during operation compared to internal combustion engine vehicles.

Disadvantages of Electric Vehicles:

- High initial cost, often exceeding that of conventional vehicles.
- Limited driving range, leading to concerns about range anxiety.
- Longer recharging times compared to refuelling with gasoline.
- Insufficient charging infrastructure in some regions.
- The space and weight of the battery pack can reduce available vehicle space and increase weight, impacting overall vehicle design.

2.2.10 Components of Hybrid Vehicle (HV)

A hybrid vehicle integrates two distinct power sources, with potential combinations encompassing diesel/electric, gasoline/flywheel and fuel cell (FC)/battery. In these combinations, one power source involves energy storage, while the other entails the conversion of fuel into energy.

For instance, a hybrid electric vehicle combines a gasoline engine with an electric motor, while an alternative configuration might feature a diesel engine alongside an electric motor. In the case of a Hybrid Electric Vehicle (HEV), it aligns with the hybrid definition by amalgamating a gasoline engine with an electric motor.

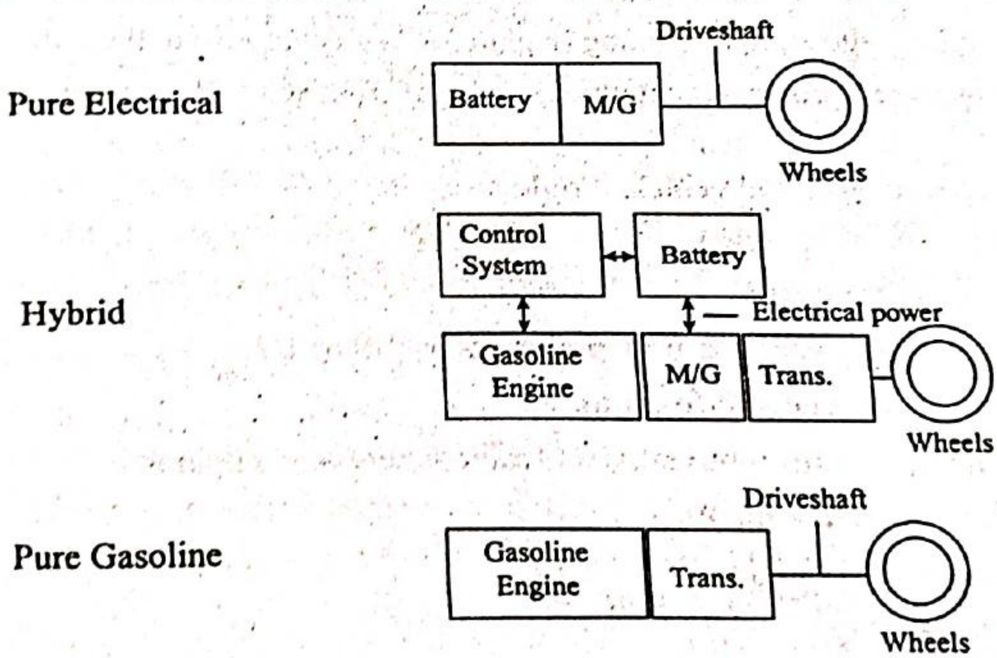


Fig. 2.54: Components of a hybrid vehicle that combines pure gasoline with a pure EV.

As shown in Fig. 2.54, a hybrid electric vehicle (HEV) is a fusion of components derived from both fully electric vehicles and traditional gasoline-powered vehicles. Just as an Electric Vehicle (EV) utilizes a Motor/Generator (M/G) to enable regenerative braking, an HEV also incorporates this M/G to facilitate regenerative braking. In HEVs, the M/G is typically positioned directly behind the internal combustion engine. In the case of Honda hybrids, the M/G is directly connected to the engine.

The battery within these vehicles provides energy to power various electrical components, typically including the inverter. This equipment is designed to accept a wide range of input voltage levels but cannot function with extremely low voltage. There is also a minimum voltage requirement imposed by the battery.

HEVs can be categorized based on the path of energy flow:

- **Mechanical Power Transmission Path (MPTP):** These HEVs rely primarily on mechanical power transmission for energy transfer.
- **Electrical Power Transmission Path (EPTP):** These HEVs predominantly use electrical power transmission for energy transfer.
- **Combination of MPTP and EPTP:** Some HEVs utilize a combination of both mechanical and electrical power transmission paths for energy transfer.

Additionally, HEVs can be classified based on their architectural design:

- **Series:** Series HEV primarily operate with the electric motor, while the internal combustion engine serves as a generator to recharge the battery or provide supplemental power.
- **Parallel:** Parallel HEVs can operate with both the internal combustion engine and the electric motor working in tandem to drive the vehicle.
- **Series-Parallel:** Series-parallel HEVs combine elements of both series and parallel architectures to optimize energy efficiency and performance.

Advantages of Hybrid Vehicles

- The electric motor is far more efficient (70%-85% efficiency) than the heat engine.
- EV's can use regenerative braking (regain 30% of energy used, theoretically).
- HEV's are more environmentally friendly (if electricity if produced from renewable sources)
- Reduction in engine and vehicle weight
- Fuel efficiency is increased
- Emissions are decreased
- Cut emissions of global warming pollutants by 1/3 or 1/2
- Reduce the dependency on fossil fuels
- Approximately 2 times more efficient than conventional engines

Disadvantages of a hybrid vehicle:

- Potential for higher weight
- Electrical losses

Comparison of I.C Engines

TABLE 2.8 *Comparison of Electric Vehicles and Hybrid Electric Vehicles*

Types of EVs	*Electric Vehicles*	*Hybrid Electric Vehicles*
Propulsion	• Electric motor drives	• Electric motor drives • Internal combustion drives
Energy system	• Battery • Ultracapacitor	• Battery • Ultracapacitor • ICE generating unit

Conventional machining ... as follows:

Machining Processes :-

1. **Turning:** In the turning process, the cutting tool remains stationary while the workpiece undergoes rotation. This operation typically takes place on a lathe and entails the removal of excess material from the workpiece with the assistance of a cutting tool. The cutting tool operates along two axes, ensuring precise cuts in terms of both width and depth.

Moreover, the turning process is highly effective for machining either the exterior or interior sections of a material. When applied to the external surface, it is referred to as "facing," whereas its application to the interior is termed "boring."

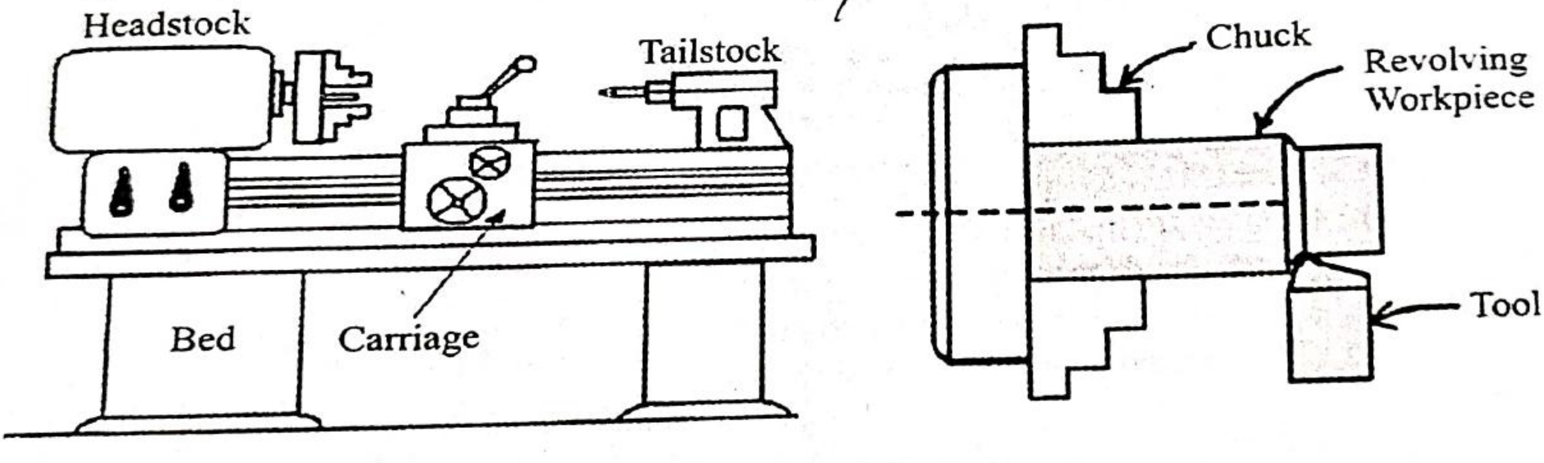


Fig. 2.19: The Turning Process

2. **Milling:** Milling stands as a machining process in which rotating cutters are employed to meticulously eliminate material from a workpiece. Within the realm of milling, two primary operations are recognized: face milling and slab milling.

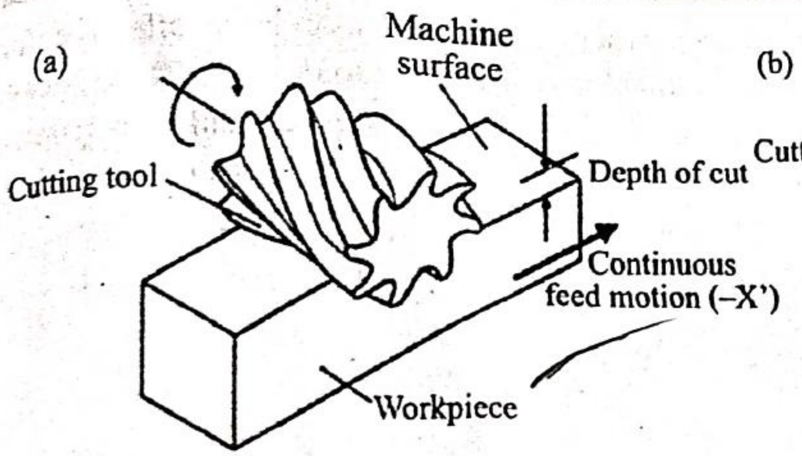


Fig. 2.20(a): Slab Milling

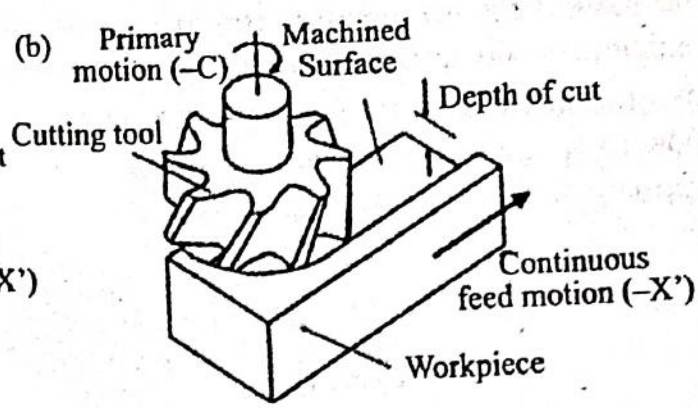


Fig. 2.20(b): Face Milling

3. **Drilling:** Drilling is a machining process that involves the creation of cylindrical holes within solid materials using specialized drill bits. It holds immense significance in manufacturing, primarily because the holes produced often play a crucial role in the assembly of components. While

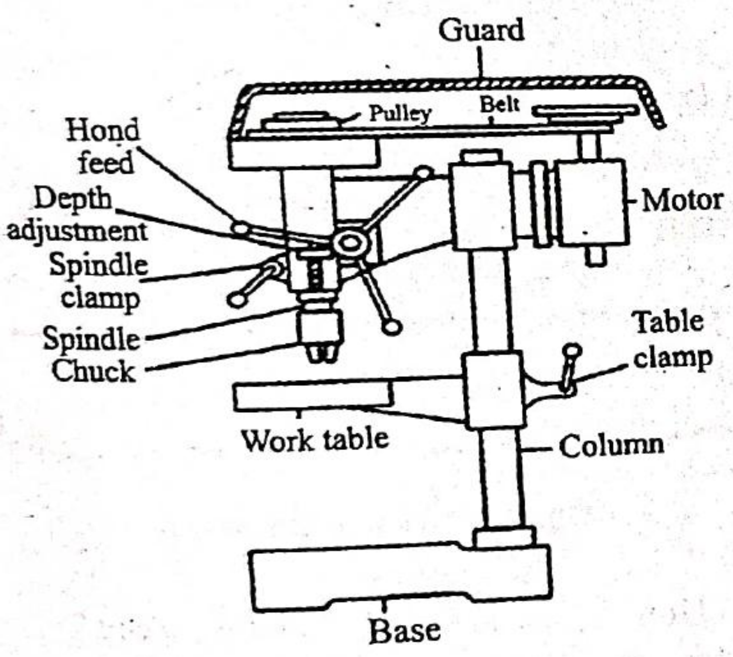


Fig. 2.21(a): *Drilling Machine*

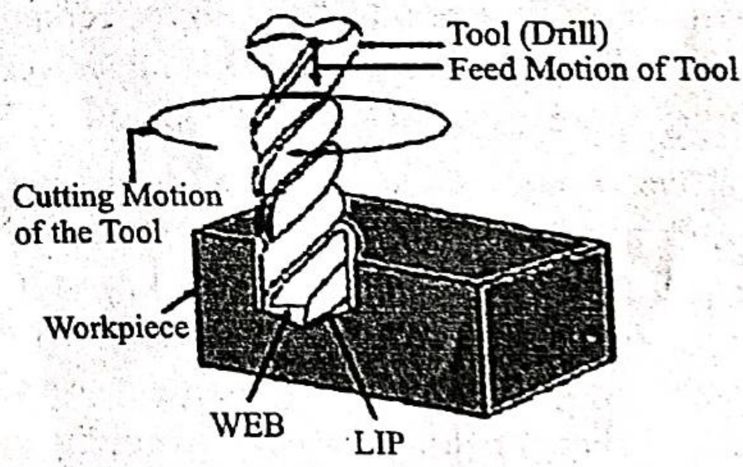
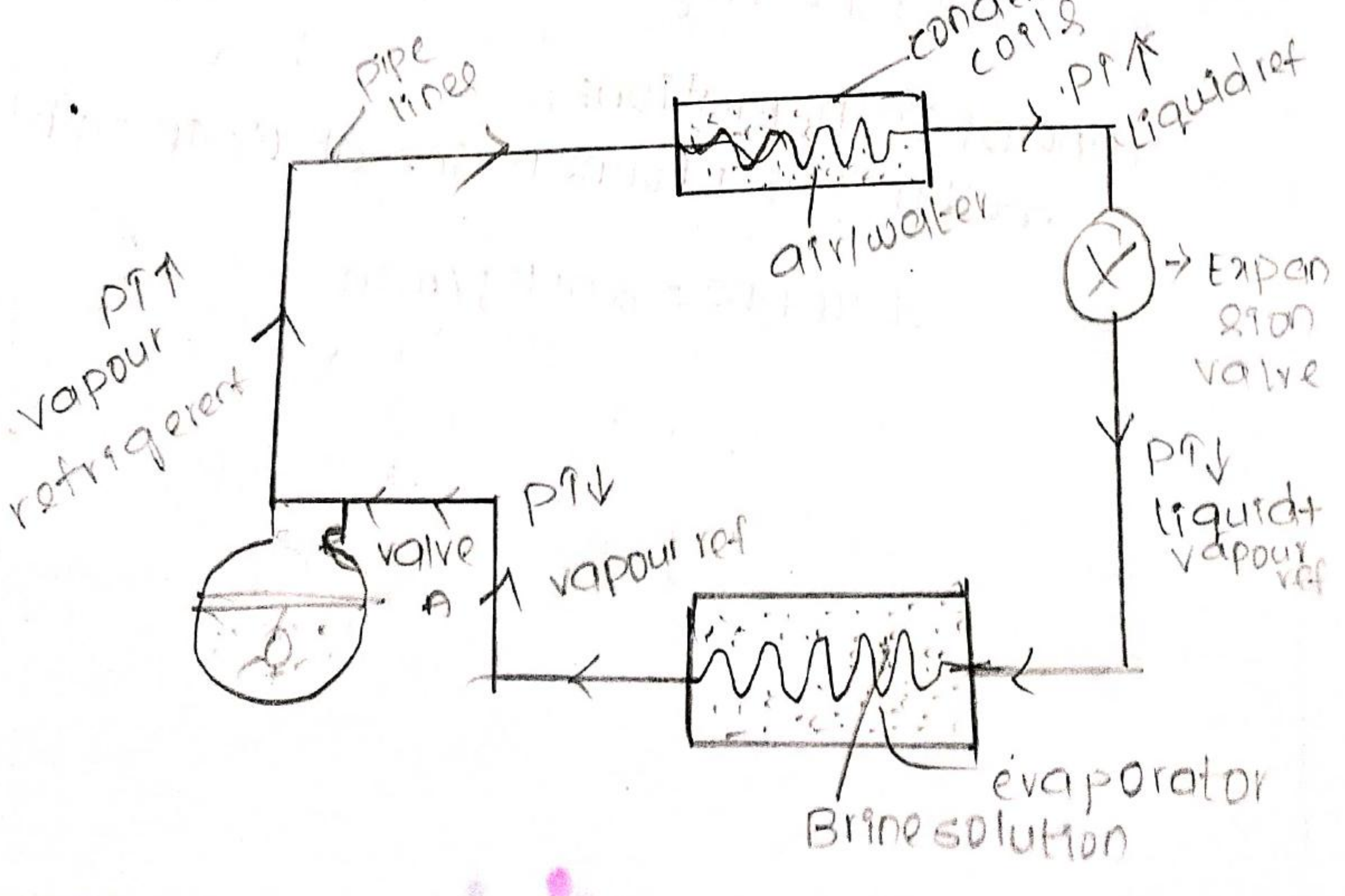


Fig. 2.21(b): *Drilling Operation*

(1) vapour compressor refrigiration method(VCR):-



The Schematic Diagram of simple vapour compression Refridgeration system as shown in above figure it consist of following parts

(1) compressor
(2) condensor coil
(3) Expansion valve
(4) Evaporator

(A) (1) compressor:- The low pressure temperature vapour refridgirent is converted into high pressure, temperature vapour refrigirent.

P↓ T↓ → P↑ T↑

(2) condenser coils:- The condensor coils consist of coils of pipe in which high pressure temperature vapour refrigirent cooled. The refrigirent while passing through the condensor gives up latent heat to the surroundings condensing medium which is normally air or water. so that high pressure temperature vapour refrigirent converts high P, T liquid refrigirent

P, T ↑ vapour → P T ↑ Liquid

(3) Expansion valve:- The function of expansion valve is decreasing the P, T of Liquid refrigirent. Hence Liquid and vapour is formed.

(4) Evaporator:- An evaporator consist of coils in which. liquid vapour refrigirent is evaporated and change into low P, T vapour refrigirent. with help of brine solution.

↓P T (liquid + vapour) → ↓P T (vapour)

Advantages:-

(1) Less running cost

(2) COP is high than air refrigiration

(3) small in size

Disadvantages:-

(1) Initial cost is high

(2) prevention of leakage of refrigirent of major problem in VCR (vapour compression refrigirent).

Disadvantag

Psychrometric Terms

v. v. Imp

1. Dry air
2. Moist air
3. Saturation air
4. Humidity :- Amount of water vapour presents 1 Kg of dry air is called Humidity (or) Specific Humidity.
5. Degree of saturation
6. Absolute humidity :- Amount of water vapour presents $1m^3$ of dry air is called Absolute humidity.
7. Relative humidity.
8. wet bulb temperature (WBT)
9. Dry bulb temperature (DBT)
10. Wet bulb depression
11. Dew point temperature.

18.8 Winter Air Conditioning System

In winter air conditioning, the air is heated, which is generally accompanied by humidification. The schematic arrangement of the system is shown in Fig. 18.3. (Heating & Humidification.)

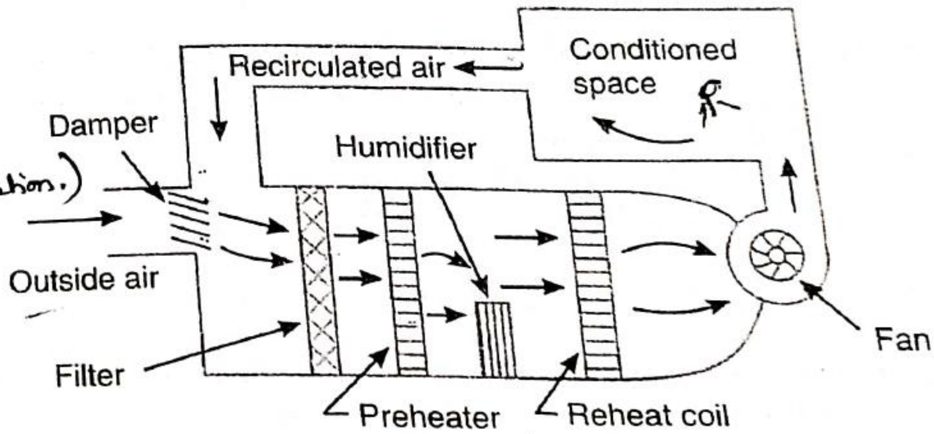
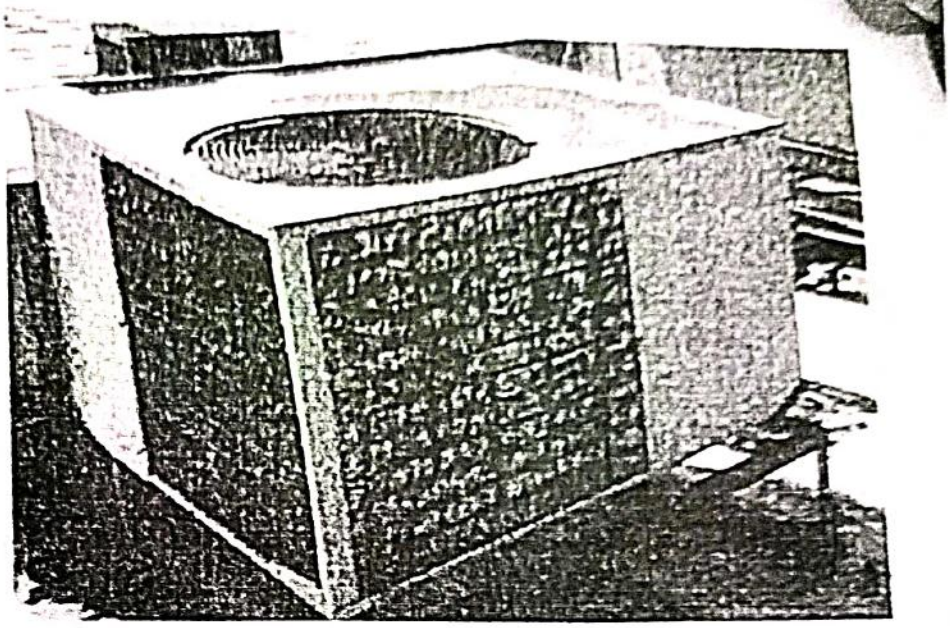


Fig. 18.3. Winter air conditioning system.

The outside air flows through a damper and mixes up with the recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove dirt, dust and other impurities. The air now passes through a preheat coil in order to prevent the possible freezing of water and to control the evaporation of water in the humidifier. After that, the air is made to pass through a reheat coil to bring the air to the

18.9 Summer Air Conditioning System

It is the most important type of air conditioning, in which the air is cooled and generally dehumidified. The schematic arrangement of a typical summer air conditioning system is shown in Fig. 18.5.



Summer air-conditioning system.

The outside air flows through the damper, and mixes up with recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove dirt, dust and other impurities. The air now passes through a cooling coil. The coil has a temperature much below the required dry bulb temperature of the air in the conditioned space. The cooled air passes through a perforated membrane and loses its moisture in the condensed form which is collected in a sump. After that, the air is made to pass through a heating coil which heats up the air slightly. This is done to bring the air to the designed dry bulb temperature and relative humidity.

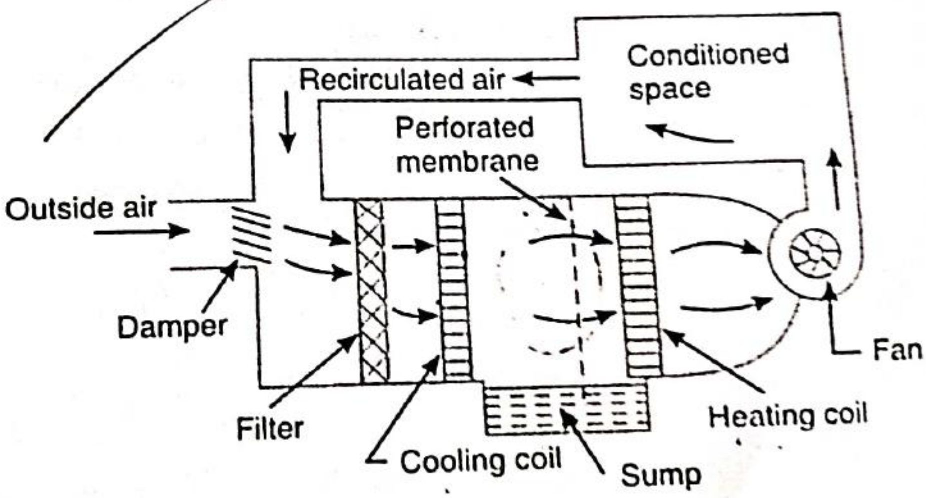


Fig. 18.5. Summer air conditioning system.

Now the conditioned air is supplied to the conditioned space by a fan. From the conditioned space, a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators. The remaining part of the used air (known as recirculated air) is again conditioned as shown in Fig. 18.5. The outside air is sucked and made to mix with the recirculated air in order to make up for the loss of conditioned (or used) air through exhaust fans or ventilation from the conditioned space.

...ir conditioned hall is 300 m³/min. The

"Cooling & De-humidification. process is used in Summer Air-conditioning"

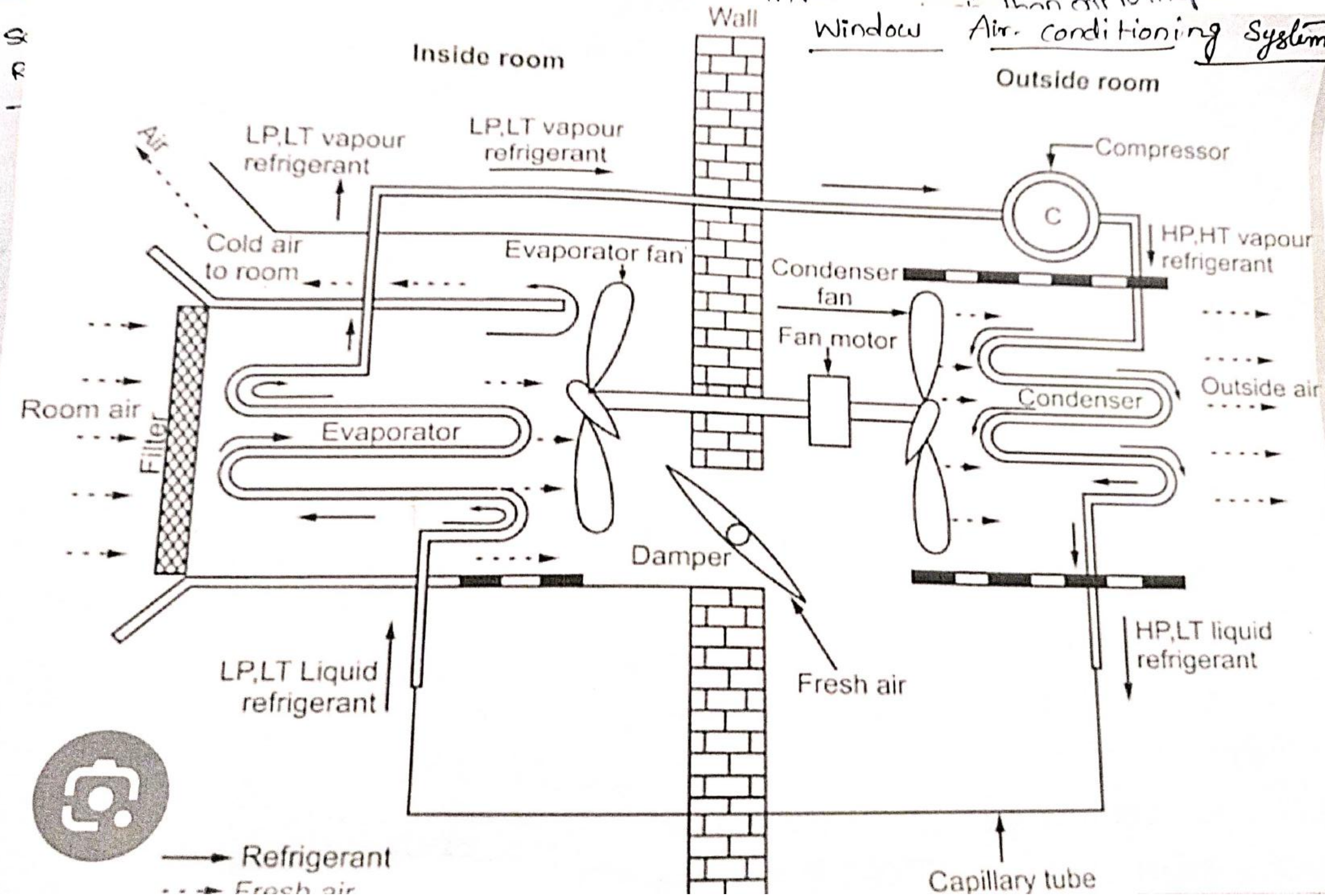
v. v. Imp.

Explain the working of window air conditioner with neat sketch.

Answer:

The low pressure and low temperature refrigerant vapour from evaporator is sucked by compressor. The compressor compresses the vapour to high pressure and high temperature and discharges to the condenser. On the condenser the refrigerant vapour condenses by dissipating heat to the cooling medium (air) the liquid refrigerant coming out of condenser passes through filter, dryer into capillary tube where it is again throated back to the evaporated pressure. The low pressure low temp liquid refrigerant then flows to evaporator which it boil off by extracting heat from air to be circuited to the conditioned space.

Window Air conditioning System



3

Power Plant

Advantages of Power plants

- They provide a reliable source of power.
- Power plants can be built to generate specific amounts of power, making them very efficient.
- They can be located near population centres, making power accessible to more people.

Disadvantages of Power plants

- They can be expensive to build.
- They can be difficult to maintain.
- They can have a negative impact on the environment.

- Biomass Power Plants

3.1.1 Principle of Operation in a Steam Power Plant

Thermal power plants, also known as steam power plants, play a pivotal role in meeting nearly two-thirds of the world's electricity demand. These power stations operate by generating steam through the combustion of fossil fuels, such as coal, which is then harnessed to drive a steam turbine. Consequently, thermal power stations are sometimes referred to as Steam Power Stations. The steam, having passed through the steam turbine, undergoes condensation in a condenser before being reintroduced into the boiler to be transformed back into steam. This recurring process is recognized as the Rankine cycle. This article provides an insight into the electricity generation process within thermal power plants, with a particular focus on coal-fired thermal power plants, as coal serves as the predominant primary fuel source for most of these facilities.

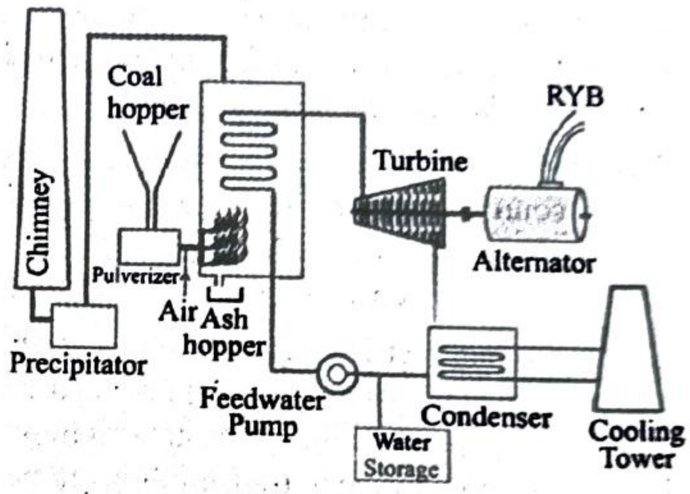


Fig. 3.1: Depiction and Layout of a Steam Power Plant

A Typical Layout and Operation of a Thermal Power Plant

Figure 3.1 is a simplified depiction of the layout and operation of a thermal power station.

Coal Fuel Utilization: In a coal-based thermal power plant, coal is transported from mines to the power generating station. Typically, bituminous coal or brown coal serves as the primary fuel source. The coal is stored in two ways: 'dead storage,' which provides a 40-day backup coal supply for times when coal delivery is unavailable and 'live storage,' which is a raw coal bunker located in the boiler house. To ensure the longevity of equipment, the coal is initially cleaned in a magnetic cleaner to remove any iron particles. Subsequently, it undergoes a crushing process to reduce it to small particles and is then sent to a pulverizer to be converted into a powdered form. The complete combustion of finely powdered coal enhances the boiler's efficiency. The ash generated during coal combustion is removed from the boiler furnace periodically to ensure proper combustion and disposal of the ash.

Boiler Operation: The mixture of pulverized coal and preheated air is introduced into the boiler and ignited in the combustion zone. This ignition creates a substantial fireball at the boiler's centre, emitting a significant amount of heat energy. This heat energy is harnessed to convert water into steam under elevated temperature and pressure conditions. Steel tubes lining the boiler walls facilitate this transformation of water into steam. The resulting flue gases pass through a superheater, economizer and air preheater before being released into the atmosphere through the chimney.

- **Superheater:** Superheater tubes are in the hottest part of the boiler, where saturated steam from the boiler tubes is heated to approximately 540°C before being fed into the steam turbine.
- **Economizer:** The economizer acts as a feedwater heater, preheating the water before supplying it to the boiler.
- **Air Pre-heater:** The primary air fan draws in atmospheric air and warms it in the air preheater. Preheated air is then injected with coal in the boiler, enhancing coal combustion efficiency.

Steam Turbine Operation: High-pressure superheated steam is directed into the steam turbine, causing the turbine blades to rotate. This rotation converts the energy in the steam into mechanical energy, making the steam turbine the prime mover. As the steam passes through the turbine, its pressure and temperature decrease, while its volume expands. The expanded, low-pressure steam is subsequently exhausted into the condenser.

Condenser Function: The exhaust steam is condensed in the condenser using a circulation of cold water. During this process, the steam loses both pressure and temperature, reverting to a liquid state. Condenisation is essential because compressing a gaseous fluid requires significantly more energy than compressing a liquid, thus improving cycle efficiency.

Alternator and Electrical Generation: The steam turbine is linked to an alternator, which generates electrical energy as the turbine rotates. The generated electrical voltage is then increased via a transformer and transmitted to where it is needed.

Feed Water Pump: The condensed water is returned to the boiler by a feed water pump, compensating for any water loss that may occur during the cycle.

This summarizes the fundamental operation of a thermal power station and its typical components. Real-world thermal power plants may feature more intricate designs with multiple turbine stages, such as High-Pressure Turbine (HPT), Intermediate Pressure Turbine (IPT) and Low-Pressure Turbine (LPT).

Advantages:

- Economical Initial Cost
- Smaller Land Footprint Compared to Hydro Power Plants
- Cost-Effective Coal Fuel

- Manageable Maintenance Costs
- Flexibility in Location Due to Access to Water Sources and Transportation

Disadvantages:

- High Operational Costs (Fuel and Maintenance)
- Relatively Low Overall Efficiency (Approximately 35% to 41%)
- Contribution to Global Warming Through Emissions
- Adverse Impact on Aquatic Ecosystems Due to Heated Water Discharge into Natural Bodies of Water, Disrupting Ecology.

3.1.2 Diesel Power Plant

This power plant operates on fossil fuel, specifically diesel, classifying it as a fossil fuel-based facility. Diesel engine power plants are typically installed in locations where there is an insufficient supply of coal and water. These power plants have a power generation capacity ranging from 2 to 50 MW. They serve as standby power sources to ensure uninterrupted supply, particularly in critical facilities such as hospitals, telephone exchanges, radio stations, cinemas and industrial establishments. Diesel power plants are well-suited for mobile power generation and find extensive use in the transportation sector, including railways and ships. They are renowned for their reliability when compared to alternative power generation methods. The increasing popularity of diesel power plants can be attributed to challenges encountered in the construction of new hydroelectric and thermal power plants.

Layout of Diesel Power Plant

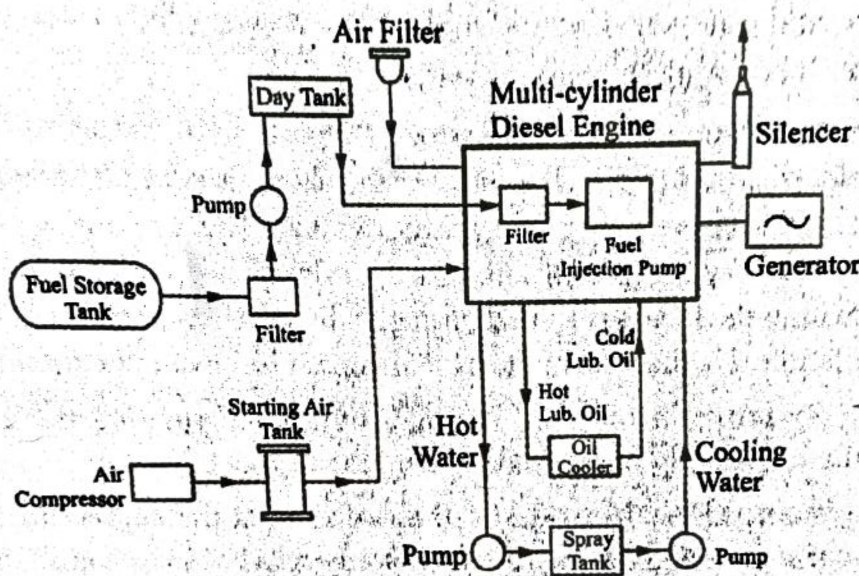


Fig. 3.2: Diagrammatic Representation of a Diesel Power Plant

Working of Diesel Power Plant

In a diesel engine power plant, the air-fuel mixture serves as the working medium. Atmospheric air enters the combustion chamber during the suction stroke, while fuel is injected via the injection pump. Inside the engine, air and fuel combine and the mixture ignites due to the high compression within the engine cylinder. The fundamental principle of a diesel engine lies in the conversion of thermal energy into mechanical energy, which is subsequently transformed into electrical energy through a generator or alternator.

Advantages:

- Ease of design and installation for these power stations.
- Availability in standard capacities.
- Responsiveness to load changes with minimal difficulty.
- Compact footprint, requiring less space.
- Quick start-up and shutdown capabilities.
- Lower capital costs.
- Reduced staffing needs for operation and supervision.
- High efficiency in converting fuel into electricity.

Disadvantages:

- Elevated operating costs.
- Higher maintenance and lubrication expenses.
- Limited capacity.
- Noise emissions can be problematic.
- Inability to manage overload situations.
- Emissions may pose hygiene concerns.

Applications:

- Used in combination with thermal or hydroelectric plants as peak load units.
- Employed as mobile power plants.
- Serve as standby units and emergency power sources during interruptions.
- Power auxiliaries for starting large steam power plants.
- Function as central stations when smaller capacity is required.

3.1.3 Working principle of Hydropower Plant

The energy harnessed from the flow of water represents one of the most potent sources of clean, renewable and cost-effective energy. This resource operates in a perpetual cycle: water evaporates into the clouds, falls like rain and repeats the process, making it an enduring and sustainable energy source. It occupies a substantial share in global electricity generation from renewable sources. The fundamental concept revolves around the movement of water from higher elevations to lower ones, causing turbines to rotate and this rotational motion is transformed into electricity through generators in hydroelectric power plants.

India's largest hydroelectric power plant is situated on the Koyna River in Maharashtra, with the capacity to generate 1920 MW of electricity. Additionally, India is home to the Bhakra Nangal Dam, the world's tallest straight gravity dam and the largest of its kind in the country.

Working Principle:

The principle behind hydroelectric power generation involves converting the potential energy stored in water into kinetic energy, which is then utilized to spin a turbine, ultimately generating electricity through a generator. The amount of energy produced depends on two primary factors: the height at which water is stored in a reservoir and the quantity (mass) of water striking the turbine blades per second, commonly referred to as the mass flow rate of water.

The most effective design approach is to maximize the height of the water reservoir while minimizing the height of the flow passage, which may even be situated below ground level. This design strategy capitalizes on the difference in water height between the reservoir and the flow passage to the turbine. The greater this height difference, the higher the power output that can be achieved.

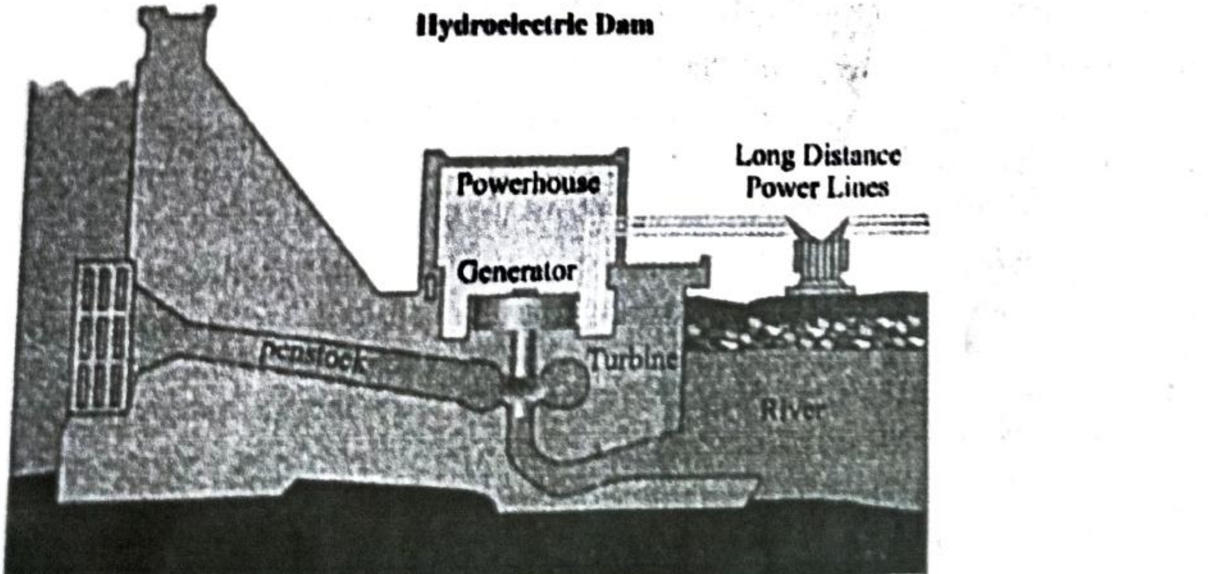


Fig. 3.3: Hydropower Plant

Working of a Hydropower Plant:

1. The dam serves as a barrier, raising the water level in the reservoir to increase its potential energy. The height difference between the reservoir and the penstock is the key factor behind the pressure that drives the turbine, generating power.
2. When the control gates are opened, water flows through the penstock toward the turbine. Along the penstock's length, surge tanks and trash racks are strategically placed. The surge tank is vital for preventing water hammering, compensating for sudden changes in load on the turbine and ensuring a consistent flow of water to the turbine, preventing power output fluctuations.
3. Trash racks remove impurities from the water before it reaches the turbine, reducing wear and tear on the turbine and extending its lifespan.

... It relies on the natural flow of water in the ... river's flow is ... not provide consistent energy output throughout the year.

Advantages:

- Abundant and reliable renewable energy source in India.
- Provides consistent power without fluctuations, even during increased load conditions.
- Allows controlled water supply for downstream agriculture.
- Modest maintenance and operational costs.
- Can mitigate downstream flooding.
- Offers tourism opportunities.

Disadvantages:

- High initial construction costs.
- Dependent on rainfall or snowmelt.
- Impedes fish migration and disrupts natural habitats.
- Displacement of downstream communities.
- The risk of dam failure can have catastrophic consequences.
- Contributes to carbon dioxide emissions due to cement used in construction.

Applications:

- Historically used for mechanical milling.
- Generates electricity for towns, industries, schools, hospitals and more.

3.1.4 Nuclear Power Plant

In a nuclear power plant, heat energy is produced through a process known as nuclear fission. Nuclear fission of heavy elements like Uranium or Thorium takes place within a specialized apparatus called a nuclear reactor. This process generates a substantial amount of heat energy. The remaining components of a nuclear power plant closely resemble those of conventional thermal power plants. Notably, just one kilogram of Uranium undergoing fission produces as much heat energy as 4,500 tons of high-grade coal. This significantly reduces fuel transportation costs, which is a key advantage of nuclear power plants. Moreover, abundant deposits of nuclear fuel exist worldwide, ensuring a sustained supply of electrical energy for thousands of years. Approximately 10% of the world's total electricity is generated in nuclear power plants.

Working of a Nuclear Power Plant:

- In a nuclear power plant, heavy elements like Uranium (U235) or Thorium (Th232) undergo nuclear fission reactions within a nuclear reactor.
- This fission process triggers a chain reaction, resulting in the generation of a substantial amount of heat energy.
- This heat energy is transferred to a coolant within the reactor, which can be water, gas, or a liquid metal.
- The heated coolant is then directed through a heat exchanger, where it causes water to transform into high-temperature steam.
- The produced steam is employed to drive a steam turbine.
- After performing its work, the steam is reverted to a liquid state and recycled back to the heat exchanger.
- The steam turbine is connected to an alternator, which generates electricity.
- This electrical voltage is subsequently increased using a transformer to facilitate long-distance transmission.

Figure 3.4 illustrates the fundamental components and layout of a nuclear power station.

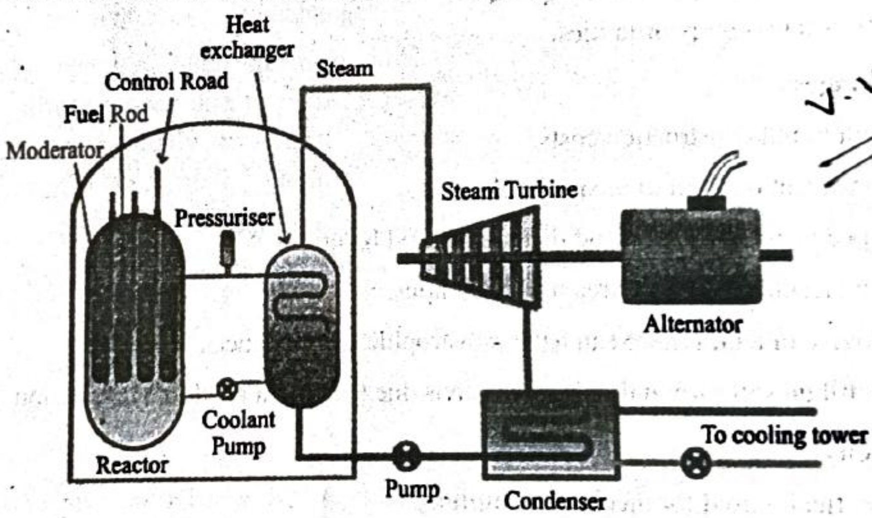


Fig. 3.4: Basic Components of a Nuclear Power Plant

Working Principle of a Nuclear Power Plant:

A nuclear reactor serves as the core component of a nuclear power plant, where nuclear fission takes place. Given the radioactivity of nuclear fission, the reactor is enclosed within a protective shield. Nuclear fission involves the splitting of heavy atom nuclei, releasing an immense amount of energy. It is achieved by bombarding slow-moving neutrons onto the nuclei of heavy elements. As the nuclei split, they release both energy and additional neutrons, triggering the fission of neighbouring atoms. This creates a chain reaction, which must be carefully controlled to prevent potential explosions. A nuclear reactor comprises fuel rods, control rods and a moderator. Fuel rods contain small spherical fuel pellets, often made of uranium. Control rods, typically composed of cadmium, absorb neutrons and can be adjusted to regulate the reaction. The moderator, which can be graphite rods or the coolant itself, slows down neutrons before they impact the fuel rods.

Two widely used types of nuclear reactors are:

- **Pressurized Water Reactor (PWR):** This reactor employs regular water as a coolant. The coolant (water) is maintained at high pressure to prevent boiling. Heated water is channelled through a heat exchanger, where a secondary coolant loop is transformed into steam. This secondary loop remains free from radioactive substances. In a PWR, the coolant water also acts as a moderator. Due to these advantages, pressurized water reactors are the most prevalent.

- **Boiling Water Reactor (BWR):** In this reactor type, only a single coolant loop is used and water is allowed to boil within the reactor. Steam is generated as it exits the reactor and then flows through a steam turbine. One drawback of a BWR is that the coolant water comes into direct contact with both the fuel rods and the turbine, potentially introducing radioactive materials to the turbine.

Advantages:

- Generating electricity from nuclear reactions in nuclear power plants does not produce pollution.
- Reactor operating costs are relatively low, with a lifespan of around 50-60 years.
- Nuclear power offers reliability and consistency over extended periods, independent of weather conditions.
- Uranium, a key fuel source, is abundant and more enduring than fossil fuels.
- Nuclear power plants provide energy security by reducing dependence on fluctuating fossil fuel prices and global environmental regulations.

Disadvantages:

- Proper storage of used nuclear fuel poses a significant challenge, occupying large areas for many years.
- Vigilance is required for the safety and radiation levels of waste storage facilities.
- The risk of nuclear accidents, such as the Fukushima incident in Japan, can have lasting and intergenerational effects due to radiation exposure.
- The immense power of nuclear energy poses security concerns if misused, potentially threatening humanity.

There are two main categories of drives:

- **Flexible Drives:** These drives connect the driver and driven shafts through an intermediate flexible element. Examples include belt drives, chain drives and rope drives.
- **Fixed Drives:** In fixed drives, the driver and driven shafts are directly connected by two rigid bodies, eliminating the need for an intermediate flexible element. Gear drives are an example of this type.

3.2.1 Belt Drive:

Belt drives utilize belts or ropes to transmit power from one shaft to another using pulleys that rotate at the same or different speeds. To transmit power, pulleys are mounted on two shafts and they are connected by an endless belt passing over the pulleys. The connecting belt is kept under tension to ensure motion transfer between the pulleys without slipping. By altering the diameter of the two pulleys, the speed of the driven shaft can be adjusted.

The amount of power transmitted through a belt drive depends on several factors, including:

- The velocity of the belt.
- The tension applied to the belt on the pulleys.
- The arc of contact between the belt and the smaller pulley.

Types of Belt Drives

Belt drives come in various types, each tailored for specific applications and operational requirements:

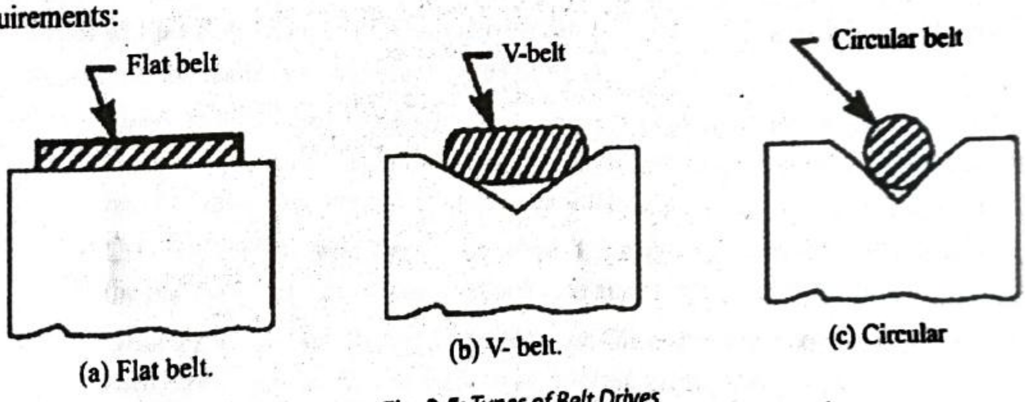


Fig. 3.5: Types of Belt Drives

1. Flat Belt:

- Flat belts have a rectangular cross-section.
- They are suitable for low-power applications with high speed.
- Typically used when the shaft distance is between 5 to 10 meters.
- Power transmission in flat belts relies on friction between the belt and the pulley.
- The rotation direction of the pulley and the belt is the same.
- Flat belts exhibit an efficiency of around 98 per cent.
- They are known for their quiet operation.

2. **V-Belt:**

- V-belts feature a trapezoidal cross-section.
- Ideal for applications with a shaft distance of less than 2 meters and requiring moderate speed and high power.
- V-belts are suitable for multiple drives.
- Often used in variable-speed drives.
- They offer a balanced combination of traction, speed, bearing load and service life.
- Transmit higher power than flat belts at the same tension level.
- Not suitable for large distances between shafts.

3. **Circular Belt:**

- Circular belts have a circular cross-section and are used with grooved pulleys.
- These belts are well-suited for applications requiring smaller initial tension and where vibration and noise reduction are crucial.
- Grooved pulleys used with circular belts can have two types of grooves: trapezoidal (with a 40° angle between the sides) or half-round (with a radius equal to that of the belt).

Materials Used for Belts: Belts are made f

1. Open Belt Drives:

- Open belt drives are employed when both pulleys need to rotate in the same direction.
- In this arrangement, the tension in the lower-side belt is greater than that in the upper-side belt.
- The lower-side belt, due to its higher tension, is referred to as the tight side, while the upper-side belt, with lower tension, is known as the slack side.

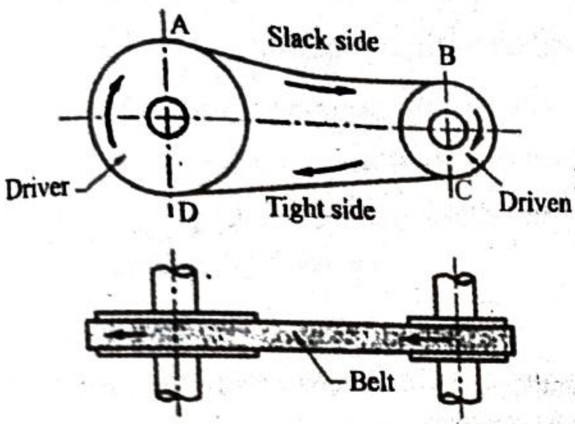


Fig. 3.6(a): Open Belt Drive

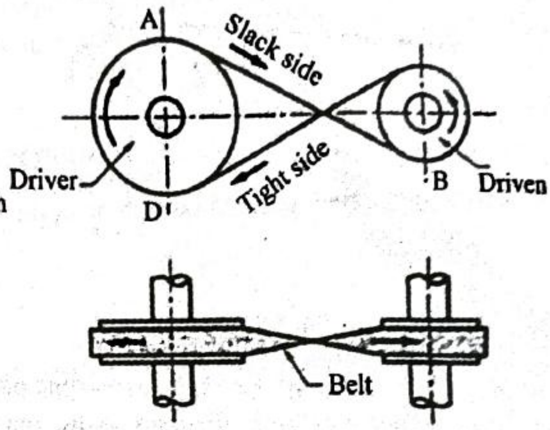


Fig. 3.6(b): Crossed Belt Drive

2. **Crossed Belt Drive:**
   - A Crossed Belt Drive is employed when the pulleys need to rotate in opposite directions.
   - In this configuration, the driver side pulls the belt from one side and delivers it to the other side.
   - As a result, the tension in the belt on one side is greater than that on the other side.

Quarter-Turn Belt Drive:

- The Quarter-Turn Belt Drive, also known as a right-angle belt drive, is utilized when shafts are arranged at right angles and rotate in a specific direction.
- To ensure the belt remains on the pulley, the width of the pulley's face should be equal to or greater than 1.4 times the width of the belt, denoted as 'b'. Please refer to the diagrammatic representation in Figure 3.7 (a) and (b).

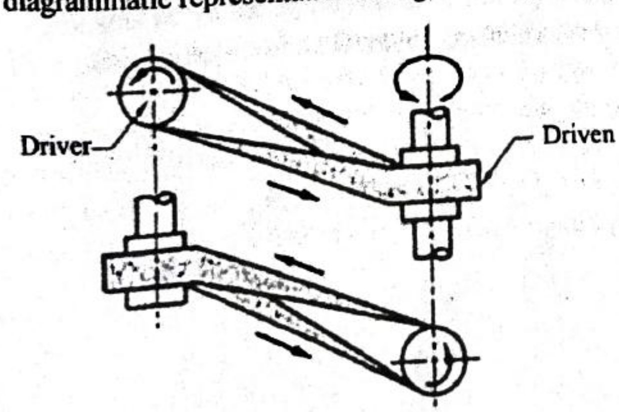


Fig. 3.7(a): Quarter Turn Belt Drive

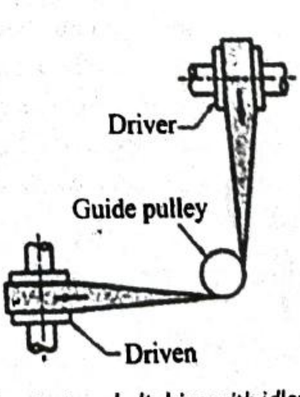


Fig. 3.7(b): Quarter turn belt drive with idler pulley

Advantages of belt drives:

- Belt drives are suitable for shafts with non-parallel axes due to their flexibility.
- They offer a cost-effective initial investment.
- Lubrication is not necessary for belt drives.
- Belt drives generate relatively low levels of noise.
- They act as flexible components that slip or break during overload conditions, safeguarding the machinery.

Disadvantages of Belt Drive:

- Belt drives are not entirely positive because belts can slip over pulleys.
- They occupy a relatively larger amount of space.
- Maintaining a consistent speed ratio can be challenging due to belt slippage.
- Periodic tension adjustment of the belt is required.
- The lifespan of belt drives is relatively shorter.

3.2.2 Chain Drive

Chains and sprockets establish a reliable form of power transmission that eliminates slippage, making them suitable for applications where precise synchronization of motion is crucial. Various types of chains are available, with the roller chain being the most common. Many maintenance practices discussed here also apply to other chain types like silent chains and rollerless chains.

Operating Principles:

Chains and sprockets serve the same fundamental purpose as belts and pulleys by transferring power between two parallel shafts. However, instead of relying on friction, chain drives operate as positive drives in which the chain links engage with specially designed teeth on the sprocket. Chain drive sprockets feature teeth arranged around their periphery, akin to gears and are characterized by parameters such as pitch circle diameter, width and the number of teeth.

The chain drive comprises three essential components: the driving sprocket, the driven sprocket and an endless chain that wraps around these sprockets, as depicted in the figure. This type of chain, featuring pin joints consisting of pins, bushes and rollers to minimize friction, is commonly known as roller bush chains. The chain drive offers a positive drive mechanism with no slippage, allowing for the maintenance of a constant velocity ratio. Chain drives find application in various devices, including bicycles, motorcycles, printing machines, textile machinery and more.

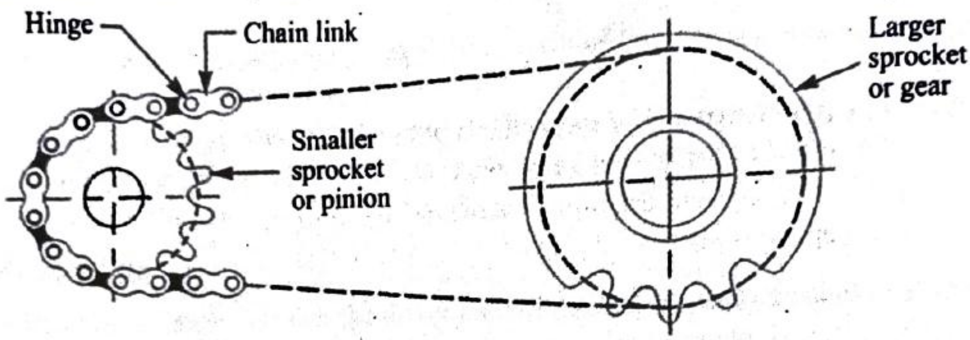


Fig. 3.11 (a): Sprockets and Chains

Standard roller chain is made up of alternate roller links and pin links.

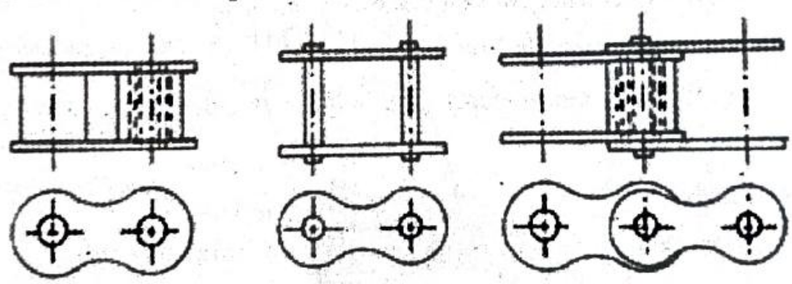


Fig. 3.11 (b): Different Links of Roller Chains

Types of Chains:

1. Hoisting and Hauling Chains
2. Conveyor Chains
3. Power Transmission Chains

Advantages of Chain Drive:

- **Positive Drive:** Chain drives offer a positive drive mechanism where there is no slipping, unlike belt drives.
- **Space Efficiency:** They require less space compared to belt drives, making them suitable for compact installations.
- **High Transmission Efficiency:** Chain drives exhibit excellent transmission efficiency.
- **Increased Power Transmission:** They can transmit more power than belt drives.

- **Robust Performance:** Chain drives can operate effectively in adverse temperature and atmospheric conditions.
- **Versatile Velocity Ratio:** They provide a higher degree of control over velocity ratios.
- **Suitable for Long Distances:** Chain drives are suitable for both long-distance and short-distance applications.

Disadvantages of Chain Drive:

- **Noise:** Chain drives tend to produce more noise compared to belt drives.
- **Higher Initial Cost:** The initial cost of chain drives is typically higher than that of belt drives.
- **Centre Distance Adjustment:** Periodic adjustment of the centre distance is necessary for proper chain drive operation.
- **Maintenance Complexity:** Maintaining chain drives can be more complex and costly compared to belt drives.

3.2.3 Rope Drive

In cases where the distance between the driver and driven shaft exceeds 5 meters and there's a need for transmitting substantial power, rope drives come into play. In these scenarios, wire ropes are employed instead of traditional belts.

Types of Ropes:

Rope drives utilize two primary types of ropes:

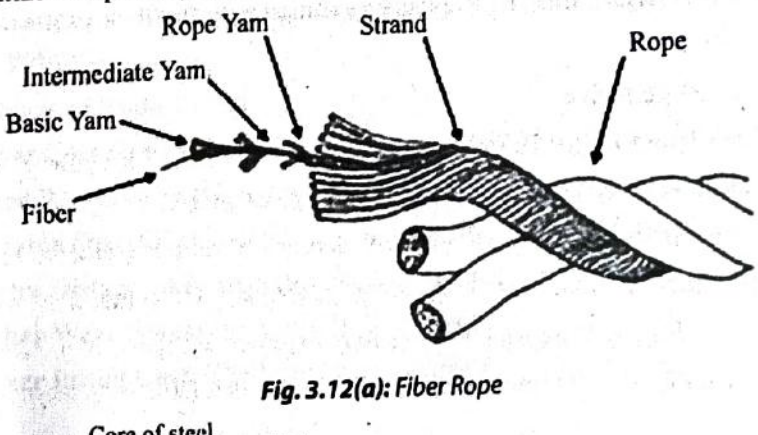


Fig. 3.12(a): Fiber Rope

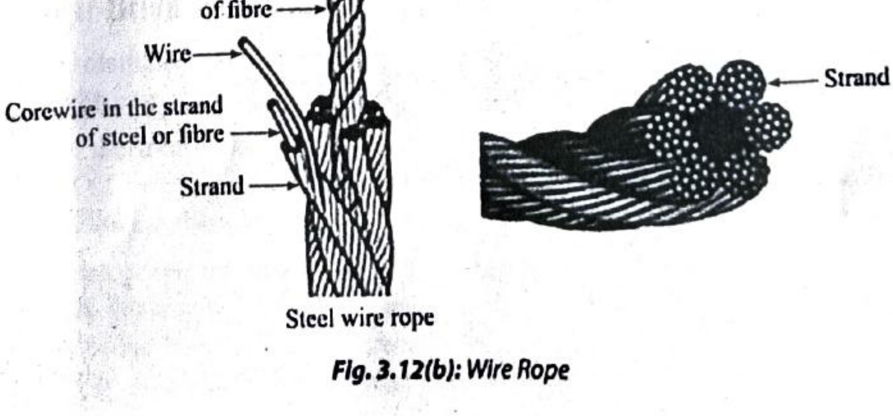


Fig. 3.12(b): Wire Rope

- **Fiber Ropes:**

Fiber ropes are suitable for applications where pulleys are spaced approximately 60 meters apart. These ropes, used for power transmission, are typically crafted from fibrous materials such as hemp, manila and cotton. However, due to the rough texture of hemp and manila fibres, ropes made from these materials tend to be less flexible and possess inferior mechanical properties.

- **Wire Ropes:**

When there's a need to transmit a substantial amount of power over considerable distances between pulleys, especially when the pulleys are separated by up to 150 meters, wire ropes are the preferred choice. Wire ropes find extensive use in elevators, mine hoists, cranes, conveyors, hauling equipment and suspension bridges.

Advantages of Rope Drive:

- **Capability for Transmitting High Power:** Multiple ropes can be employed to transmit large amounts of power.
- **Simple Maintenance:** Rope drives are known for their ease of maintenance.
- **Multiple Drives from a Single Pulley:** It is possible to accommodate more than one drive from a single pulley.
- **Quiet Operation:** Rope drives operate silently.
- **Enhanced Friction:** The presence of grooves in pulleys provides a higher coefficient of friction compared to flat belt drives.
- **Tolerance for Misalignment:** Rope drives can tolerate slight misalignments in the drive components.

Disadvantages of Rope Drive:

- **Power Loss Due to Slip:** Rope drives can experience power loss due to slip.
- **Space Requirement:** They occupy a larger physical space.
- **Variable Speed Ratio:** Maintaining a constant speed ratio is challenging.
- **Centre Distance Adjustment:** Frequent adjustment of the centre distance is necessary.
- **Higher Wear Rates:** Wire rope pulleys may experience relatively higher wear rates.
- **Higher Initial Cost:** The initial cost of rope drives is relatively higher.

3.2.4 Gear Drive

A gear is a rotational machine component equipped with precisely cut teeth or cogs designed to engage with complementary toothed parts, enabling the transmission of torque and power.

To facilitate the transmission of a specific amount of power from one shaft to another, the introduction of projections on one disc and corresponding recesses on another disc can be employed, allowing them to mesh seamlessly.

In earlier times, power transmission often utilized friction discs, as depicted in the figure. In this configuration, the capacity for power transmission relied on the frictional interaction between the surfaces of the two discs. Consequently, this method is unsuitable for transmitting higher levels of power, as it is prone to slippage between the discs.

Types of Gear Drives:

- Spur Gear
- Helical Gear
- Double Helical or Herringbone Gear
- Plain Bevel Gear
- Spiral Bevel Gear
- Hypoid Gear
- Planetary Gear
- Worm and Worm Wheel
- Rack and Pinion Gear

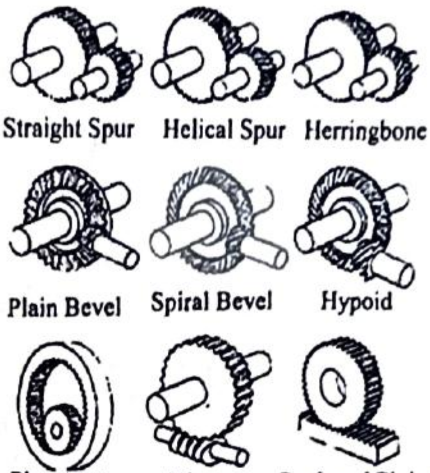


Fig. 3.13: Types of Gear Drives

Advantages of Gear Drive:

- **Positive Drive and High Efficiency:** Gear drives provide a positive and efficient method of power transmission compared to belt and rope drives.
- **Simplicity and Effectiveness:** Gear drives operate with simplicity and effectiveness, making them dependable in various applications.
- **Longer Lifespan:** Gear drives typically have a longer lifespan compared to alternative drive systems.
- **Variable Output Speeds:** They allow for the generation of multiple output speeds from a single input speed by employing suitable gear combinations.
- **Safety and Compactness:** Gear drives offer safe and compact solutions for power transmission needs.
- **Consistent Velocity Ratio:** Gear drives maintain a constant velocity ratio, ensuring steady and predictable motion.
- **Versatile Shaft Alignment:** Distinct types of gears enable power transmission between shafts with parallel, inclined, or intersecting axes.

Disadvantages of Gear Drive:

- **Susceptible to Locking:** If the tooth geometry of the gears is not properly maintained, gear drivers may experience locking issues.
- **Not Ideal for High-Speed Transmission:** Gear drives are not the preferred choice for very high-speed transmission requirements.
- **Noise Generation:** Without proper lubrication arrangements, gear drives may produce noise during operation.

TABLE 3.1 *Comparison of Belt Drives, Chain Drives and Gear Drives*

S. No.	Particulars	Belt drive	Chain drive	Gear drive
1	Main element.	Pulleys, belt	Sprockets, chain	Gears
2	Slip	Slip may occur	No slip (Positive drive)	No slip (Positive drive)
3	Suitability	For large center distance	For moderate center distance	For short center distance

3.3 INTRODUCTION TO ROBOTICS

Definition of a Robot: The Robot Institute of America defines a robot as[1] "A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks."

Components of a Robot:

- **Mechanical Platform or Hardware Base:** This is the foundational mechanical structure of the robot, which can take various forms such as a wheeled platform, articulated arm, fixed frame, or any other structure that enables interaction with the environment and the execution of its tasks.
- **Sensor System:** Positioned on or around the robot, the sensor system provides crucial environmental information and feedback to the robot's controller. Sensors enable the robot to perceive its surroundings and make informed decisions.
- **Joints:** Joints are pivotal components that grant versatility to the robot. They are not mere connectors but enable flexing, rotating, revolving and translating motions. Joints are fundamental in granting the robot a range of motion and degrees of freedom.
- **Controller:** Functioning as the robot's "brain," the controller is responsible for executing programmed instructions and governing the robot's movements and actions. It effectively manages the robot's memory, logic and decision-making capabilities.
- **Power Source:** The power source supplies the energy required for the robot's operations. It can be a battery for direct current, electricity from a power plant, solar energy, hydraulic power, or gas, depending on the robot's specific needs.
- **Artificial Intelligence (AI):** AI endows robots with the ability to simulate certain human thought processes. While modern AI allows robots to mimic some simple aspects of human thinking, achieving an elevated level of AI sophistication requires advanced programming, sophisticated controllers and enhanced sensory capabilities.
- **Actuators:** Actuators serve as the "muscles" of the robot, converting control signals into mechanical motion. They can be pneumatic, hydraulic, or electronic devices that activate

---

1 Considine, Douglas M. and Glenn D. Considine. "Robot Technology Fundamentals." Essay. In Standard Handbook of Industrial Automation. Boston, Massachusetts: Springer US, 1987.

and control various robotic functions. Common types include synchronous actuators like brush and brushless DC servo motors, stepper motors and asynchronous actuators like AC servo motors, traction motors, pneumatic and hydraulic systems.

Robot Anatomy: The manipulator or physical structure of an industrial robot is composed of a series of joints and links. Robot anatomy concerns itself with the types, sizes and configurations of these joints and links, as well as other aspects of the robot's physical construction. It plays a crucial role in determining the robot's range of motion and its ability to perform specific tasks effectively.

3.3.1 Links

In robotics, a link refers to a physical component that connects two or more joints in a robot's body. Typically, links are used to create a robot's arm, leg, or other body parts that need to move in multiple directions. Two links, an input link and an output link are connected to each joint. By moving (e.g., rotating) the joints, the links can be moved and the whole robot can be articulated. The joints typically contain some kind of motor.

Robot links are like "bones" of the robot's body. They connect and function as a foundation for the whole system, forming its skeleton. Typically, these links work with joints - the "knuckles" - to create the robot's range of motion.

Links play a key role in determining the robot's overall stability, precision and mobility. They are made of varied materials based on the requirements of the specific robotic application. They can be made of various materials from lightweight aluminum or heavy-duty steel and have different shapes, such as cylinders or boxes, depending on the robot's design and the movement it needs to perform.

3.3.2 Joints

A joint in an industrial robot bears a resemblance to a joint in the human body, as it facilitates relative motion between two body parts. Its primary function is to govern controlled relative movement between the input link and the output link.

In most cases, industrial robots are affixed to a stationary base on the floor. This base, along with its connection to the initial joint, is designated as "link 0." This serves as the input link for the first joint, denoted as "joint 1," which is the inaugural component in the series of joints that comprise the robot's structure. The outcome of this joint, "link 1," then becomes the input link for the subsequent joint, "joint 2," whose output link is "link 2," and so on. This systematic joint-link numbering scheme is visually depicted in figure 3.14.

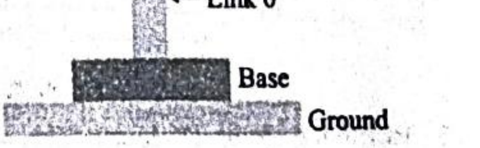


Fig. 3.14: Diagram of Robot Construction Showing that a robot is made of a Series of Joint link Combinations.

Robot Joints are pivotal components in a robot, facilitating a diverse range of movements for its links. Like human body joints, industrial robot joints enable relative motion between two parts. Most industrial robot joints fall into one of five distinct types:

These five joint types encompass two that facilitate linear motion and three that enable rotary motion:

Translational Motion:

1. **Linear Joint (Type L):** Linear joints can execute both translational and sliding movements. These motions can be achieved through various mechanisms, such as telescoping mechanisms and pistons. To achieve linear motion, the two links must be aligned with parallel axes.

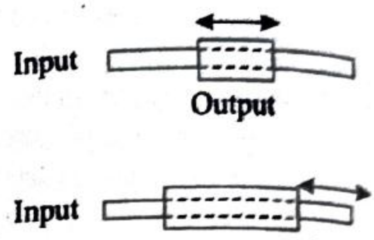


Fig. 3.15: Linear Joint (Type L)

2. **Orthogonal Joint (O-Joint):** The orthogonal joint shares similarities with the linear joint as it also enables linear motion. However, what sets it apart is that the input and output links are positioned at right angles to each other. In this configuration, the output and input links move at right angles, creating a distinct motion pattern.

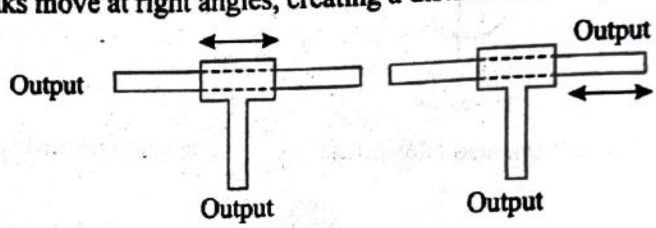


Fig. 3.16: Orthogonal Joint (O-Joint)

Rotary Motion:

3. **Rotational Joint (R-Joint):** The rotational joint permits motion in a rotary fashion along an axis that is typically vertical to the arm's axes or perpendicular to the axes of the input and output links. This joint enables rotational movement, which is crucial for various robotic applications.

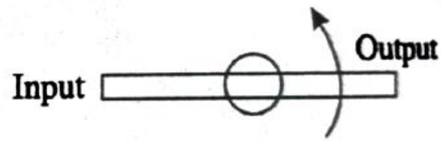


Fig. 3.17: Rotational Joint (R-Joint)

4. **Twisting Joint (T-Joint):** The twisting joint facilitates a twisting or torsional motion between the output and input links. In this type of joint, the output link's axis is typically oriented vertically to the rotational axis. This results in the output link rotating relative to the input link, allowing for twisting movements.

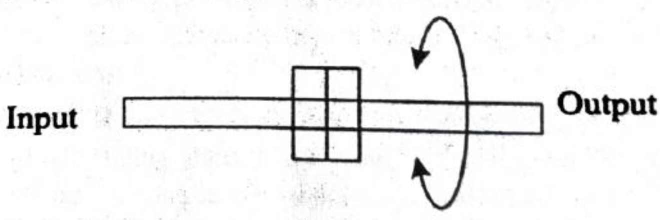


Fig. 3.18: Twisting Joint (T-Joint)

5. **Revolving Joint (V-Joint):** The revolving joint, like the twisting joint, enables rotational motion. In this configuration, the output link's axis is positioned perpendicular to the rotational axis, while the input link aligns parallel to the rotational axes. Consequently, the output link revolves around the input link, allowing for rotational movements.

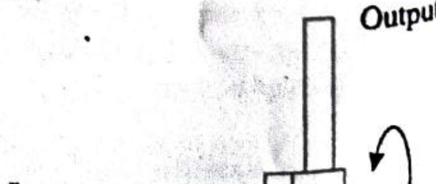


Fig. 3.19: Revolving Joint (V-Joint)