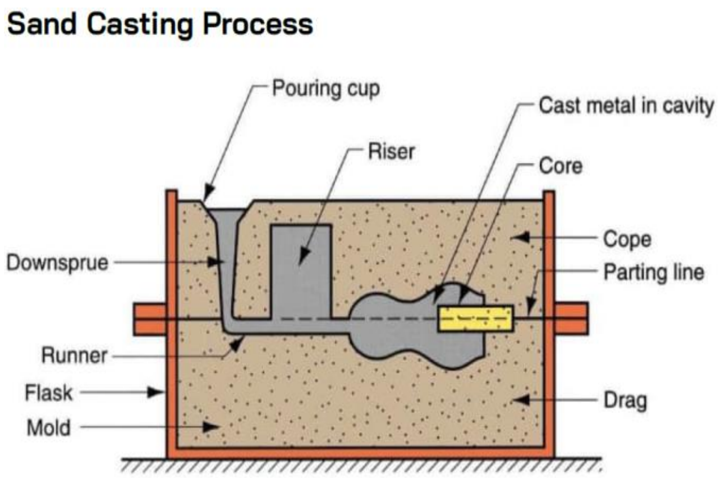
Unit II BCME

2. Manufacturing Processes:

2.1 Casting: It involves a solid dissolving into a liquid when heated and poured into a mold or cavity. Casting can create complex or simple shapes from any kind of meltable metal with a wide option for designs.

2.1.1 Casting types:

1. Sand Casting Process,
2. Gravity Die Casting
3. Pressure Die Casting
4. Investment Casting
6. Centrifugal Casting
7. Continuous Casting



2.1.2 Basic Steps of Different Casting Production:

1. Pattern making,
2. Mold making,
3. Choose metal alloys,
4. Melt and pour the alloy,
5. Finishing

2.1.2 Sand casting has its advantages and disadvantages:

Advantages	Disadvantages
Relatively inexpensive in terms of production costs, especially in low-volume production	Lower degree of accuracy as compared to alternate methods
Fabrication of large components	Difficult to use this method for products with pre-determined size and weight specifications
Casting both ferrous and non ferrous alloys	The process yields products with a rough surface finish
Recycling ability	
Processing of metals with high melting temperatures, such as, steel and titanium	

2.1.3 Applications of Castings:

- Transport : Automobile, aerospace, railways and shipping
- Heavy Equipment : Construction, farming and mining
- Machine Tools : Machining, casting, plastics molding, forging, extrusion and forming
- Plant Machinery : Chemical, petroleum, paper, sugar, textile, steel and thermal plants
- Defense : Vehicles, artillery, munitions, storage and supporting equipment
- Electrical Equipment Machines : Motors, generators, pumps and compressors
- Hardware : Plumbing industry pipes, joints, valves and fittings
- Household : Appliances, kitchen and gardening equipment, furniture and fittings
- Art Objects : Sculptures, idols, furniture, lamp stands and decorative items

2.1.4 Casting Defects:

1. Gas Porosity: Blowholes, open holes, pinholes
2. Shrinkage defects: shrinkage cavity
3. Mold material defects: Cut and washes, swell, drops, metal penetration, rat tail
4. Pouring metal defects: Cold shut, misrun, slag inclusion
5. Metallurgical defects: Hot tears, hot spot.

2.2.0 Metal forming processes

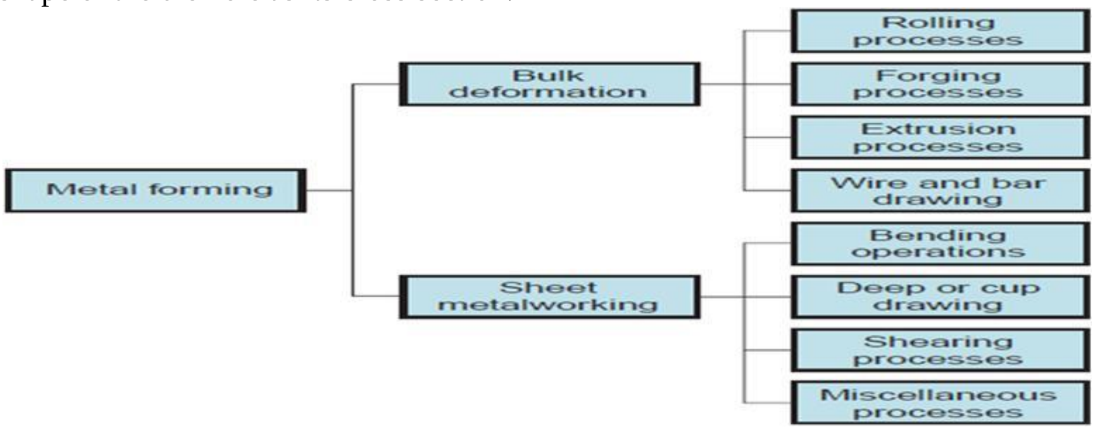
Metal forming: Largest of manufacturing processes in which the material is deformed plastically to take the shape of the die geometry. The tools used for such deformation are called die, punch etc. depending on the type of process.

2.2.1 Classification of basic bulk forming processes

a. Bulk forming: It is a severe deformation process resulting in massive shape change. The surface area-to-volume of the work is relatively small. Mostly done in hot working conditions.
b. Forging: The workpiece is compressed between two dies containing shaped contours. The die shapes are imparted into the final part.
c. Rolling: In this process, the workpiece in the form of slab or plate is compressed between two rotating rolls in the thickness direction, so that the thickness is reduced. The rotating

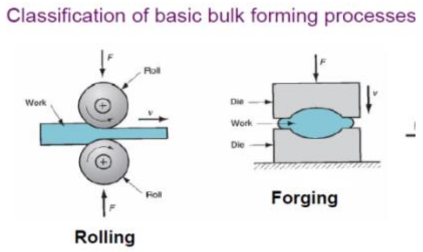
rolls draw the slab into the gap and compresses it. The final product is in the form of sheet.

d. Extrusion: In this the workpiece is compressed or pushed into the die opening to take the shape of the die hole as its cross section.



e. Wire or rod drawing: Similar to extrusion, except that the workpiece is pulled through the die opening to take the cross-section

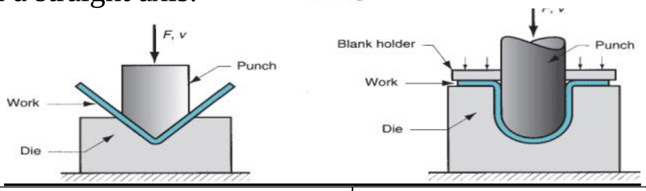
2.2.2 Classification of basic sheet forming processes:



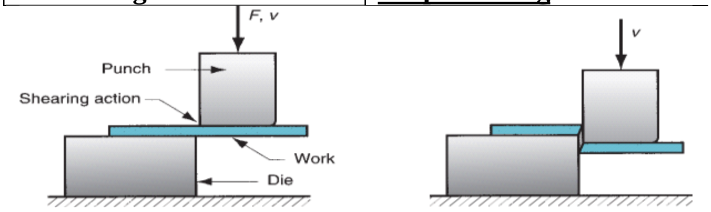
a. Sheet Forming: Sheet metal forming involves forming and cutting operations performed on metal sheets, strips, and coils. The surface area-to volume ratio of the starting metal is relatively high. Tools include punch, die that are used to deform the sheets.

b. Bending: In this, the sheet material is strained by punch to give a bend shape usually in a straight axis.

c. Deep (or cup) drawing: In this operation, forming of a flat metal sheet into a hollow or concave shape like a cup, is performed by stretching the metal in some regions. A blank holder is used to clamp the blank on the die, while the punch pushes in to the sheet metal. The sheet is drawn into the die hole taking the shape of the cavity.



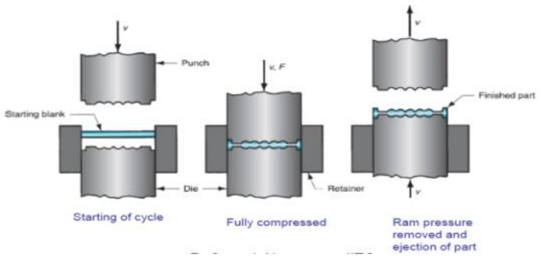
V-Bending	**Deep Drawing**



shearing

d. Shearing: This is nothing but cutting of sheets by shearing action.

e. Coining: is a simple application of closed die forging in which fine details in the die impression are impressed into the top or/and bottom surfaces of the work piece.



2.2.3 Applications of Metal Forming:

Automotive Manufacturing, Aerospace Engineering, Construction & Press working

2.2.4 Advantages & Disadvantages of Metal Forming:

Advantages:

1. Uses the simplest, Most versatile Lowest-cost tools.
2. It can accommodate all shapes from thin sheet metal to heavy plate or tubing.
3. The products made through Forming Processes are stronger and more durable than those made through casting.
4. The Forming Processes are more efficient than casting.
5. These processes allow for fabricating complex geometric shapes –
6. Great for shaping metal because the process is quick, easy, and it produces strong shapes that can often be reused.
7. It is a very economical process..

Disadvantages:

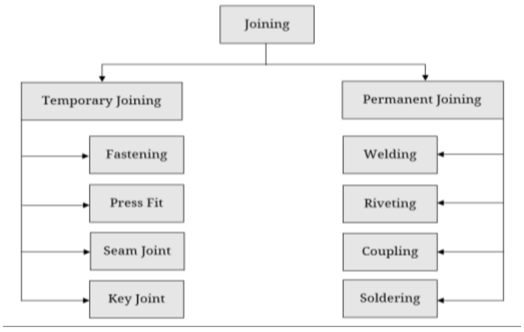
1. High power input due to large surface area contact to ambient air which requires expensive equipment for heating and cooling.
2. Slow cycle time–sometimes up to 1 hour per piece if one is producing long rods or lengths

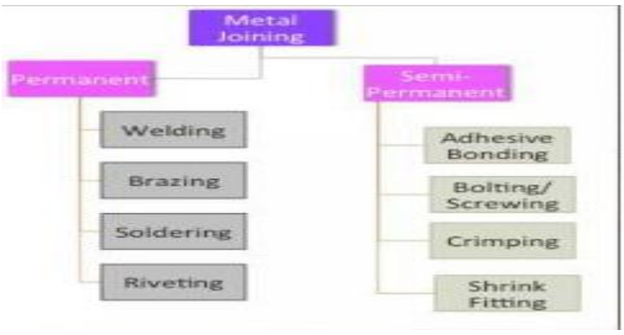
of pipe.
3. Large variations in part thickness make it difficult to maintain accurate tolerances over the entire cross-section profile.
4. Requires investment in tooling upfront.
5. High initial cost (in both time and money) for this process because special equipment may be needed to complete it.
6. Forming Processes are more expensive than casting.

2.3 Joining process

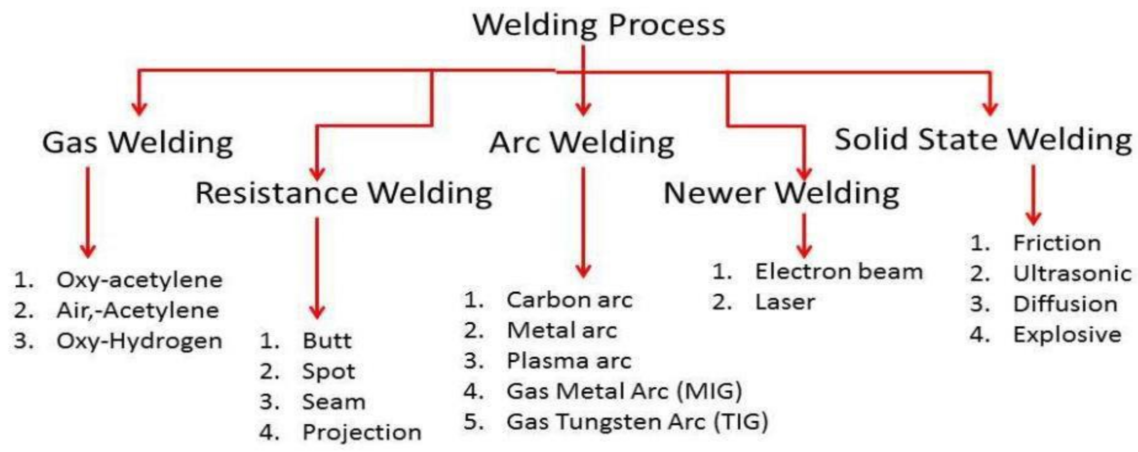
Joining is one of the manufacturing processes by which two or more materials can be permanently or temporarily joined or assembled together with or without the application of external element in order to form a single unit.

2.3.1 **Welding:** it is the process of joining two metallic components as the process of joining two similar or dissimilar metallic components with the application of heat, with or without the application of pressure and with or without the use of filler metal.

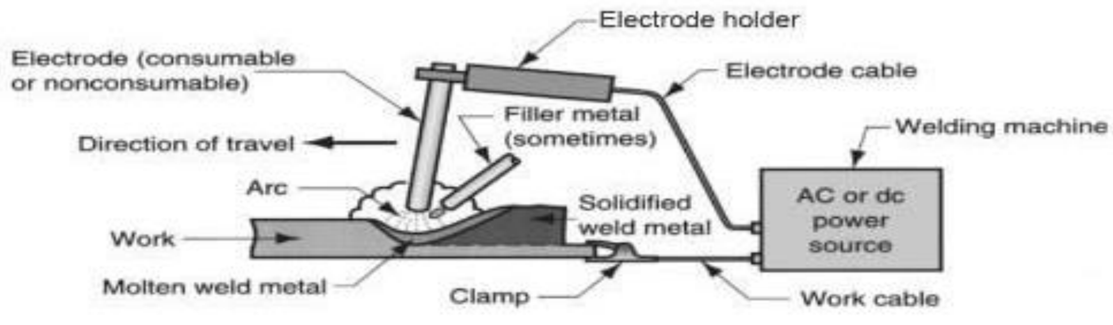




a. **Arc welding** is a type of welding process using an electric arc to create heat to melt and join metals. A power supply creates an electric arc between a consumable or non-consumable electrode and the base material using either direct (DC) or alternating (AC) currents.



The arc welding can be shown as,

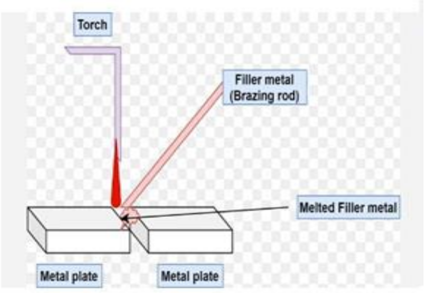


Arc Welding

b. **Gas welding:** It is carried out by a flame produced by burning approximately equal volumes of oxygen and Acetylene which are delivered at equal pressures from gas bottles to a welding torch. The flame temperature is approximately 3100°C, which is high enough to melt steel and other metals.

c. Soldering: It is a process used for joining metal parts to form a mechanical or electrical bond. It typically uses a low melting point metal alloy (solder) which is melted and applied to the metal parts to be joined and this bonds to the metal parts and forms a connection when the solder solidifies.

d. Brazing: It is a process for joining two pieces of metal that involves the application of heat and the addition of a filler metal. This filler metal, which has a lower melting point than the metals to be joined, is either pre-placed or fed into the joint as the parts are heated.



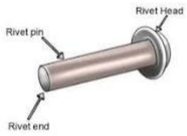
2.3.2 Applications of welding process:

1. Welding processes are commonly used across a range of industries including aerospace, automotive, energy and construction amongst others.
2. Used to join metals, thermoplastics for a variety of applications,
3. Used to create artwork by a growing community of artists.

2.3.3 Safety equipment in welding: Gloves, Apron, Shoes, Respirator, Goggles

2.3.4 Welding defects: Porosity, Spatter, Cleaning, Incomplete penetration, Slag inclusions, Misalignment, Surface porosity, Hot crack, Hydrogen embrittlement.

2.3.5 Riveting: It is a semi-permanent and non-thermal joining method that involves using a mechanical fastener/rivet (a metallic part with a dome-shaped head) to join sheet metal parts. Riveting involves drilling a hole in the two sheet metal parts you want to join together and installing a rivet.

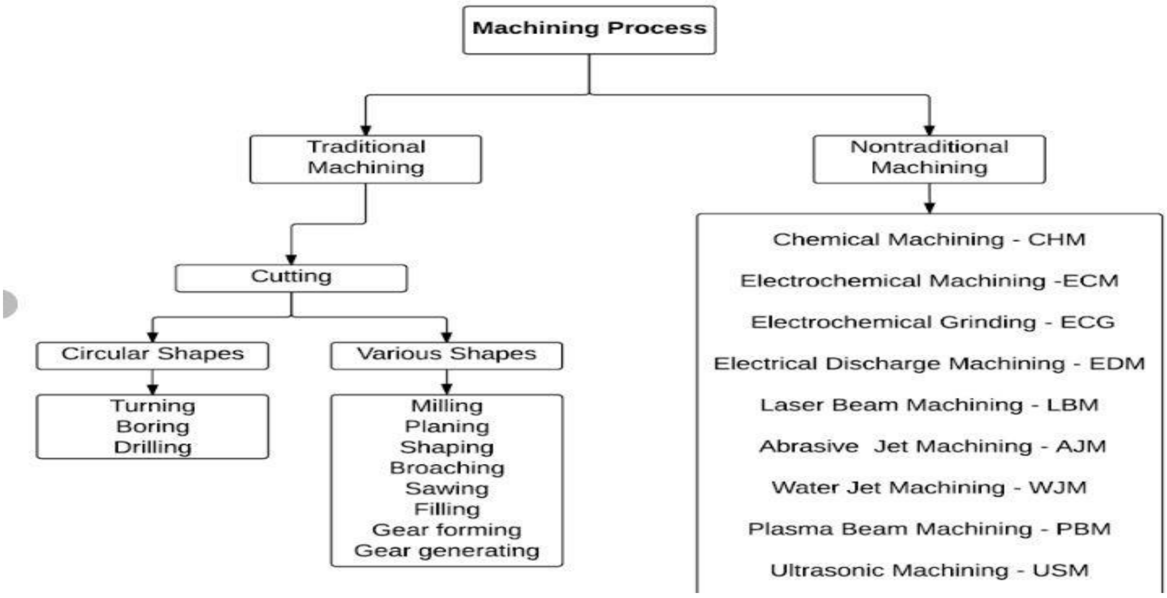


2.4 MACHINING PROCESS

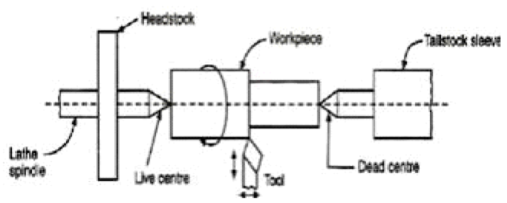
Machining is essentially the process of removing unwanted material from wrought(rolled) stock, forgings, or castings to produce a desired shape, surface finish and dimension.

It is one of the four major types of manufacturing processes used to create product components. Machining is done by shaving away the material in small pieces, called chips, using very hard cutting tools and powerful, rigid machine tools.

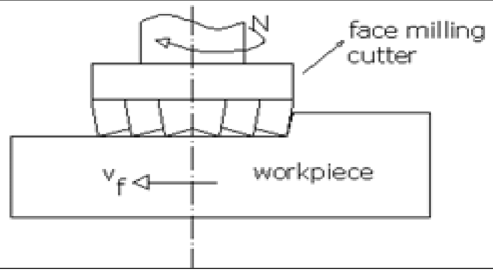
The cutting tool may be held stationary and moved across a rotating workpiece as on a lathe, or a rigidly held workpiece may move into a rotating cutting tool as on a milling machine. Machining is more costly than casting, molding and forming processes, which are generally quicker and wasteless material, but machining is often justified when precision is needed



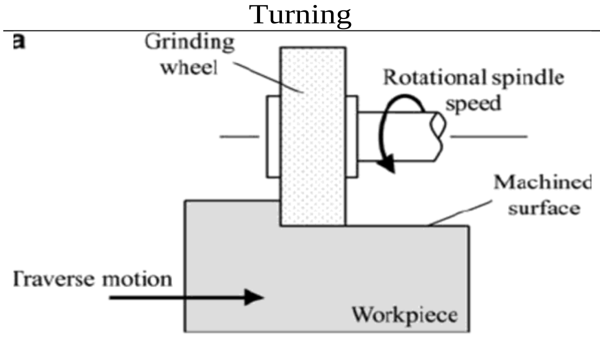
a. Turning is usually done on cylindrical metal bars and rods with a non-rotary cutting tool. This process is used for making external cuts on the metal. If turning is done from the inside, the process is called boring.
b. Milling: uses a rotary cutting tool to remove material from a stationary workpiece. It can use many different types of tools to achieve the desired result.



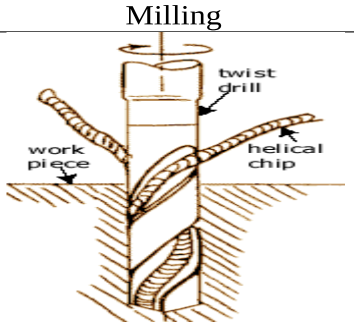
Turning



Milling



Grinding



Drilling

c. Grinding uses abrasive wheels to remove minimal material from the workpiece. It is generally applied in the secondary finishing processes for metals. The material removed by this process is minimal. However, it does not have any significant cutting capabilities.
d. Drilling is a cutting process where a drill bit is spun to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multi-point. Two basic types of cutting tools: Single point tool; and Multiple-cutting-edge tool

2.4.1 Cutting fluid: It is often applied to the machining operation to cool and lubricate the cutting tool.

a. Types of cutting fluids: soluble cutting oil, neat cutting oil, synthetic coolants, and solid lubricants.
b. Cutting parameters: cutting speed, feed and depth of cut.
c. Applications of Machining: Automotive Industry, There are various parts in a vehicle which require the precision of machining. Consumer Goods, Competing with automotive industry for the consumption of machined components are consumer goods, Aerospace Industry, Medical Industry

2.5 Computer Numerical Control (CNC):

CNC machining is a manufacturing process in which pre-programmed computer software dictates the movement of factory tools and machinery. The process can be used to control a range of complex machinery, from grinders and lathes to mills and CNC routers.

The first CNC machine was developed in 1952 by a team of researchers working at MIT (Massachusetts Institute of Technology). This advancement followed the development of the first NC (Numerical Control) machine in 1949.

2.5.1 Main Steps For CNC Machining Process

Step 1: Prepare a CAD Model

Step 2: Conversion to CNC Compatible Format (part programming): CNC part programming involves a series of coded instructions that are required to produce a part. The program controls the machine tool movements and controls auxiliary functions including spindle, coolant, and rotation. The instructions may include numbers, letters, and symbols arranged in functional format blocks.

Step 3: By virtually building the real-life machining environment prior to production, Hexagon Manufacturing Intelligence's CNC simulation software helps manufacturers avoid errors, decrease setup times, and switch CNC programs between machines to increase shop-floor productivity and reduce costs.

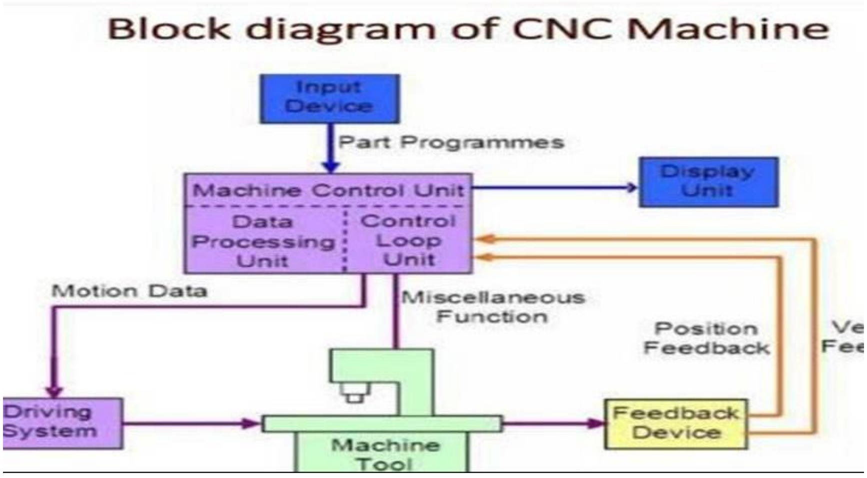
Step 4: Setup Execution: CNC (Computer Numerical Control) part programming is the process of creating a set of instructions, also known as a "program" or "code," that a CNC machine can understand and execute in order to manufacture a part.

Step 5: Machine the Part

2.5.2 Types of CNC Machines

I. CNC milling,
II. CNC turning,
III. 2-Axis CNC machines.

2.5.3 Elements in CNC machine tools: Part program, Program input device Machine Control Unit (MCU), Drive System, Machine tool, Feedback system



2.5.4. Advantages, Disadvantages & Applications of CNC machines

Advantages:

1. Machining is accurate and have very high precision.
2. Time taken to perform a job is very less.
3. Safe to operate and Reliable.
4. Number of operators required to operate a machine are reduced
5. No possibility of human error.
6. Even very complex designs can also be made.
7. Low maintenance required and energy efficient.
8. Wastage generated by CNC machining is low as compared to conventional machining.
9. It reduces the number of defective products produced to almost zero.
10. It is more efficient and faster compared to conventional machining.
11. It reduces overall production cost.
12. Products manufactured by CNC machines are highly consistent in nature.
13. One operator can supervise more than one machine at a time.
14. It can work on a wide range of materials.

Disadvantages:

1. They are costly.
2. Trained operator is required to operate the machine.
3. In case of breakdown a highly skilled professional is required to solve the problem.
4. Reduction in manual labour can lead to unemployment.
5. Its installation cost is high.

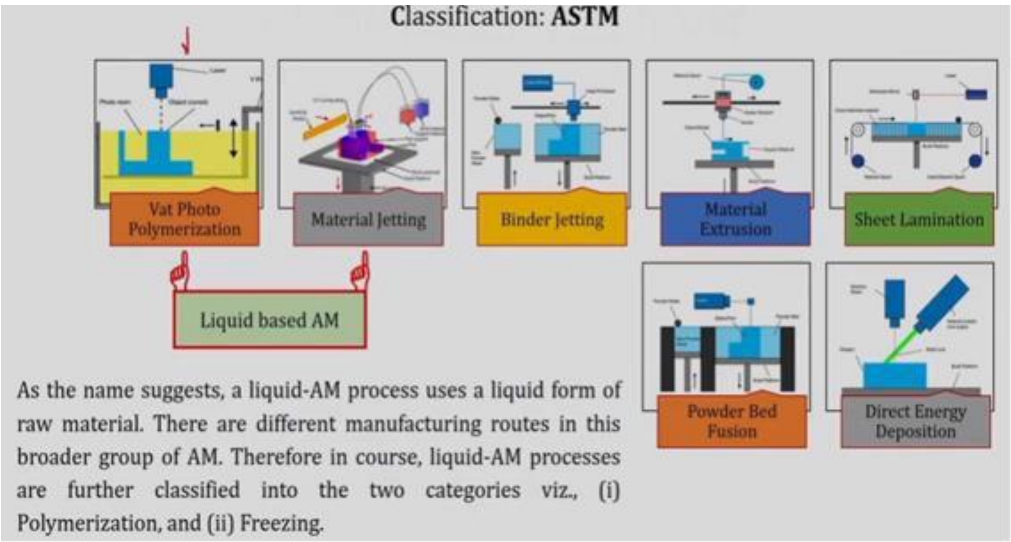
Applications:

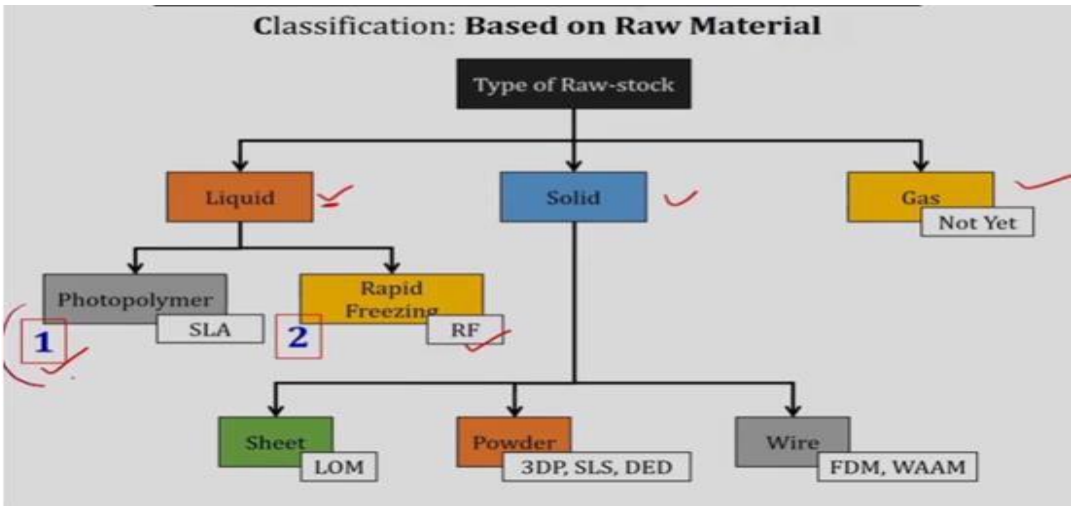
1. Automotive Industries.
2. Aerospace Industries.
3. Medical and Health care Industry.
4. Electronics Industry.
5. Optical Communication Industry.
6. Military and Defense Industry.
7. Oil and Gas Industry.
8. Energy Industry
9. Jewellary.
10. Musical Instruments.
11. Construction and Architecture.
12. Semiconductors

2.6 3D PRINTING

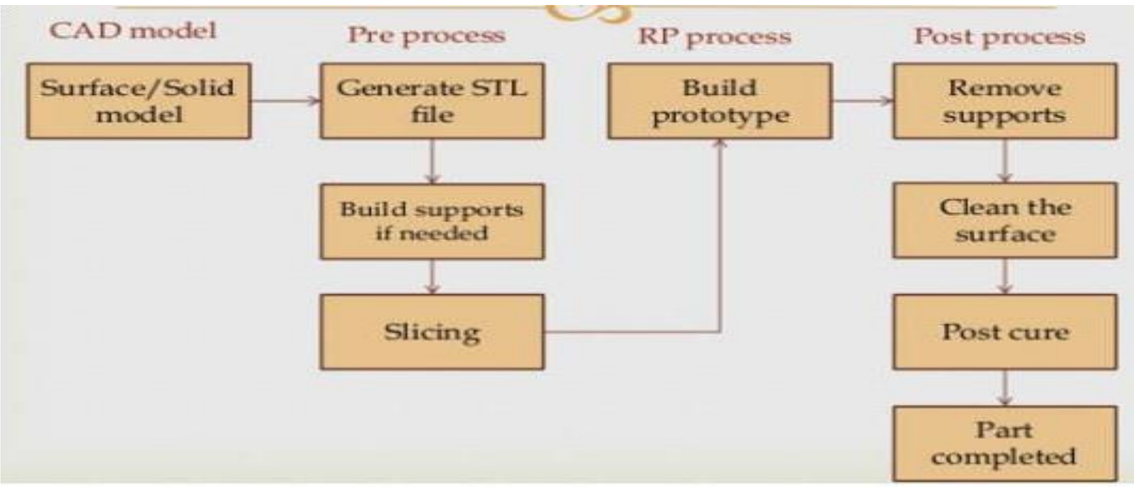
3D Printing or additive manufacturing is the construction of a three-dimensional object Roma CAD model or digital 3Dmodel. It can be done in a variety of processes in which material is deposited, joined or solidified under computer control, with the material being added together (such as plastics, liquids or powder grains being fused),typically layer by layer.
In the1980s, 3D printing techniques were considered suitable only for the production of functional or aesthetic prototypes, and a more appropriate term for it at the time was rapid prototyping.

As of 2019, the precision, repeatability, and material range of 3D printing have increased to the point that some 3D printing processes are considered viable as an industrial-production technology, whereby the term additive manufacturing can be used synonymously with 3D printing. One of the key advantages of 3D printing is the ability to produce very complex shapes or geometries that would be otherwise infeasible to construct by hand, including hollow

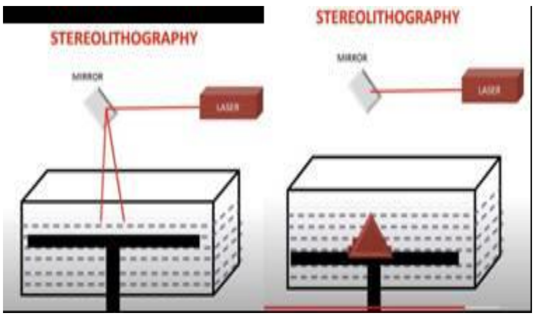




2.6.1 WORK FLOW:

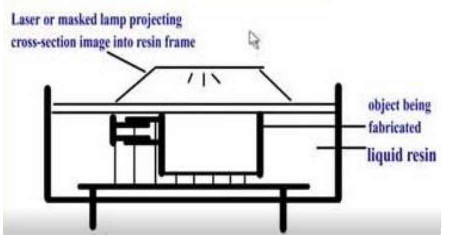


2.6.2 Types of 3D Printing or additive manufacturing:



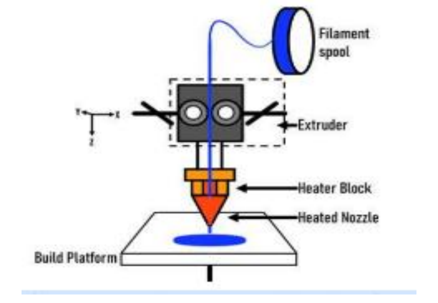
a. <u>Stereo Lithography (SLA):</u> in this process uses UV light to convert photosensitive liquid into 3D solid plastics. These layers are derived from two-dimensional cross sections of the 3D CAD model and controlled with a software file by default computer language used by most modern 3D printers, regardless of the printing technology employed. Stereolithography is best for creating. high-quality prototypes, complex geometrical shapes and master patterns for vacuum casting. SLA is also fast and inexpensive and the finished product is often strong with a smooth finish. Supports may or may not be needed depending on the machine.

b. Selective Laser Sintering (SLS): uses a high-power laser to fuse powdered thermoplastics into parts. These parts are formed on a build plate one layer at a time. They can be made with complex geometries.



Selective Laser Sintering (SLS):

c. Fused Deposition Modeling FDM printers use a thermoplastic filament to create 3D objects. The filament is then melted inside the barrel of a printing nozzle. Once it becomes hot liquid resin, it is laid down layer-by-layer. Before an object can be printed, it has to be converted into a format the 3D printer can comprehend, which is typically an. STLformat.



Fused Deposition Modeling

2.6.3 Applications of 3D printing:

1. Prosthetics.
2. Replacement Parts.
3. Implants.
4. Pharmaceuticals.
5. Emergency Structures.
6. Aeronautics and Space Travel.
7. Custom Clothing.
8. Custom-Fitted Personal Products.
9. Rapid tooling

2.7 Smart manufacturing (SM)

It is a technology-driven approach that utilizes Internet-connected machinery to monitor the production process. The goal of SM is to identify opportunities for automating operations and use data analytics to improve manufacturing performance.
SM is a specific application of the Industrial Internet of Things (IIoT). Deployments involve embedding sensors in manufacturing machines to collect data on their operational status and performance.

The Industrial Internet of Things (IIoT) is the collection of sensors, instruments and autonomous devices connected through the internet to industrial applications.

2.7.1 Technologies that enable smart manufacturing:

- Artificial intelligence (AI)/machine learning – enables automatic decision-making based on the reams of data that manufacturing companies collect. AI/machine learning can analyze all this data and make intelligent decisions based on the inputted information.

- Drones and driverless vehicles – can increase productivity by reducing the number of workers needed to do rote tasks, such as moving vehicles across a facility.

- Blockchain – blockchain's benefits, including immutability, traceability and disintermediation, can provide a fast and efficient way to record and store data.

- Edge computing – edge computing helps manufacturers turn massive amounts of machine-generated data into actionable data to gain insights to improve decision-making. To accomplish this, it uses resources connected to a network, such as alarms or temperature sensors, enabling data analytics to happen at the data source.

- Predictive analytics – companies can analyze the use huge amounts of data they collect from all their data sources to anticipate problems and improve forecasting.

- Digital twins – companies can use digital twins to model their processes, networks and machines in a virtual environment, then use them to predict problems before they happen as well as boost efficiency and productivity.

2.7.2 Comparison between smart manufacturing and traditional manufacturing

Key	Traditional manufacturing	Smart manufacturing
Data	Not fully exploited, not total accessible	Real time data collection and visualization
Process and operations	Manual optimization	Automatically optimized, and full traceability
Downtime	unpredictable	Predictable
Maintenance	Preventive/Corrective	Preventive/Corrective/Predictive
Supply chain	Traditional	Smart and 100% transparency
Efficiency	Not fully exploited	Fully exploited
Product development	Time wasting and not flexible	Faster developed products even for complex products
Energy optimization	N/A	Yes
Quality	Manual inspection	Hight quality, less cost, automatic inspection
Flexibility	Not totally flexible	Totally flexible
Decision making	Poor data	Real time data, smart algorithm to prediction

2.7.3.Big data processing:

Smart manufacturing utilizes big data analytics, to refine complicated processes and manage supply chains. Big data analytics refers to a method for gathering and understanding large data sets in terms of what are known as the threeV's ,velocity, variety and volume.

Examples of Smart Manufacturing :

- AI/Machine Learning.
- Augmented Reality/Virtual Reality.
- Automation/Robotics.
- Additive Manufacturing/Hybrid Manufacturing.
- Big Data Analysis.
- Cloud Computing.
- CNC Machining.
- Design for Manufacturing.

2.7.4 Advantages, Disadvantages & Applications of Smart Manufacturing :

Advantages :

1. Predictive Maintenance
2. Asset Optimization
3. Supply Chain Management

Disadvantages:

1. Initial implementation cost.
2. Smart Manufacturing is a bit complex. This means poorly designed systems would produce more losses than gains. But relying on the best and most reputed CAD design company will let the manufacturers overcome this disadvantage.
3. There is more need for highly skilled employees.

Applications:

1. Digital Twins
2. AI and Machine Learning
3. Autonomous Robots
4. Cloud Storage in Manufacturing

2.8 BOILER

A steam generator or a boiler is defined as a closed vessel in which water is converted into steam by burning of fuel in presence of air at desired temperature, pressure and at desired mass flow rate.

2.8.1 Function of a boiler

The steam generated is employed for the following purposes

- Used in steam turbines to develop electrical energy
- Used to run steam engines
- In the textile industries, sugar mills or in chemical industries as a cogeneration plant
- Heating the buildings in cold weather
- Producing hot water for hot water supply

2.8.2 Principle:

In case of boiler, any type of fuel burn in presence of air and form flue gases which are at very high temperature (hot fluid). The feed water at atmospheric pressure and temperature enters the system from other side (cold fluid). Because of exchange of heat between hot and cold fluid, the cold fluid (water) temperature raises and it form steam. The flue gases (hot fluid) temperature decreases and at lower temperature hot fluid is thrown into the atmosphere via stack/chimney.

2.8.3 Types and Examples of Boilers

According to the flow medium inside the tubes, the boilers are of two types.

The boiler in which hot flue gases are inside the tubes and water is surrounding the tubes is called as “fire tube boiler”. When water is inside the tubes and the hot gases are outside, then the boiler is called as “water tube boiler”.

Examples:

Fire tube boilers : Lancashire, locomotive. Cochran and Cornish boiler

Water tube boiler : Simple vertical boiler, Babcock and Wilcox boiler.

2.8.4 Comparison between water tube and fire tube boilers

Water Tube boiler	**Fire Tube boiler**
➢ Water is inside the tube and flue gases surrounded to it.	➢ Flue gases inside the tube and water surrounded to it.
➢ Operating pressure is up to 170-180 bar (high pressure boilers).	➢ Operating pressure is up to 25 bar (low and medium pressure boilers).
➢ Steam generation rate is very high (more than 3000 kg/hr)	➢ Less steam generation rate.
➢ Suitable for power plants.	➢ Suitable for small industries.
➢ Chance of explosion is more due to high steam pressure.	➢ Chance of explosion is less due to low steam pressure.
➢ Provide steam in power plants to develop electrical energy.	➢ Provide steam in chemical and pharmaceutical industries.
➢ Small chance of scale formation due to flue gases are in shell	➢ More chance of scale formation

2.8.5 Construction and working of a simple vertical boiler:

Vertical, natural circulation, natural draft, single turbular, stationary, medium pressure, solid fuel fired, fired tube boiler with internally located furnace.

Figure depicts a typical water tube boiler of early period. It has a cylindrical fire box surrounded by a cylindrical water shell connected by one inclined cross tube for improved water circulation. It is provided with standard safety control and inspection mountings.

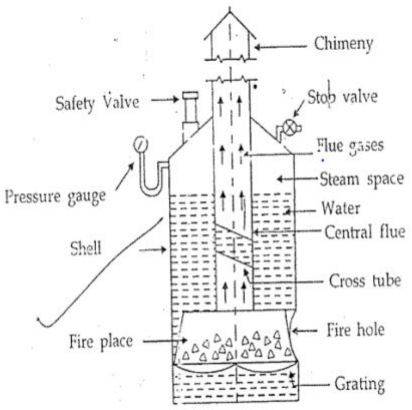


Figure: Simple Vertical boiler

Boiler drum is filled with water, the flue gas from the furnace rise in the tube. The exchange of heat takes place between water and flue gases. The water temperature raises and it converts into steam. The flue gases temperature drops and low temperature flue gases enters into environment via chimney.

Due to provision of crosstube, the total heat transfer area increases and more amount of steam is available with the same amount of flue gases. They can built for small capacity and occupy small space. The boiler is fitted with all themountingsasper RBI.

2.8.6.1 Boiler Mountings :

The boiler mountings are the different fittings and devices which are mounted on a boiler shell for proper functioning and safety. These form an integral part of the boiler. These are in two groups :

(a) Mountings for safety
   i. Safety valves – 2 nos.
   ii. High pressure and low water safety valve on Lancashire and Cornish boiler – 1 no. each.
   iii. Water level indicators – 2 nos.
   iv. Fusible plug – 1 no.

(b) Mountings for control
   i. Pressure gauge – 1 no.
   ii. Steam stop valve – 1 no.
   iii. Feed check valve – 1 no.
   iv. Blow off cock – 1 no.
   v. Man hole – 1 no.
   vi. Mud Box – 1 no.

2.8.6.2 Boiler Accessories:

The accessories are mounted on the boiler to increase its efficiency. They are :

i. Superheater
ii. Economiser
iii. Air preheater
iv. Feed water pump
v. Steam injector
vi. Steam separator
vii. Steam trap
viii. Boiler draught equipment

(a) Boiler Mountings

Name	*Function*
1. *Safety valves*	Do not allow boiler pressure to rise beyond its safe pressure
2. *Water-level indicator*	Shows working level of water in the boiler
3. *Pressure gauge*	Indicates working pressure of boiler
4. *Steam stop valve*	Regulates the amount of outgoing steam
5. *Feed check valve*	Checks the amount of feed water going to the boiler and does not allow its return
6. *Blow-off cock*	Allows to drain water from boiler
7. *Man hole*	Allows a person to go inside the boiler drum for repairs, etc.
8. *Mud hole (with door)*	Facilates removal of heavy impurities settled in the boiler drum
9. *Fusible plug*	Stops the boiler if its heating surface is overheated due to low water level
10. *Dual function safety valves*	
(a) *High pressure, low water safety valve*	Allows escape of steam in case of (i) unsafe higher pressure, or (ii) unsafe low water level
(b) *Low water, high water safety valve*	Whistles by blowing steam in case of (i) unsafe low or (ii) high water level in the drum
11. *Feed pipe*	Lead the feed water to the inside of the boiler

(b) Boiler Accessories

Name of the accessory	*Function*
1. *Economiser*	Preheating the feed water by utilising the heat of waste flue gases
2. *Superheater*	Increase the temperature of steam at constant pressure beyond saturation
3. *Anti-priming pipe (anti-priming devices)*	Filter out moisture from outgoing steam
4. *Air preheater*	Preheat the fresh air by using the heat of waste flue gases
5. *Steam injector*	Lift and force the feed water into the boiler

2.9 Heat Engines – I.C. Engines

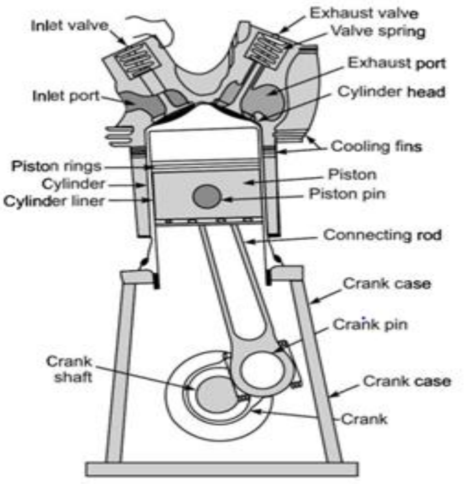
An *internal combustion engine* is a machine that converts chemical energy in a fuel into mechanical energy. Fuel is burnt in a combustion chamber, releases its chemical energy in the form of heat, which is converted into mechanical energy with the help of a reciprocating piston and crank mechanism.

Two principal types of reciprocating internal combustion engines are in general use: the Otto-cycle engine and the Diesel engine. The Otto-cycle engine, named after its inventor, the German technician *Nikolaus August Otto*, is the familiar gasoline engine used in automobiles and airplanes. The Diesel engine, named after the French-born German engineer *Rudolf Christian Karl Diesel*, operates on a different principle and usually uses oil as a fuel. It is employed in electric-generation and marine-power plants, in trucks and buses, and in other automobiles. Both Otto-cycle and Diesel-cycle engines are manufactured in two-stroke and four-stroke cycle models.

2.9.1 Schematic Diagram And Parts of An IC Engine :

The essential parts of Otto cycle (Petrol) and Diesel cycle (Diesel) engines are the same.

1. Cylinder : It is the heart of the engine. The piston reciprocates in the cylinder. It has to withstand high pressures and temperatures, and thus it is made generally by cast iron.
2. Cylinder head : The top cover of the cylinder towards TDC, is called “cylinder head”. It houses the spark plug in petrol engines and fuel injector in diesel engines. For four stroke cycle engines, the cylinder head has the housing of inlet and exhaust valves.
3. Piston : It is the reciprocating member of the engine. It reciprocates in the cylinder.
4. Piston rings : Two or three piston rings are provided on the piston. The piston rings seal the space between the cylinder liner and piston in order to prevent the leakage of high pressure gases from the cylinder to crank case.
5. Crank : It is a rotating member. It makes circular motion in the crank case. Its one end is connected with a shaft called “crank shaft” and the other end is connected with a “connecting rod”.



Details of an internal combustion engine

6. Crank case : It is the housing of the crank and the body of the engine to which the cylinder and other engine parts are fastened. It also acts as a ground for lubricating oil.
7. Connecting rod : It is a link between the piston and crank. It is connected its one end with a crank and on the other end with a piston. It transmits power developed on the piston to the crank shaft through crank. It converts the reciprocating motion of the piston into the rotary motion of the crank shaft.
8. Crankshaft : It is the shaft, a rotating member, which connects the crank. The power developed by the engine is transmitted outside through this shaft. It is made of medium carbon or alloy steels.
9. Cam shaft : It is provided on 4 stroke engines. It carried two cams, for controlling the opening an closing of inlet and exhaust valves.
10. Inlet valve : This valve controls the admission of charge into the engine during the suction stroke.
11. Exhaust valve : The removal of exhaust gases after doing work on the piston is controlled by this valve.
12. Spark Plug : It is provided on petrol engines to produce a high intensity spark which initiates the combustion process.
13. Fuel Pump : It is provided on diesel engines to inject diesel at very high pressure, through a fuel injector, into the engine cylinder at the end of compression stroke.
14. Carburettor : It is provided in a petrol engine for the preparation of a homogeneous mixture of air and petrol. This mixture is supplied to the engine cylinder through the intake or suction valve or port.

2.9.2.1 Spark Ignition (Or SI) Engines : The petrol engines use low compression ratio. The fuel i.e. petrol and air mixture, as a charge, is ignited by a high intensity spark. Therefore, they are called as “spark ignition (or SI) engines.

2.9.2.2 Compression Ignition (Or CI) Engines : The diesel engines use high compression ratio and the compressed charge is auto ignited. Therefore, they are called as “compression ignition (or CI) engines.

2.9.3 Some important terms related to the engine :

a. Dead Centre : The position at which the piston reverses its direction of motion inside the engine cylinder is called as “Dead Centre”.

b. Top Dead Centre (TDC) : If the piston reverses its direction of motion at the top of the engine cylinder, then that position of the cylinder is called “top dead centre” (TDC).

c. Bottom Dead Centre (BDC) : If the piston reverses its direction of motion at the bottom of the engine cylinder, then that piston of the cylinder is called “bottom dead centre” (BDC).

d. Bore (D) : The diameter of the engine cylinder is called as “bore” and it is represented by ‘D’.

e. Stroke length (or) stroke (or) piston stroke (L) : The distance between the top and bottom dead centres is called as “piston stroke” or “stroke” or “stroke length” and it is represented by ‘L’.

f. Swept volume (or) stroke volume (v_s) : The volume swept by the piston as it moves from one dead centre to another dead centre is called as “swept volume” or “stroke volume” and it is represented as ‘V_s’.

g. Clearance Volume (V_c) : The volume between the piston top surface and the cylinder head when the piston is at TDC is called as “clearance volume” and it is represented as ‘V_c’. The clearance volume is usually expressed as a percentage of swept volume.

h. Total volume (or) cylinder volume : The total volume of the engine cylinder is the sum of swept volume and clearance volume.

i. Compression Ratio : The ratio of cylinder volume to clearance volume is called as “compression ratio” and it is represented as ‘r’. Its value ranges between 4 and 11 for SI or petrol engines and 14 to 22 for CI or diesel engines.

2.9.4 Working Of An I.C.Engine & its types

The working of an I.C. engine is explained by 4 processes. They are i) suction or intake stroke ii) compression stroke iii) expansion or power or working stroke and iv) exhaust stroke.

Types: Four stroke engines :If in an I.C. engine, the power stroke is obtained in 4 strokes of the piston, then that engine is called as ‘four stroke engine’.

Two stroke engines : If in an I.C. engine, the power stroke is obtained in 2 strokes of the piston, then that engine is called as ‘two stroke engine’.

2.9.5 Otto Cycle:

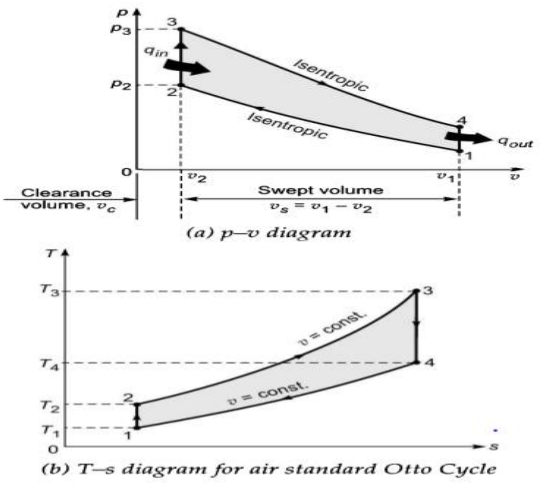


Fig. 11.9 Otto cycle

OTTO CYCLE ENGINES:
PETROL ENGINES

The ordinary Otto-cycle engine is a four-stroke engine; that is, its piston makes four strokes, two toward the cylinder head (TDC) and two away from the head (BDC). By suitable design, it is possible to operate an Otto-cycle as a two-stroke cycle engine with one power stroke in every revolution of the engine. Thus, the power of a two-stroke cycle engine is theoretically double that of a four-stroke cycle engine of comparable size. These engines are also called *spark ignition engines.*

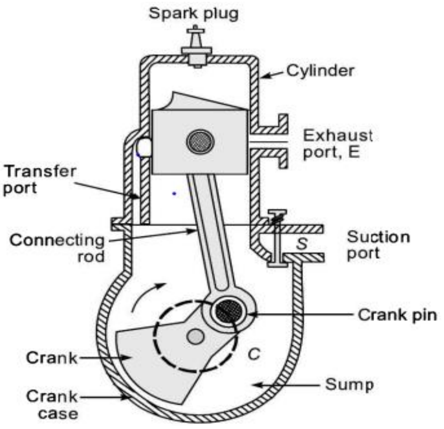


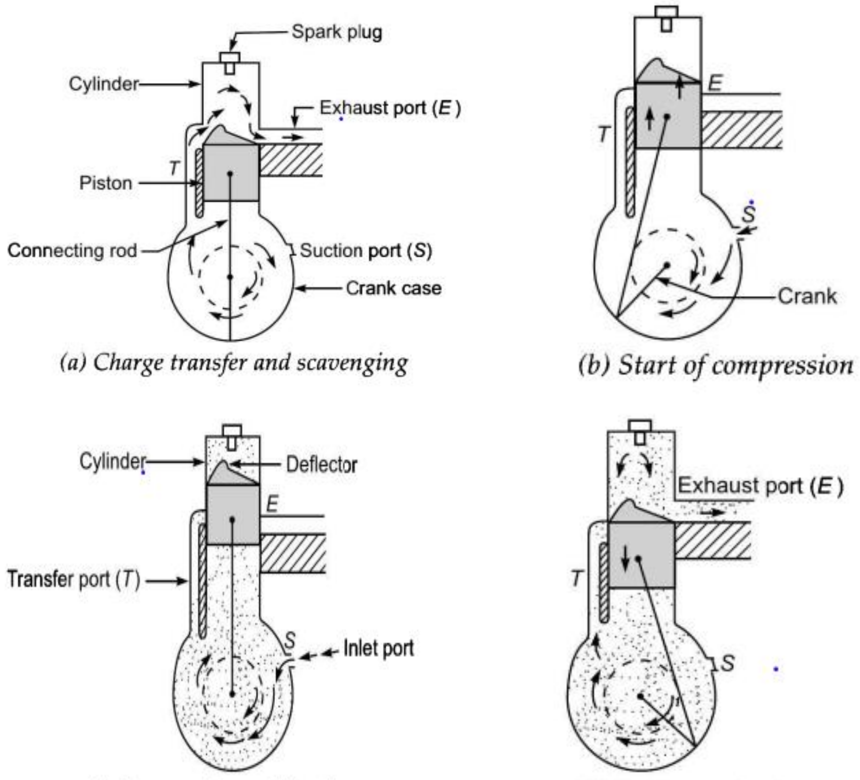
Fig. 24.2 *Two stroke petrol engine*

The two stroke petrol engine as shown in the fig 24.2 consists of a cylinder, cylinder head, piston, piston rings, connecting rod, crank, crank case, crankshaft, etc. The charge i.e. air + petrol mixture is prepared outside the cylinder in the carburettor. Ports are provided for charge inlet and exhaust, which are uncovered and covered by the moving piston. The suction port S inducts the charge into the crank case, the transfer port T transfers charge from crank case to the cylinder and the exhaust port E discharges burnt gases from the engine cylinder. The spark plug is located in the cylinder head.

2.9.6 Working principle of 2 Stroke petrol engine :

a. Charge transfer and scavenging : When the piston is at BDC, the transfer port and exhaust port are uncovered by the piston as shown in fig. (a). At the same time slightly compressed charge in the crank case enters through the transfer port T and drives out the burnt gases of the previous cycle through the exhaust port E. At the same time, the incoming charge is directed upwards due to piston top deflection and sends burnt gases out of the cylinder. This process is known as “scavenging”. As the piston moves further upwards, the fresh charge enters. Also the exhaust port remains open for a longer time than the transfer port.

b. <u>Compression and Suction :</u> Due to further piston movement, both transfer and exhaust ports are covered by the piston and the charge trapped in the cylinder is compressed as shown in fig. (b). At the same time, due to partial vacuum in the crank case, the suction port S opens and the fresh charge enters the crank case.



(a) Charge transfer and scavenging *(b) Start of compression*

(c) Compression and Suction *(d) Power and exhaust*

c. <u>Combustion :</u> When the piston reaches the TDC, a high intensity spark from the spark plug ignites the charge and initiates the combustion.

d. <u>Power and Exhaust :</u> The burnt gases exert pressure on the piston top and forces the piston downwards. While the piston is nearer the BDC, the piston uncovers the exhaust port E and the exhaust gases leave the engine cylinder. At the same time, from the underside of the piston charge enters into the crankcase as shown in fig. (d).

e. <u>Charging :</u>When the piston reaches BDC, the slightly compressed charge in the crank case enters the engine cylinder through transfer port and the cycle is completed.

<u>2.9.7 Applications of 2 Stroke Petrol Engines :</u>

Two stroke petrol engines are used where simplicity and low cost are mainly considered. They are scooters, dirt bikes, jet skis, smaller outboard motors and lawn equipment such as lawn mowers and chain saws

<u>2.9.8 Four Stroke Petrol Engine & applications:</u>

Four-Stroke Cycle Petrol Engine

All operations are carried out in four strokes of the piston, i.e., two revolutions of the crank shaft. Therefore, the engine is called a four stroke engine.

(a) Constructional Details

Similar to a two-stroke engine, it also consists of a cylinder, cylinder head attached with spark plug, piston attached with piston ring, connecting rod, crank, crank shaft, etc., as shown in Fig. 24.6. In a four-stroke engine, valves are used instead of ports. There are suction and exhaust valves. These valves are operated by cams attached on a separate shaft, called a *cam shaft*. It is rotated at half the speed of a crank shaft.

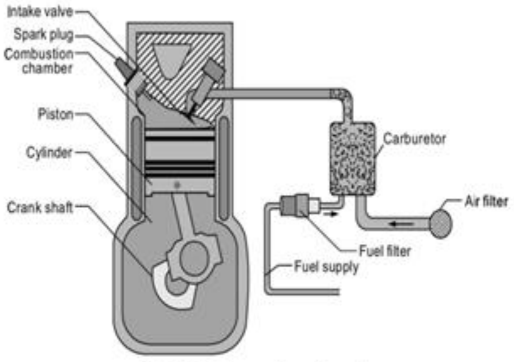
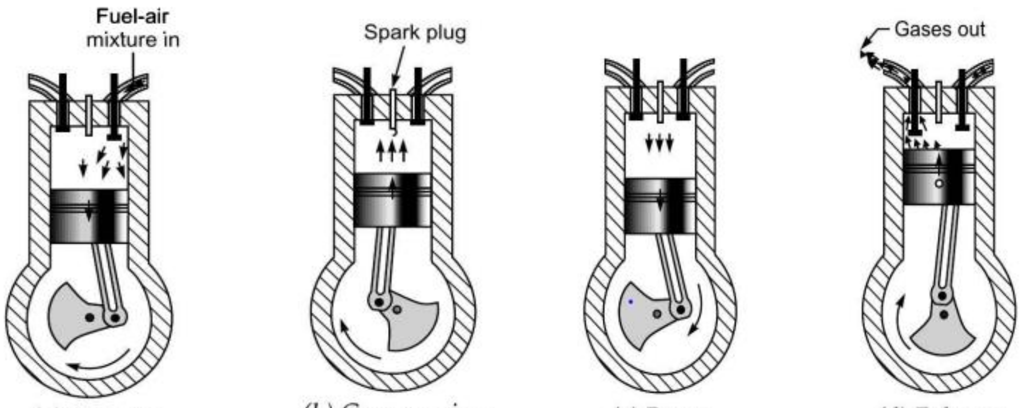


Fig. 24.6 *Four-stroke petrol engine*

Applications: They are used in Automobiles, trucks, diesel trains, light aircraft and motorcycles.

2.9.9 Working principle of 4 stroke petrol engine:



(a) Suction *(b) Compression* *(c) Power* *(d) Exhaust*

a. Suction Stroke : Suction valve opens, exhaust valve remains closed as shown in fig. The piston moves from TDC to BDC and the charge i.e. air + petrol mixture is drawn into the engine cylinder.
b. Compression Stroke : The piston moves from BDC to TDC. Both the valves are closed as shown in fig. (b). The trapped charge is compressed.
c. Expansion stroke (or) power stroke (or) working stroke : At the end of compression stroke, spark is ignited through the spark plug into the high temperature compressed charge. Then the charge is burnt and the gases are produced and they expand and exert pressure on the piston and pushes it downwards. So the piston moves from TDC to BDC. Due to this, work is performed at the crankshaft. So this stroke is called as expansion stroke or power stroke or working stroke. Both the valves are still closed.
d. Exhaust Stroke : The piston moves from BDC to TDC. The exhaust valve is opened and the burnt gases inside the engine cylinder are sent out through it.

2.9.10 DIESEL CYCLE

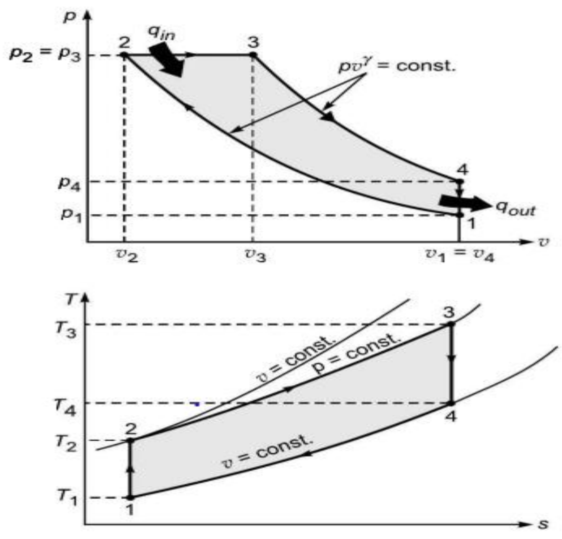


Fig. 11.10 *Air-Standard Diesel cycle*

The Diesel cycle is an ideal cycle for reciprocating *compression ignition* (*CI*) *engines*. It was proposed by Rudolph Diesel in 1892.

In gasolene engines, a mixture of air and fuel is compressed during the compression stroke, and thus the compression ratio is limited by engine knock (auto-ignition of charge). In a Diesel engine, only air is compressed during the compression stroke, thus eliminating the possibility of auto-ignition. Therefore, Diesel engines are designed to operate at a very high compression ratio, typically between 12 and 24.

In the air-standard Diesel cycle (shown in Fig. 11.10) the combustion process is approximated as a constant-pressure, heat-addition process. The remaining three processes are same for both Otto and Diesel cycles.

Process 1 - 2 : Isentropic compression
Process 2 – 3 : Reversible constant pressure heat addition
Process 3 – 4 : Isentropic expansion and
Process 4 – 1 : Reversible constant volume heat rejection

2.9.11 Two sroke Diesel engines

All engines using diesel as a fuel operate on the diesel cycle. They work similar to a petrol engine except that they take in only air as charge during suction and the fuel i.e. diesel is injected at the end of the compression stroke. The diesel engines have a fuel injector instead of a spark plug in the cylinder head as shown in the above fig. The diesel engines use a high compression ratio in the range of 14 to 21. The temperature of intake air reaches quite a high value at the end of compression. Therefore, the injected fuel is self ignited. The diesel engines use a heterogeneous air – fuel mixture, ratio ranging from 20 to 60.

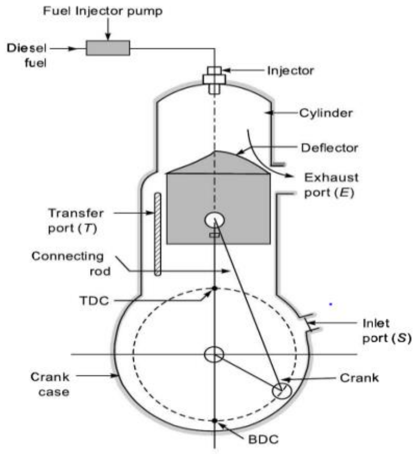


Fig. 24.10 *Schematic of two-stroke Diesel engine*

2.9.12 Operation of 2 stroke Diesel engine:

The operation ofa two stroke diesel engine is similar to a petrol engine, except it takes air as charge and fuel is injected at the end of the compression stroke. It uses a high compression ratio. Therefore the injected fuel is self ignited.

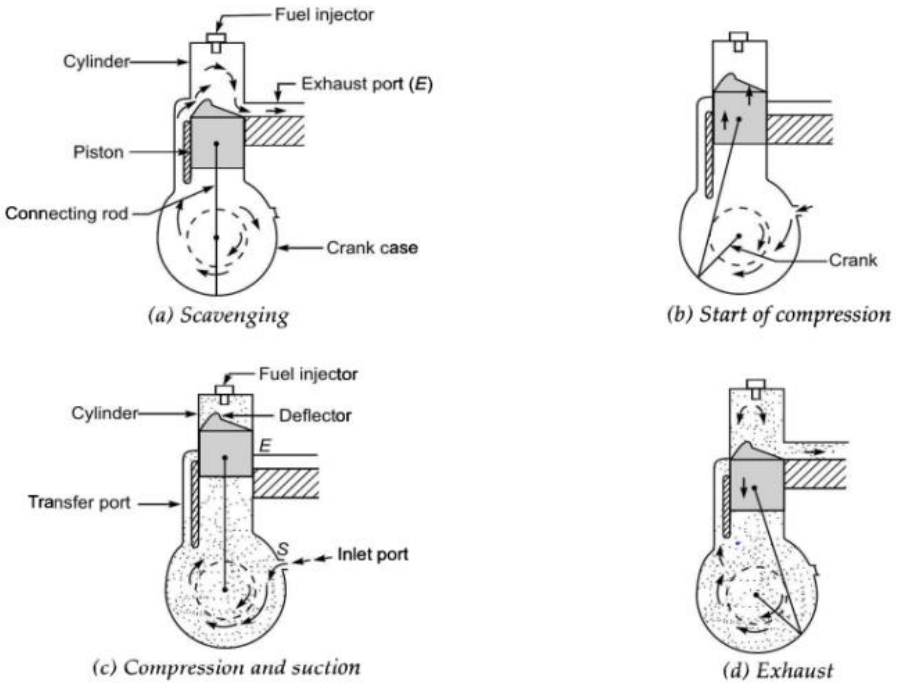
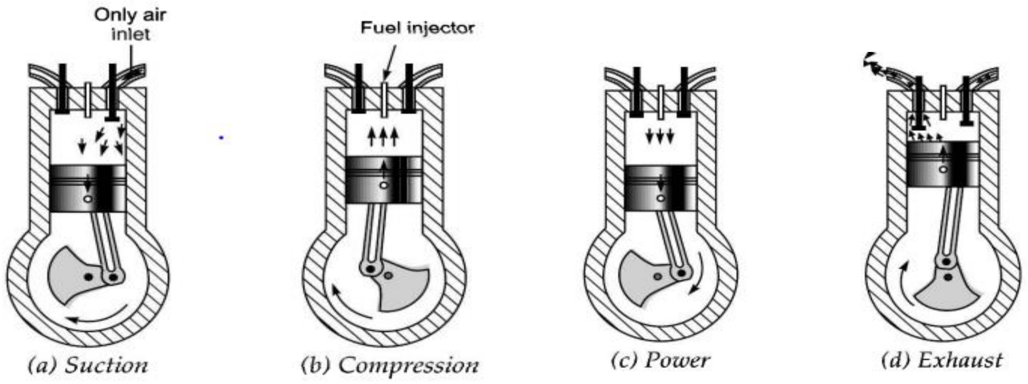


Fig. 24.11 *Operations of a two-stroke Diesel engine*

2.9.13 Working principle of 4 stroke diesel engine:



a. Suction Stroke : The piston moves from TDC to BDC. Only air enters into the engine cylinder due to the opening of the inlet valve.
b. Compression Stroke: The piston moves from BDC to TDC. Both the inlet and exhaust valves are closed. The air is compressed because of the piston movement and its temperature reaches to about 800^{0}C. At the end of compression stroke, fuel is injected at very high pressure through the fuel pump and fuel injector into the hot compressed air. As a result, ignition starts.
c. Expansion Stroke (or) Power Stroke (or) Working Stroke : Both the valves are closed. The piston moves from the TDC to BDC. Due to ignition, gases are released and they expand and pushes the piston downwards at high pressure due to their expansion. Because of this,

work is done and power is produced.

d. Exhaust stroke :Now the piston moves from BDC to TDC. The exhaust valve is opened and the burnt gases are expelled out through the exhaust valve and the cycle of operations are completed.

COMPARISON BETWEEN TWO-STROKE AND FOUR-STROKE ENGINES

According to	*Two-Stroke Engine*	*Four-Stroke Engine*
1. Working stroke	There is one working stroke in each revolution. Hence engine has more even torque and reduced vibration.	There is one working stroke in two revolutions. Hence engine has uneven torque and large vibration.
2. Engine design	It uses ports and hence engine design is simple.	It uses valves, therefore, mechanism involved is complex.
3. Mechanical efficiency	The working cycle completes in one revolution and hence it has high mechanical efficiency.	Working cycle completes in two revolution, hence, it has more friction, thus less mechanical efficiency.
4. Scavenging	The burnt gases are not completely driven out. It results in dilution of fresh charge.	It has separate stroke for explusion of burnt gases, thus ideally no dilution of fresh charge.
5. Thermal efficiency	Poor thermal efficiency due to poor scavenging and escaping of charge with exhaust gases.	Very good thermal efficiency.
6. Cost	Less cost due to less parts in engine.	More cost due to large number of parts.
7. Maintenance	Cheaper and simple.	Costlier and slightly complex.
8. Weight	Lighter engine body.	Heavier engine body.

COMPARISON BETWEEN PETROL AND DIESEL ENGINES

According to	*Petrol Engine*	*Diesel Engine*
1. Basic cycle	It operates on constant-volume cycle.	It operates on constant-pressure cycle.
2. Fuel used	It uses gasolene or petrol as fuel.	It uses diesel and oils as a fuel.
3. Fuel induction	The air–fuel mixture is prepared in the carburettor and inducted into the engine cylinder during the suction stroke.	The Diesel engine takes in only air during the suction stroke, and it is compressed. At the end of the compression stroke the fuel is injected under the high pressure by a fuel injector.
4. Ignition of charge	The charge (air–fuel mixture) is ignited by a high-intensity spark produced at the spark plug.	Fuel is injected in very hot air, therefore, it is self-ignited.
5. Compression ratio	It uses less compression ratio, usually range of 4 to 10.	It uses high compression ratio, range of 14 to 21.
6. Pressure rise	Lower and controlled rate of pressure rise; therefore, operation is salient and smooth.	High rate of pressure variation, so engine operation is rough, and noisier.
7. Efficiency	For the same compression ratio, the efficiency of petrol engine is better.	It has lower efficiency for same compression ratio.
8. Pollution	Comparatively lower pollution for same power output.	Higher pollution for same power output.
9. Weight	It has comparatively less number of parts, thus is less in weight.	It uses large number of sturdier parts, thus engine is heavy.
10. Cost	Engines are cheaper.	Costlier engine due to complicated parts.
11. Maintenance	It requires less and cheaper maintenance.	It requires costlier and large maintainance.
12. Starting	Very easy to start due to lower compression ratio.	Very difficult to start due to higher compression ratio.

2.9.14 Advantages and disadvantages of Petrol & Diesel engines

Petrol engines:

❑ **Advantages**

- Relatively clear exhaust
- Low maintenance cost
- Less engine vibration

❑ **Disadvantages**

- Poor engine efficiency
- Lower compression ratio

Diesel Engines:

❑ **Advantages**

- Higher compression ratio
- Greater efficiency
- Low running cost

❑ **Disadvantages**

- Increased NOx emissions due to higher combustion temperatures
- Increased UHC emissions due to incomplete combustion

2.10 Refrigeration and Air conditioning cycles

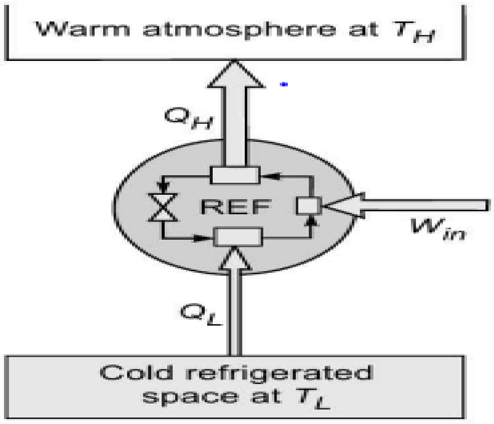
"Refrigeration" is a branch of science which deals with the transfer of heat from a low temperature region to a high temperature region, in order to maintain a desired region at a temperature below than that of the surroundings.

This process of transferring or removing heat from a substance is done under controlled conditions by using a low boiling point refrigerant. External power is required to carry out this process. Therefore, the refrigeration systems are power absorbing devices.

2.10.1 Refrigerator and Refrigerant:

A "refrigerator" is a reversed heat engine or a heat pump which takes out heat from a cold body and delivers it to a hot body.

The "refrigerant" is a heat carrying medium which during its cycle in a refrigeration system absorbs heat from a low temperature system and delivers to a high temperature system.



(a) Schematic of refrigerator

2.10.2 Applications of Refrigeration:

1. Refrigeration is used for preservation of food items, fruits, vegetables, dairy products, fish and meats, etc.
2. Refrigeration is used for preservation of life-saving drugs, vaccines, etc., in hospitals and medical stores.
3. It is used in operation theaters and intensive care units (ICU) of hospitals.
4. It is used for making ice and preservation of ice-creams.
5. It is used for providing comfort air-conditioning in offices, houses, restaurants, theatres, hotels, etc.
6. It is used in industries for improving working environment for their employees.
7. It is used for providing suitable working environment for some precision machines and precision measurement.
8. It is used in cold storages for preservation of seasonal vegetables, fruits, etc.
9. It is used for preservation of photographic goods, archeological and important documents.

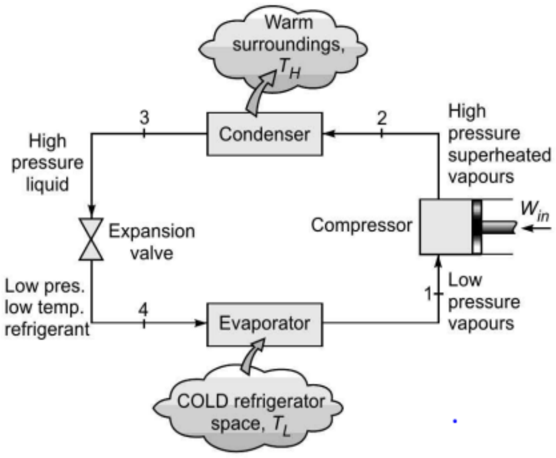
10. It is used for chilling beverages (soft drinks).
11. It is used for cooling of drinking water.
12. It is used for liquefaction of gases.
13. It is used for processing of textiles, printing work, precision articles, photographic materials, etc.
14. It is used in control rooms and air-crafts.

2.10.3 Properties of Refrigerants :

i. Non toxic
ii. Non flammable
iii. Readily available/low cost
iv. Non corrosive to metals having high thermal conductivity such as Copper, Aluminium, etc.
v. Low freezing point
vi. Low condensing pressure and high evaporator pressure

2.10.4 Refrigeration systems (or) Cycles :

(i) Vapour Compression Refrigeraton Cycle :



(a) Basic components of a refrigerator

The vapour compression refrigeration cycle consists of four processes discussed below:

Process 1–2 Isentropic compression of saturated vapour in the compressor,

Process 2–3 Constant pressure heat rejection in the condenser,

Process 3–4 Throttling of refrigerant in an expansion device, and

Process 4–1 Constant pressure heat absorption in evaporator.

Main Components of a vapour compression refrigeration system are :

a) Compressor : The function of a compressor is to remove the vapour from the evaporator and to raise its temperature and pressure.

b) Condenser : The function of a condenser is to provide a heat transfer surface through which heat passes from the hot refrigerant vapour to the condensing medium.

c) Expansion Valve : Its function is to meter the proper amount of refrigerant to the evaporator and to reduce the pressure and temperature of the refrigerant.

d) Evaporator : An evaporator provides a heat transfer surface through which heat can pass from the refrigerated surface into the vapourizing refrigerant.

Working Principle :

The refrigerant enters the compressor at the state 1, as dry and saturated vapour, and there it is compressed to a relatively high pressure and temperature, the state 2 and becomes superheated.

The superheated refrigerant at state 2 enters the condenser and leaves as saturated liquid at state 3, due to heat rejection to the surroundings.

The refrigerant at state 3 is throttled to evaporator pressure by passing through an expansion valve or a capillary tube.

The refrigerant temperature at state 4 drops below the temperature of the refrigerated space.

At state 4, the refrigerant as wet mixture, passes through an evaporator at constant pressure and is now completely evaporated by absorbing heat from the refrigerated or cold temperature space.

(ii) Bell – Coleman Cycle :

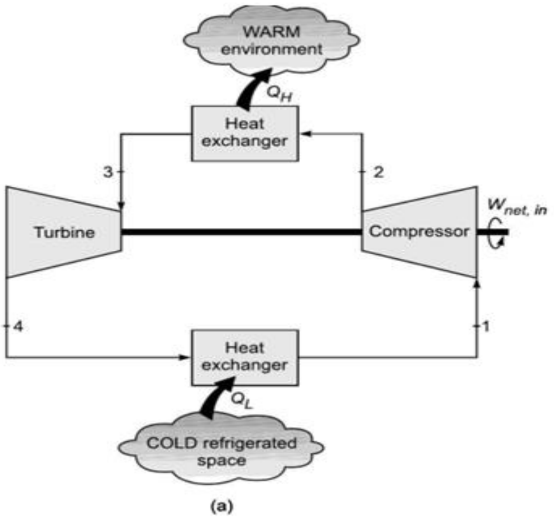
Working Principle :

The refrigerant gas enters the compressor at state 1 and is compressed to the state 2.

The gas is then cooled at constant pressure in a heat exchanger (rejecting heat to the surroundings) to the state 3 and approaches the temperature of the warm environment.

The gas is then expanded in an expander to the state 4 and attains a temperature well below the temperature of the cold region.

The refrigerant effect is achieved through the heat transfer from the cold region to gas as it passes from state 4 to 1 in a heat exchanger and the cycle is completed.



(a)

2.10.5 Air Conditioning

The term “air conditioning” is the simultaneous control of temperature, humidity, motion and purity of the atmosphere in confined space.

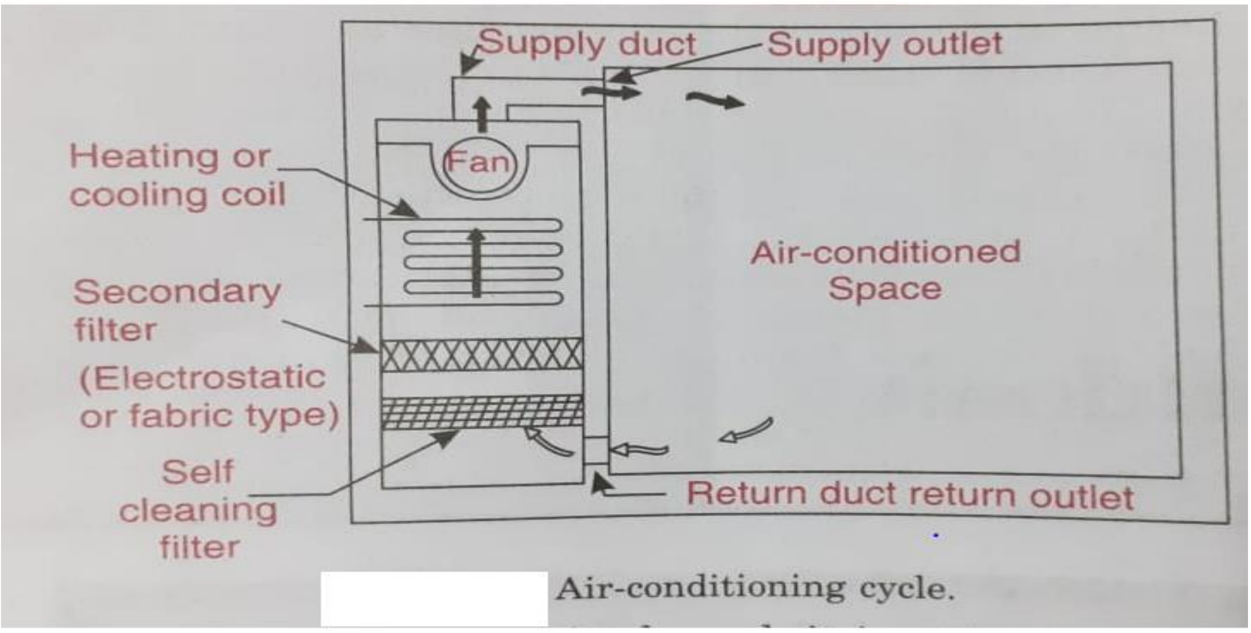
Basic Elements of Air Conditioning System :

1. Fans for moving air.
2. Filters for cleaning air, either fresh, recirculated or both.
3. Refrigerating plant connected to heat exchange surface, such as finned coils or chilled water sprays.
4. Means for warming the air, such as hot water or steam heated coils or electrical elements.
5. Means for humidification and or dehumidification.
6. Control system to regulate automatically the amount of cooling or warming.

2.10.6 Air Conditioning cycle – Main parts of the equipment :

1. Fan
2. Supply ducts
3. Supply outlets
4. Space to be conditioned
5. Return outlets
6. Return ducts
7. Filter and
8. Heating chamber or cooling coil.

PROCESS OF AIR CONDITIONING CYCLE :



Air-conditioning cycle.

1. The fan forces air into duct work which is connected to the openings in the room. These openings are commonly called as “outlets” or “terminals”.
2. The duct work directs the air to the room through the outlets.

3. The air enters the room and either heats or cools as required. Dust particles from the room enter the air stream and are carried along with it.
4. Air then flows from the room through a second outlet (or return outlet) and enters the return duct work, where dust particles are removed by a "filter".
5. After the air is cleaned, it is either heated or cooled depending upon the condition in the room.

   If cool air is required, the air is passed over the surface of a "cooling coil" ; if warm air is required, the air is passed through a "combustion chamber" or over the surface of a "heating coil".
6. Finally the air flows back to the fan and the cycle is completed.

2.10.7 Types Of Air Conditioning Systems :

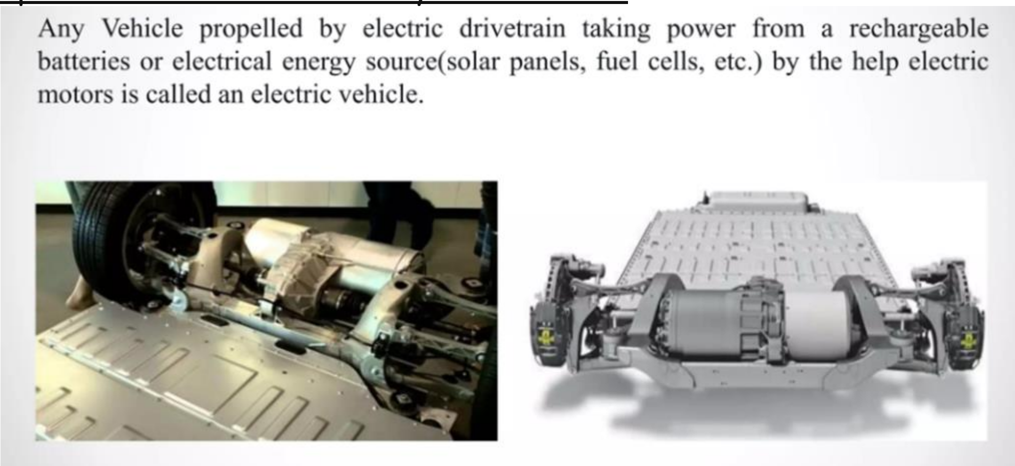
The air conditioning systems are mainly classified into :

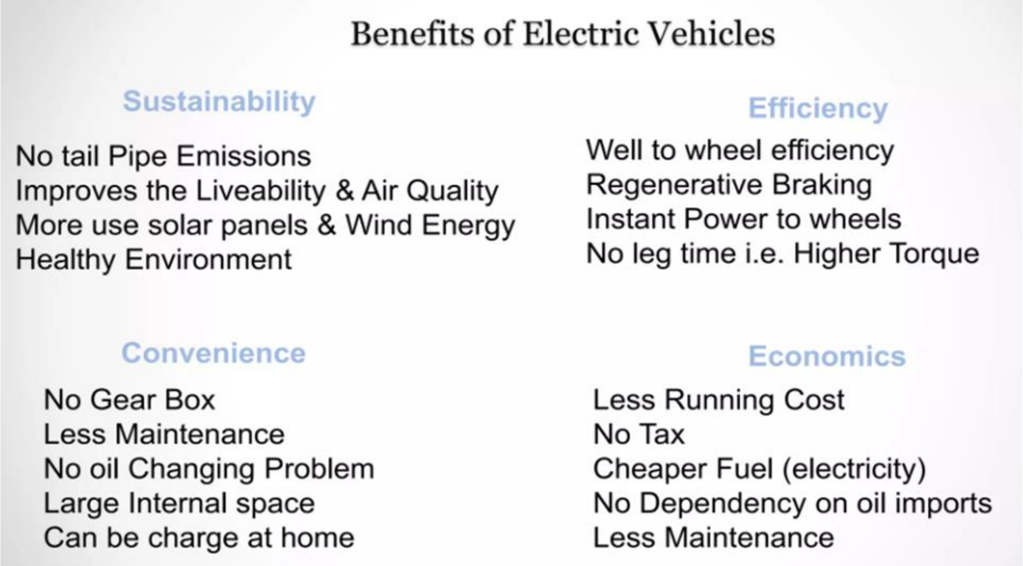
1) Central systems 2) Zoned systems 3) Unitary systems and 4) Unitary Central systems.

Another method of classification of air conditioning system is as follows :

1) Single air systems 2) Dual air systems 3) Primary air systems 4) Unit systems and 5) Panel systems.

2.11 Components Of Electric And Hybrid Vehicles





2.11.1 Hybrid Electric Vehicle (HEV)

- This type of hybrid cars is often called as standard hybrid or paralel hybrid. HEV has both an ICE and an electric motor. In this types of electric cars, internal combustion engine gets energy from fuel (petrol and others type of fuels), while the motor gets electricity from batteries.
- The petrol engine and electric motor simultaneously rotate the transmission which drives the wheels.
- The difference between HEV compared to other type of electric vehicles is where the batteries in HEV can only charged by the ICE, the motion of the wheels or a combination of both.
- There is no charging port, so that the battery cannot be recharged from outside of the system, for example from the electricity grid.

2.11.2 Various Components Of Electric And Hybrid Vehicles

The various components of electric and hybrid vehicles are : Battery, Power Converter, Electric motor, Generator, Transmission, Inverter, Rectifier, Coupler and Controller.

2.11.3 Technical Challenges of Electric Vehicles.

The technical challenges of electric vehicles are :i) Long charging time ii) Limited charging infrastructure Iii} High battery costs and iv) Range anxiety.

2.11.4 Various Concerns of Electric Vehicles

1. Technological Concerns:

i. Battery Technology and Range: Electric cars heavily rely on battery technology, and advancements in this field are crucial to improve energy storage capacity, charging speed, and overall vehicle range. Some critics argue that existing battery technology may not be sufficient to meet the demands of all vehicle types, especially long-haul transportation, and that further technological breakthroughs are necessary.

ii. Charging Infrastructure: The development of a robust and widespread charging infrastructure is vital to support the transition to electric cars. Critics argue that the current charging network is insufficient and that significant investments and planning are required to ensure convenient and accessible charging options for EV owners, particularly in rural or remote areas.

iii. Supply Chain and Resource Availability: The production of electric vehicles requires significant amounts of minerals, such as lithium, cobalt, and nickel. Meeting the increased demand for EVs may lead to resource constraints and potential environmental and ethical concerns associated with mining and supply chain management.

2. Economic Concerns

i. Affordability and Market Demand: Electric vehicles are currently more expensive to produce compared to conventional vehicles due to the cost of battery technology. Critics argue that without further technological advancements and economies of scale, the high upfront costs of electric cars may hinder their affordability and limit market demand, particularly in lower-income segments of society.

ii. Job Losses and Industry Transformation: The transition to electric cars will have a profound impact on the automotive industry, potentially leading to job losses in sectors associated with internal combustion engine vehicles. Critics argue that the rapid pace of the transition may not allow enough time for the industry to adapt, retrain workers, and ensure a smooth transition without significant social and economic disruption.

3. Environmental Concerns:

i. Energy Source and Grid Capacity: Electric cars are only as environmentally friendly as the electricity used to charge them. Critics argue that without a significant increase in renewable energy generation and improvements to the electricity grid infrastructure, the environmental benefits of electric cars may be limited, and the overall energy demand could strain the power grid.

ii. Battery Recycling and Waste: The disposal and recycling of batteries used in electric vehicles present environmental challenges. Developing efficient and sustainable battery recycling systems is crucial to minimize environmental impact and ensure the responsible management of battery waste.