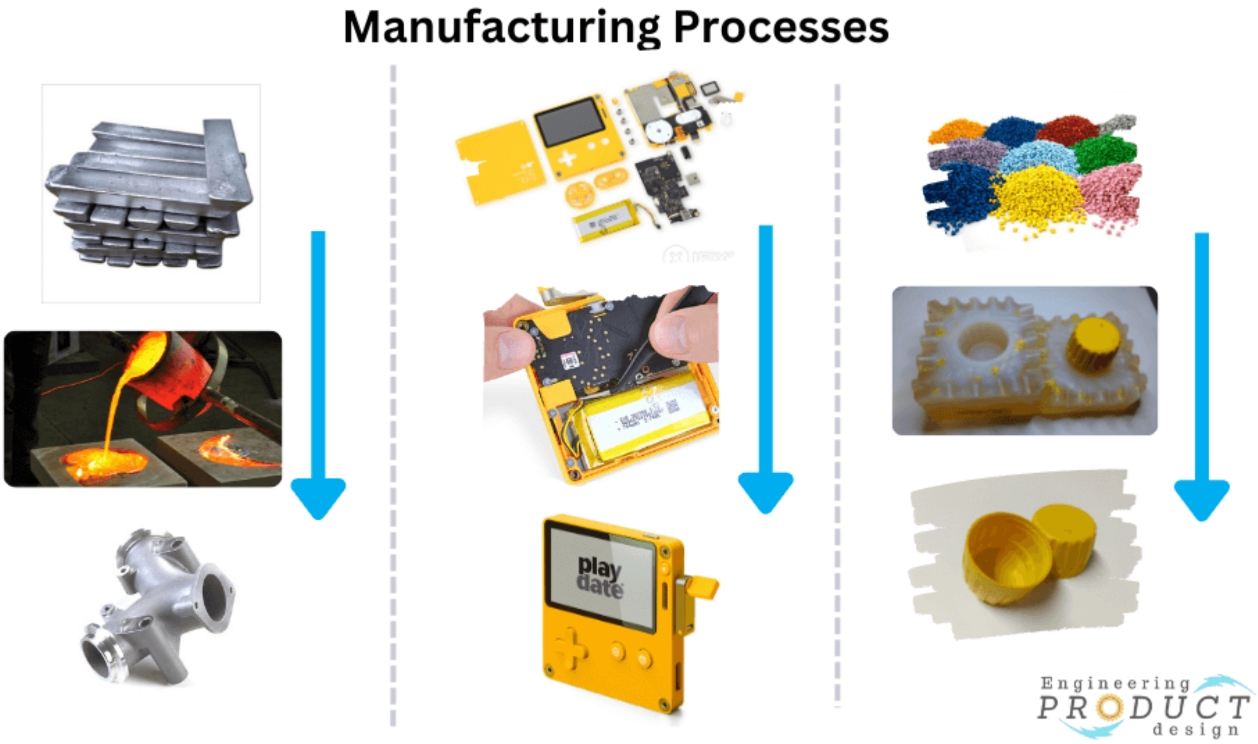
<u>Basic Mechanical Engineering of BCME Subject</u>

UNIT II

<u>*Part 1: MANUFACTURING PROCESSES:*</u>

Manufacturing processes are used in large-scale manufacturing to create value-added engineering products and components using physical and chemical processes to change a starting material's geometry, characteristics, and appearance.

<u>Examples:</u> Casting, Forming and joining processes, Machining, Introduction to CNC machines, 3D printing, and Smart manufacturing



Manufacturers typically carry out the manufacturing processes as a unit operation, which means it is a single step in a series of steps required to transform a starting material into a finished product. **Processing operations** and **assembly operations** are the two basic types of manufacturing operations.

<u>(A) PRINCIPLES OF METAL CASTING:</u>

In casting, a molten metal or other material fills a mould, then cools and hardens into a desired shape. However, a manufacturer must plan out post-cast steps to ensure effective results. Proper care should be taken at each step to deliver a final product that maintains proper quality and integrity. Casting is but one method of metal shaping, as there are many other options, including welding, forging, stamping, extrusion and machining.

Benefits of the Casting Process: These are as follows.

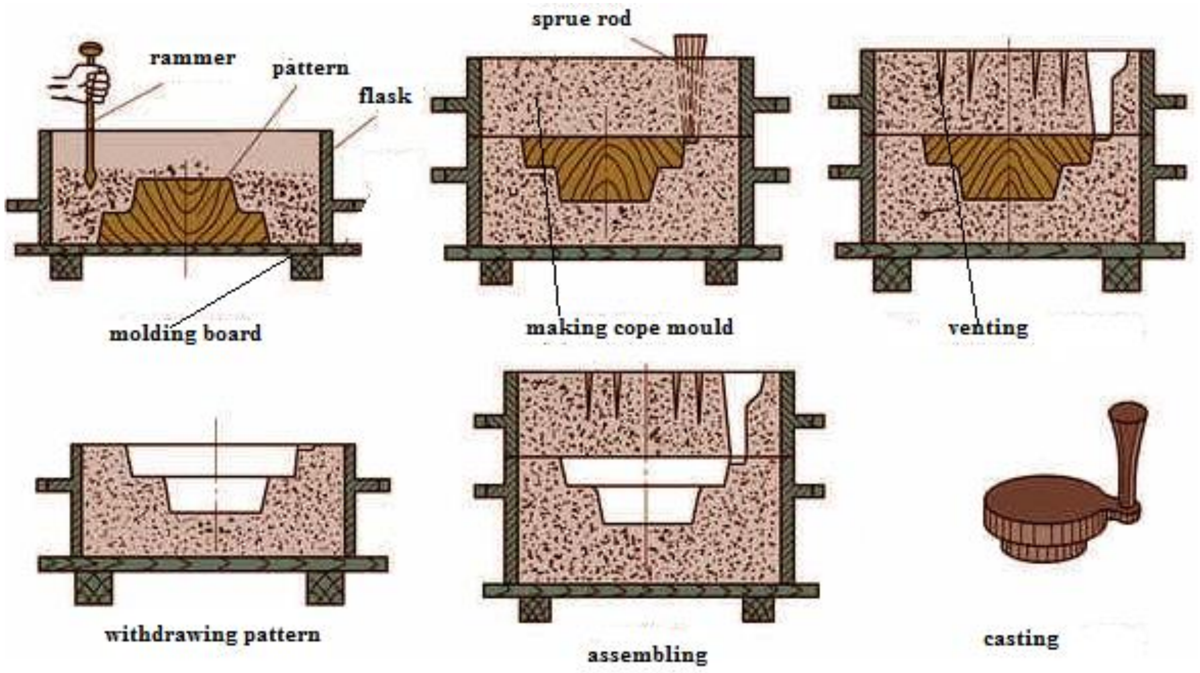
- **Ability to create complex geometries**: Liquid metal facilitates construction of intricate designs, in either simple or complex geometries.
- **Fast production cycles**: Once the casting tools are in order, very little maintenance and downtime is necessary. This makes casting an option for mass production applications.
- **Workability of hard metals**: Casting is often one of the only viable manufacturing processes for hard metals that are not malleable enough for solid state shaping.
- **Reduced assembly**: Oftentimes, casting can create items in a single, complete component, eliminating the need to assemble multiple pieces.
- **Minimal sizing restraints**: Casting can create extremely small to extremely large parts, even up to 200 tons.
- **Versatile surface textures**: Casting moulds can be designed to deliver smooth, semi-smooth or rough surface textures.

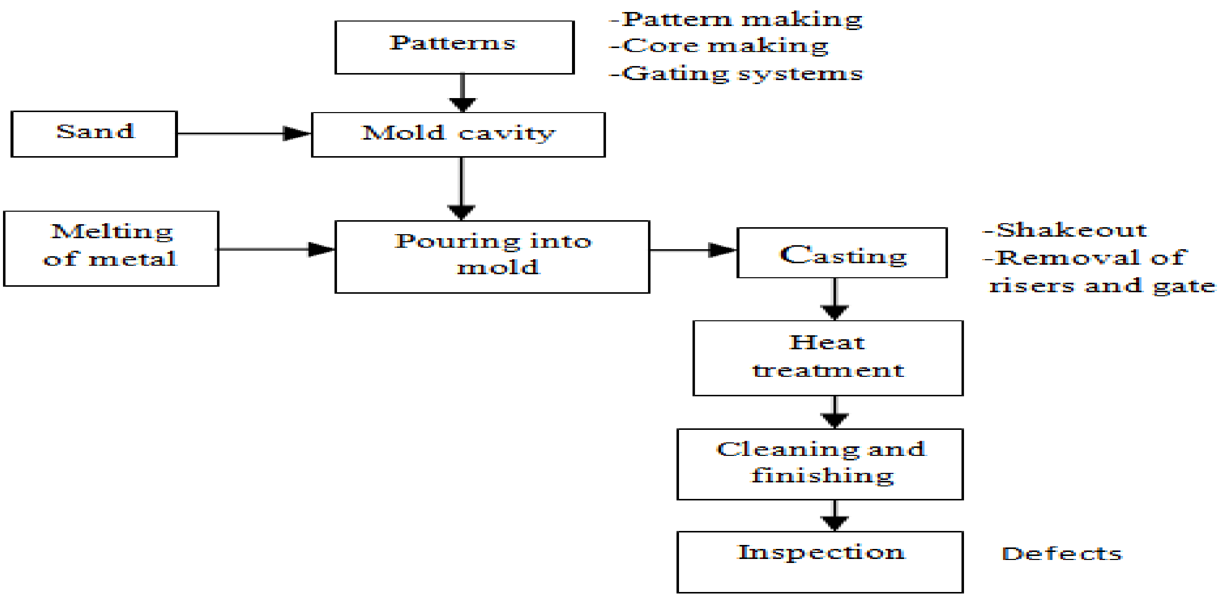
Types of Casting Processes: There are several different casting methods, each of which requires slight variations in the process. These are

- Sand casting
- Plaster casting
- Shell molding
- Wax casting
- Die casting
- Centrifugal casting etc.,

Basic Steps in Casting Process: While each casting method creates unique challenges and process enhancements, all techniques retain the same basic steps. These steps are:

1) Patternmaking
2) Core making
3) Moulding
4) Melting and pouring
5) Finishing





Patternmaking: To create a casting mould, a manufacturer must first design a physical model. The process of fabricating this model is called patternmaking. Using computer-assisted design (CAD) systems, the manufacturer designs dimensions and geometry of a mould, and then packs an aggregate material, such as sand, concrete or plastic, around the pattern. Once the pattern is removed, the mould cavity in the sand can be filled.

Core making: Many part designs require the inclusion of cores in the casting mould. Cores are solid materials placed inside the mould cavity to create interior surfaces of a casting. For example, a metal pipefitting will require a cylindrical core inside the mould cavity to create the hollow construction of the components interior.

Moulding: At this point, the manufacturer can create the casting mould. A material such as sand, plaster or wax is used in expendable mould casting, whereas metal and other durable materials are used in non-expendable mould casting techniques. The material fills the casting mold model and is allowed to harden, at which point the manufacturer removes it from the cavity and the casting of the component can now begin.

Melting and Pouring: Metal must be properly melted prior to being placed in the mould. Typically, this is done by using what is known as a crucible. Crucibles are containers made of porcelain or another melt-resistance substance in which a manufacturer can heat a metal beyond its melting point. Once properly melted, the molten metal is poured into the casting mould to cool and harden.

Finishing: Because metal can sometimes fill in cracks in a casting mould or sprues, the pouring channel for the mould, manufacturers must often finish the metal following casting. This can be accomplished through a variety of finishing techniques, including sanding, grinding and buffing. Once proper appearance and surface texture has been achieved, further post-treatment processes such as painting or electroplating may be necessary for some applications.

Things to Consider When Casting: There are numerous factors that need to be considered to ensure proper size, shape and integrity of the final component. Some of these factors include:

- **Type of material**: Each metal and casting material retains specific characteristics (hardness, melting point, density, etc.) that will affect the casting process.
- **Cooling rate**: This factor depends largely on the type of material from which you craft the mould. Proper cooling is necessary to minimize gas porosity and other negative properties that can result from a fast cooling rate.
- **Shrinkage**: As castings cool, they shrink. To ensure proper component size and integrity, you can utilize risers to feed additional molten metal into the cavity. An oversized mould may also be useful in some applications.

(B) FORMING AND JOINING PROCESSES

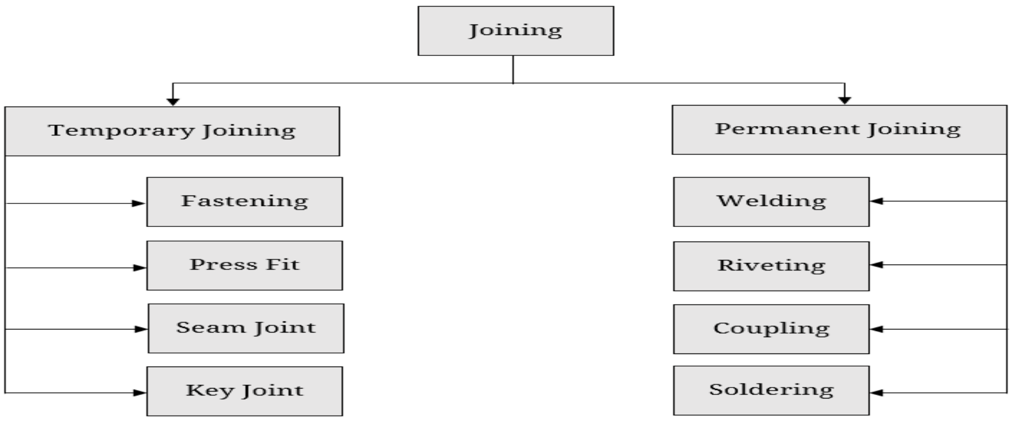
Joining and forming are two common types of manufacturing processes. Manufacturing companies often rely on one or both types of processes to convert raw materials into finished products. While joining and forming have a similar goal, however, they aren't the same.

Joining processes: These are characterized by their ability to fuse or "join" two or more components for the purpose of creating a different object, such as a ready-to-sell consumer product.

Joining includes welding, brazing, soldering, adhesive bonding of materials. They produce permanent joint between the parts to be assembled. They cannot be separated easily by application of forces. They are mainly used to assemble many parts to make a system.

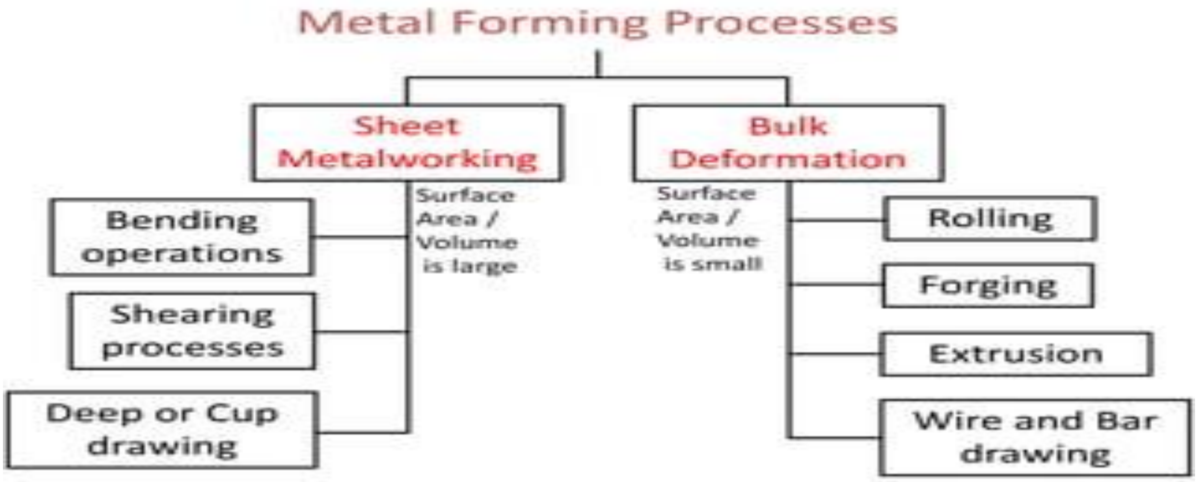
Joining processes enable the manufacture of components with complex geometries from simpler standard components. It, thus, reduces the complexity and the costs of the manufacturing processes. Furthermore, joining partners made of differing materials also play a significant role.

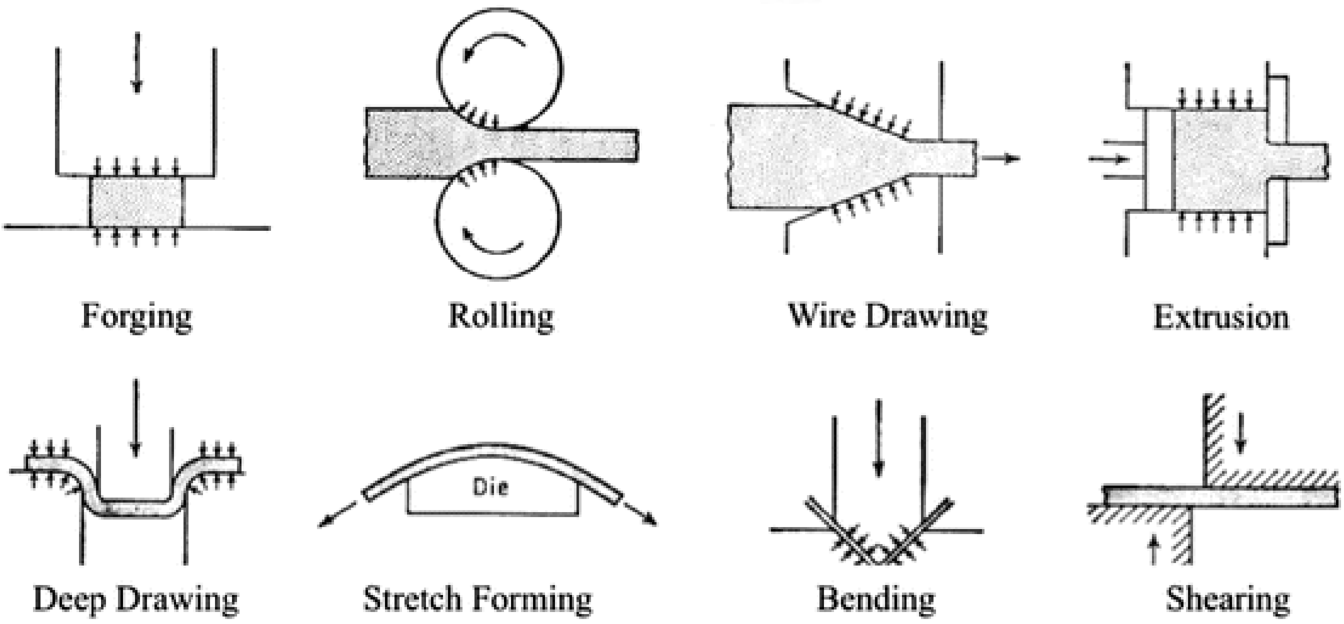
Common types of joining processes used in the manufacturing industry:



Forming processes: They involve the physical manipulation of an object. With forming, an object is physically deformed to achieve a different size and/or shape. When an object is exposed to physical stress, such as heat or pressure, it typically deforms. Depending on the type of material from which the object is made, it may expand when exposed to heat or pressure.

Common types of forming processes used in the manufacturing industry:

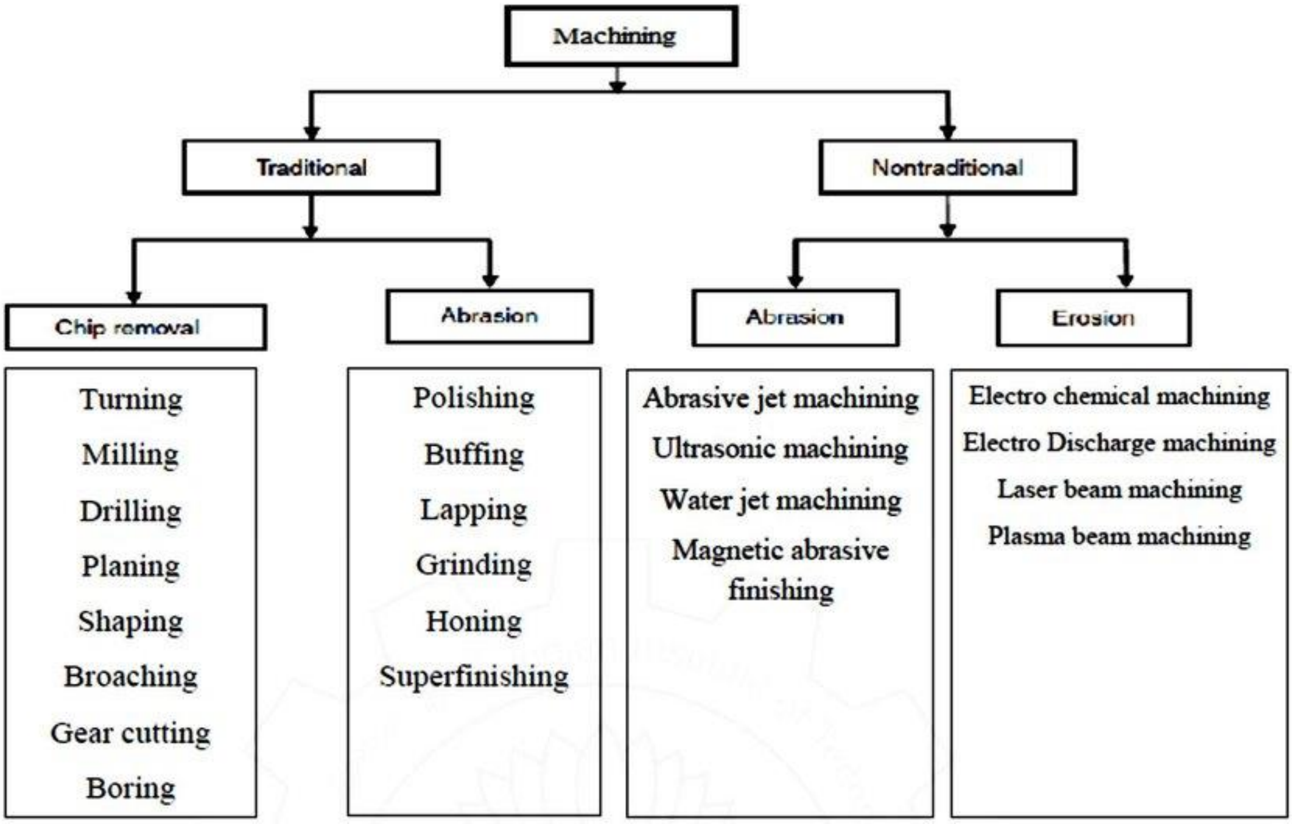




Difference between joining and forming processes: Joining processes involve fusing multiple components together, whereas forming processes involve deforming a single object. It's also worth noting that forming processes tend to create less waste than joining processes. Joining processes often create chips. In comparison, little or no chips are created with forming processes. Joining processes are designed to "join" multiple components, whereas forming processes are designed to manipulate an object.

(C) MACHINING:

Machining is a process in which a material or metal is cut to a desired final shape and size by a controlled material-removal process. The methods that have this common theme are collectively called subtractive manufacturing, which utilizes machine tools, in contrast to *additive manufacturing* (3D printing), which uses controlled addition of material.

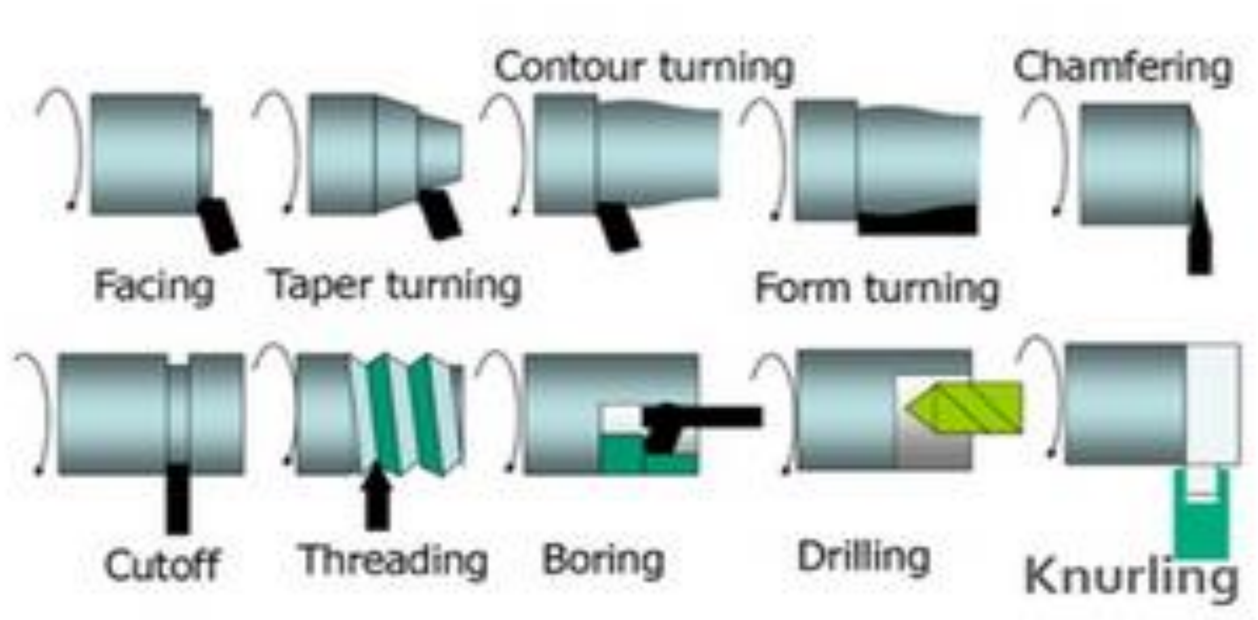


Machining is a part of the manufacture of many metal products, but it can also be used on other materials such as wood, plastic, ceramic, and composite material. A person who specializes in machining is called a machinist. A room, building, or company where machining is done is called a machine shop. Much of modern-day machining is carried out by computer numerical control (CNC), in which computers are used to control the movement and operation of mills, lathes, and other cutting machines. This increases efficiency, as the CNC machine runs unmanned, reducing labour costs for machine shops.

Machining operations

The three principal machining processes are classified as turning, drilling and milling. Other operations falling into miscellaneous categories include shaping, planing, boring, broaching, and sawing.

- Turning operations rotate the work piece as the primary method of moving metal against the cutting tool. Lathes are the principal machine tool used in turning.
- Milling operations are operations where the cutting tool rotates to bring cutting edges to bear against the workpiece. Milling machines are the principal machine tool used in milling.
- Drilling operations are those in which holes are produced or refined by bringing a rotating cutter with cutting edges at the lower extremity into contact with the work piece. Drilling operations are done primarily in drill presses but sometimes on lathes or mills.
- Miscellaneous operations may not be strictly machining because they may not produce swarf, but are still performed with a typical machine tool. Burnishing is an example; it produces no swarf but can be performed at a lathe, mill, or drill press.



(D) INTRODUCTION TO CNC MACHINES:

CNC stands for "computer numerical control." These machines represent a manufacturing process used to control a wide range of complex tasks. CNC is a manufacturing method that automates the control, movement and precision of machine tools through the use of preprogramed computer software, which is embedded inside the tools.

CNC is commonly used in manufacturing for machining metal and plastic parts. Mills, lathes, routers, drills, grinders, water jets and lasers are common cutting tools whose operations can also be automated with CNC. It can also be used to control non-machine tools, such as welding, electronic assembly and filament-winding machines. Numerical control enables machines to produce items more quickly and with better surface finishes without the need for manual machining or extensive human participation.

How CNC works:

With CNC, each object to be manufactured gets a custom computer program, usually written in an international standard language called G-code, stored in and executed by the machine control unit (MCU), a microcomputer attached to the machine. The M-code language is also used in conjunction with G-code in CNC operations.

While G-code controls the movement and functioning of the machine, M-code controls the operation's external movements. The program also contains the instructions and parameters the machine tool follows, such as the feed rate of materials and the positioning and speed of the tool's components.

Early in the process, engineers create a computer-aided design (CAD) drawing of the part to be manufactured and then translate the drawing into G-code. The program is loaded onto the MCU, and a machine operator performs a test run without the raw material in place to ensure proper positioning and performance. This step is important because incorrect speed or positioning can damage both the machine and the part.

When everything is ready, the CNC machine runs its program and completes jobs with precision as instructed. The jobs could involve anything from creating something from scratch to cutting a work piece or printing anything.

Benefits of CNC systems:

- **Cost reduction.** CNC machines are cost-effective and bring down the cost of production due to precision manufacturing. Energy consumption is decreased as a result of increased production efficiency, scalability and less material waste, which also lowers operating expenses. The weight of potential financial obligations related to worker safety is also lessened, which helps with cost-cutting.
- **Waste reduction.** The software used to run various kinds of CNC machines results in little to no waste during the manufacturing process due to simulations and repeated optimizations.
- **Improved worker safety.** CNC machines minimize the chance of accidents and guarantee worker safety because there is less need for human interaction. Most modern CNC machines are self-sufficient and can be handled remotely by people for software upgrades, design changes or other preventative maintenance.
- **Human error reduction.** Since human error is eliminated in the manufacturing process with CNC, it is thought to offer greater precision, complexity, speed, flexibility and repeatability. This ultimately results in fewer defects in the manufactured products.
- **Contour machining.** CNC provides capabilities such as contour machining, which enables milling of contoured shapes, including those produced in 3D printing and designs.
- **Faster MCU programming.** Some CNC systems are integrated with CAD software and computer-aided manufacturing software, which can speed the process of programming the MCU.
- **Improved operational intelligence.** Integration with enterprise resource planning software and related applications, such as enterprise asset management software, can facilitate operational and business intelligence processes and help improve plant performance and maintenance.
- **No bottlenecks.** With the higher level of automation used, CNC systems reduce production and manufacturing bottlenecks and improve the outcome.

Conventional Machining vs. CNC Machining:

Sl. No	Conventional Machining	CNC Machining
1	Conventional machining generally costs less and is more cost-effective and efficient for small jobs.	CNC machining is more expensive for small jobs, but provides greater 2efficiency and cost savings for larger jobs.
2	The quality of the final product is largely dependent on the skills and abilities of the machine technician or operator.	Geometry is loaded into the software, so the risk for human error is minimized in the quality equation.
3	Due to human involvement, it is difficult to guarantee a high level of part consistency, making conventional	Since machines run on computer commands, identical parts or components can be produced with ease,

	machining ideal for small runs or single pieces.	making CNC machining ideal for large quantities of highly consistent products.
4	Operator experience greatly influences part quality and consistency.	Operators with little experience can still produce highly consistent and quality parts due to computer-intervention.
5	Each machine requires a dedicated operator, and a high level of technician involvement is necessary to direct the tools. Operators must be able to produce a variety of parts, which requires extensive knowledge, skills, and experience.	Since minimal operator involvement is needed to manage the CNC process, a single operator can oversee multiple machines at once with high degrees of accuracy and precision, which reduces labour costs.

(E) 3D PRINTING:

3D printing, also known as additive manufacturing, is a method of creating a three dimensional object layer-by-layer using a computer created design.

3D printing is an additive process whereby layers of material are built up to create a 3D part. This is the opposite of subtractive manufacturing processes, where a final design is cut from a larger block of material. As a result, 3D printing creates less material wastage.

There are a variety of 3D printing materials, including **thermoplastics** such as acrylonitrile butadiene styrene (ABS), **metals** (including powders), **resins** and **ceramics**.

The printing time depends on a number of factors**,** including the **size of the part** and the **settings used** for printing. The **quality** of the finished part is also important when determining printing time as higher quality items take longer to produce.

3D printing can take anything from a few minutes to several hours or days - speed, resolution and the volume of material are all important factors here.

The advantages **of 3D printing:**

- **Bespoke, cost-effective creation of complex geometries**: This technology allows for the easy creation of bespoke (made to individual order or custom-made) geometric parts where added complexity comes at no extra cost. In some instances, 3D printing is cheaper than subtractive production methods as no extra material is used.
- **Affordable start-up costs**: Since no moulds are required, the costs associated with this manufacturing process are relatively low. The cost of a part is directly related to the amount of material used, the time taken to build the part and any post processing that may be required.
- **Completely customisable**: Because the process is based upon computer aided designs (CAD), any product alterations are easy to make without impacting the manufacturing cost.
- **Ideal for rapid prototyping**: Because the technology allows for small batches and in-house production, this process is ideal for prototyping, which means that products can

be created faster than with more traditional manufacturing techniques, and without the reliance on external supply chains.

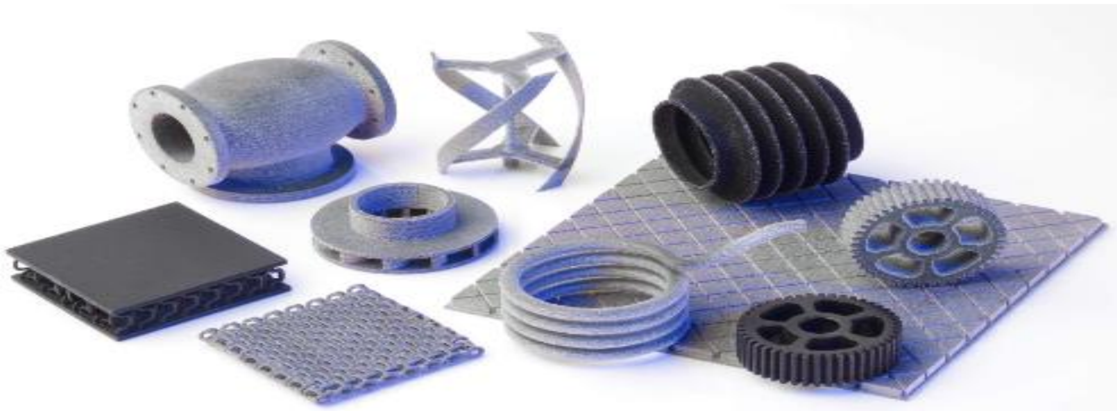
- **Allows for the creation of parts with specific properties**: Although plastics and metals are the most common materials used in 3D printing, there is also scope for creating parts from specially tailored materials with desired properties. So, for example, parts can be created with high heat resistance, water repellency or higher strengths for specific applications.

The **disadvantages** of 3D printing :

- **Can have a lower strength than with traditional manufacture**: While some parts, such as those made from metal, have excellent mechanical properties, many other 3D printed parts are more brittle than those created by traditional manufacturing techniques. This is because the parts are built up layer-by-layer, which reduces the strength by between 10 and 50%.
- **Increased cost at high volume**: Large production runs are more expensive with 3D printing as economies of scale do not impact this process as they do with other traditional methods. Estimates suggest that when making a direct comparison for identical parts, 3D printing is less cost effective than CNC machining or injection moulding in excess of 100 units, provided the parts can be manufactured by conventional means.
- **Limitations in accuracy**: The accuracy of a printed part depends on the type of machine and/or process used. Some desktop printers have lower tolerances than other printers, meaning that the final parts may slightly differ from the designs. While this can be fixed with post-processing, it must be considered that 3D printed parts may not always be exact.
- **Post-processing requirements**: Most 3D printed parts require some form of post-processing. This may be sanding or smoothing to create a required finish, the removal of support struts which allow the materials to be built up into the designated shape, heat treatment to achieve specific material properties or final machining.

Applications of 3D Printing:

Aerospace: 3D printing is used across the aerospace industry due to the ability to create light, yet geometrically complex parts, such as blisks (components comprising both rotor disk and blades). Rather than building a part from several components, 3D printing allows for an item to be created as one whole component, reducing lead times and material wastage.



Automotive: The automotive industry has embraced 3D printing due to the inherent weight and cost reductions. It also allows for rapid prototyping of new or bespoke parts for test or small-scale manufacture. So, for example, if a particular part is no longer available, it can be produced as part of a small, bespoke run, including the manufacture of spare parts. Alternatively, items or fixtures can be printed overnight and are ready for testing ahead of a larger manufacturing run.

Medical: The medical sector has found uses for 3D printing in the creation of made-to-measure implants and devices. For example, hearing aids can be created quickly from a digital file that is matched to a scan of the patient's body. 3D printing can also dramatically reduce costs and production times.

Rail: The rail industry has found a number of applications for 3D printing, including the creation of customised parts, such as arm rests for drivers and housing covers for train couplings. Bespoke parts are just one application for the rail industry, which has also used the process to repair worn rails.

Robotics: The speed of manufacture, design freedom, and ease of design customisation make 3D printing perfectly suited to the robotics industry. This includes work to create bespoke exoskeletons and agile robots with improved agility and efficiency.

(F) SMART MANUFACTURING:

Smart manufacturing is a process that optimizes manufacturing procedures through automation, Big Data analytics and computerized controls that minimize costs and maximize productivity. By combining data from IT systems and operational systems (such as product lifecycle management and ERP systems), it enables manufacturers to quickly and effectively respond to changes on the factory floor and across their value chain.

Smart manufacturing (SM) 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.

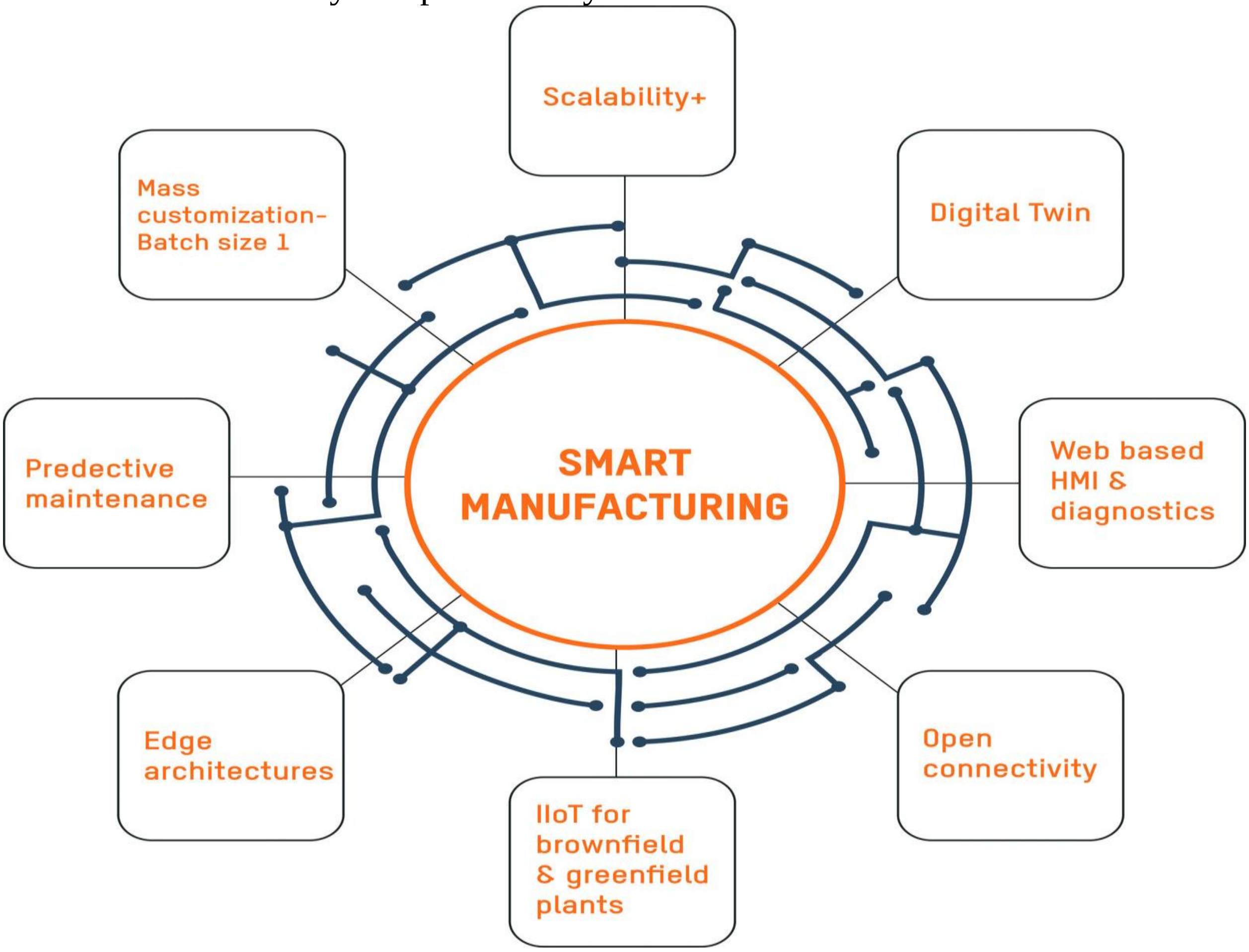
SM is a specific application of the Industrial Internet of Things (IIoT). Deployments involve embedding sensors in manufacturing machines to collect data on their operational status and performance. In the past, that information typically was kept in local databases on individual devices and used only to assess the cause of equipment failures after they occurred.
Now, by analyzing the data streaming off an entire factory's worth of machines, or even across multiple facilities, manufacturing engineers and data analysts can look for signs that particular parts may fail, enabling preventive maintenance to avoid unplanned downtime on devices.

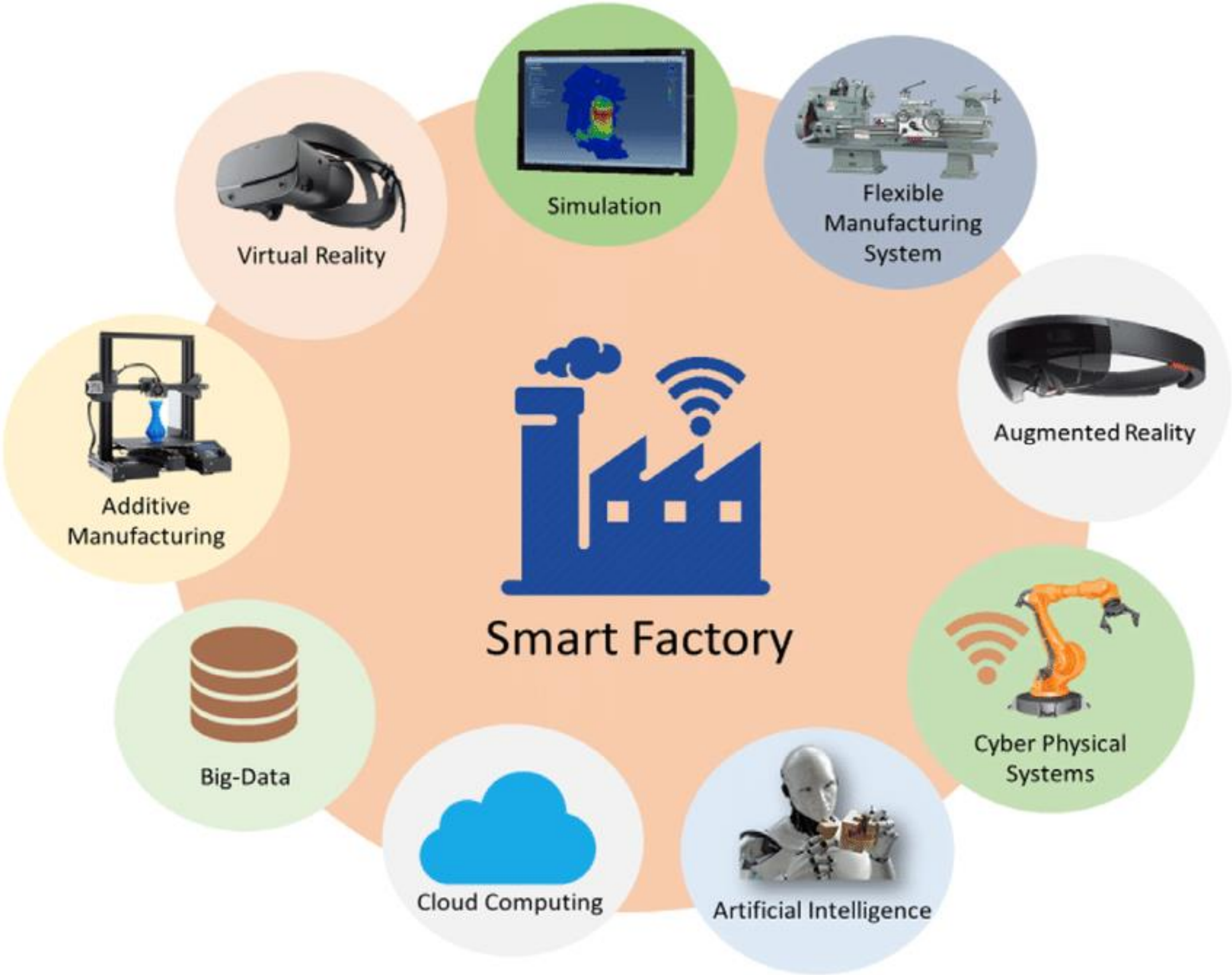
As smart manufacturing becomes more common and more machines become networked through the Internet of Things, they will be better able to communicate with each other, potentially supporting greater levels of automation.

For example, SM systems might be able to automatically order more raw materials as the supplies, allocate other equipment to production jobs as needed to complete orders and prepare distribution networks once orders are completed.

In addition to the Internet of Things, there are a number of technologies that will help enable smart manufacturing, including:

- 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.





Advantages or Benefits of smart manufacturing: Smart manufacturing enables

- Continuous operational improvement,
- Increasing productivity and reducing costs.
- Self-monitoring
- Reduces downtime and repair costs.
- Improved efficiency, increased productivity and long-term cost savings.
- In a smart factory, productivity is continuously enhanced. If a machine is slowing down production, for example, the data will highlight it, and the artificial intelligence systems will work to resolve the issue. These extremely adaptable systems enable greater flexibility.
- Reduction in production downtime.
- Modern machines are often equipped with remote sensors and diagnostics to alert operators to problems as they happen.
- Predictive AI technology can highlight problems before they occur and take steps to mitigate the financial costs.
- A well-designed smart factory includes automation as well as human-machine collaboration, features that enable operational efficiency.

- The smart factory reduces manual handling by leveraging automation. The factory becomes more efficient because production can be real-time responsive in terms of materials, sourcing, production, and human resources.

Disadvantages of smart manufacturing:

- A big downside to smart manufacturing is the upfront cost of implementation. As such, many small to midsize companies won't be able to afford the considerable expense of the technology, particularly if they adopt a short-term philosophy.
- However, since savings over the long term will outweigh the startup costs, organizations have to plan for the future even if they can't implement smart factories immediately.
- It is very complex, which means that systems that are poorly designed or not adequate for a particular operation could cut into profits.
- Lost jobs: Unemployment is a common concern with tech in manufacturing since machines can replace human labour
- Need skill labour or education and special training of workers is needed
- Machines are expensive to buy, maintain and repair.
- Machine with or without uninterrupted use will get broken and worn-out.
- Their maintenance or repairs are costly, difficult to set up and operate without previous training.
- The pollution caused by machine increases, generating waste, augmenting power or oil use

Part II: Thermal Engineering

Thermal engineering is a specialized sub-discipline of mechanical engineering that deals with the movement of heat energy and transfer. The energy can be transferred between two mediums or transformed into other forms of energy.

(A) Boiler and its function

A boiler is a pressure vessel that provides a heat transfer surface (generally a set of tubes) between the combustion products and the water. A boiler is usually integrated into a system with many components.

The function of a boiler is to either produce hot water or steam. Hot water boilers heat water for the purpose of domestic or commercial heating and hot water supply. Steam boilers generate steam in order to power turbines for power generation and various other industrial heating applications

In a conventional steam power plant, a boiler consists of a furnace in which fuel is burned, surfaces to transmit heat from the combustion products to the water, and a space where steam can form and collect.

Working Principle of Boiler

Hot gases are produced by burning fuel in the furnace. These hot gases are made to come in contact with the water vessel where the heat transfer takes place between the water and the steam. Therefore, the basic principle of the boiler is to convert water into steam by using heat energy.

What are the major components of the Boiler System?

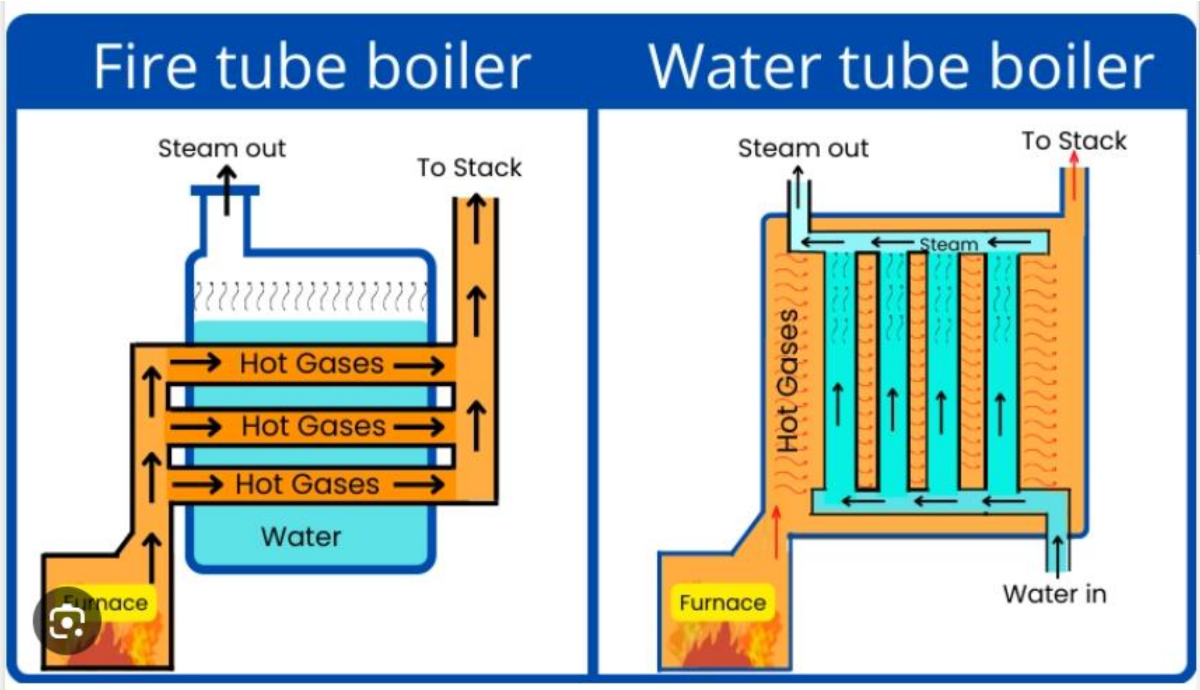
- *Burner*
- *Controls*
- *Deaerator*
- *Economizer*
- *Fan*
- *Heat Exchanger*
- *Instrumentation*
- *Stoker*
- *Tubes*

What are the basic types of Boilers?

There are two basic types of boilers: firetube and watertube. The fundamental difference between these boiler types is which side of the boiler tubes contain the combustion gases or the boiler water/steam.

Firetube Boiler: *In firetube boilers, hot gases and flames are passed through the tubes which are surrounded by water, is called fire tube or smoke tube boiler. It is very simple small capacity type boiler and is used various industries for it's simplicity. Example: Cochran boiler, Lancashire boiler, Cornish boiler etc.*

Watertube Boiler: *In water tube boiler, water is circulated inside the tubes which are surrounded by flames or hot gases. Example: Babcock and Wilcox boiler, La-mount boiler*



(B) Internal combustion engine:

An internal combustion engine (IC engine) is a heat engine in which the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit.

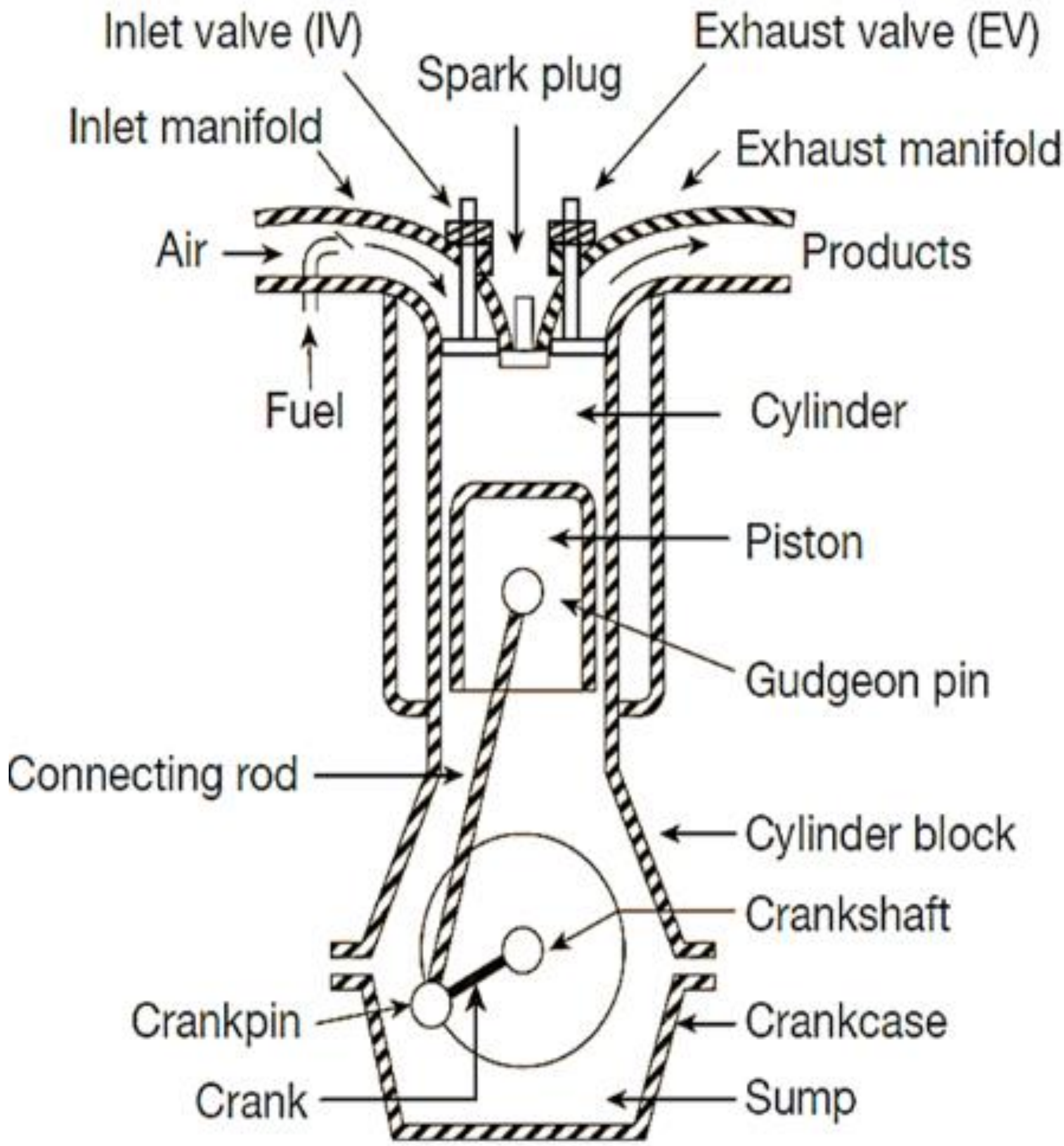
What is IC and SI engine?

Mainly IC engines are two types : SI & CI Engines

The spark Ignition (SI) engine, as its name indicates uses spark to ignite the fuel ie., petrol. And in Compression Ignition (CI) engine, the air is compressed within the cylinder and the heat of this compression air is used to ignite the fuel ie., diesel.

Parts of an IC Engine:

The principal parts of an internal combustion engine are shown in the Figure.



1 Cylinder: In an internal combustion engine, the main part is the cylinder in which combustion takes place. The cylinder has to withstand high temperature and high pressure. Normally the cylinder is made of cast iron or steel alloy.

2 Cylinder Head: This is a block placed as a cover on the cylinder. The cylinder head has provision for setting the inlet and exhaust valves. A hole is also provided to screw in a spark plug or injection nozzle. The cylinder head is normally made of cast iron. When head is mounted on the cylinder, an asbestos gasket is provided in between the cylinder and the cylinder head.

3 Valves: The valves are placed in the correct setting in the provision made especially for them in the cylinder head. Two valves are provided. Through the inlet valve the mixture of air and fuel vapour is sent in.

The exhaust valve is for discharging the products of combustion. The valves are held in position by valve springs. The opening and closing of these valves are performed with the help of cam mechanisms. They are made of Nickel Chromium Steel.

4 Piston: The piston is the main active part of the engine as shown in Figure. It has a close fit with the cylinder. The movement of the piston changes the volume of the cylinder and provides the combustion space.

Generally, pistons are made up of aluminum alloy. Aluminum alloy is the lightest one and has good heat conductive properties. A hole is centrally provided to insert a pin to connect the small end of the connecting rod. Circumferential grooves are provided on the surface of the piston to accommodate piston rings.

5 Piston Rings: Piston rings are made up of special steel alloys to retain elastic properties at high temperature. These are circular rings fitted in the circumferential grooves of the piston. There are two sets of rings.

Upper rings are called compression rings, which provide an airtight seal. This will prevent the leakage of burnt gases into the casing. The lower rings are called oil scrapper rings. These are provided to remove the oil film from the engine cylinder and to prevent the leakage of oil into the cylinder.

6 Connecting rod: This is the connecting link between the piston and the crankshaft. The reciprocating motion of the piston is converted into rotary-motion of the crankshaft.

Upper end of the connecting rod is called small end, which carries the piston by means of a floating pin called piston pin or gudgeon pin. The lower end is called big end of the connecting rod, which connects the crankshaft through the crankpin. This is made of forged steel, alloy steel.

7 Crankshaft: Crankshafts are made up' of special steel alloys. The crankshaft is the main member from which we obtain the rotary power. This shaft is build up with one or more eccentric parts called crank or crank throws. This crank throws are mainly responsible for producing reciprocating motion of the piston.

8 Crankcase: This is the main housing at the bottom of the engine, providing support for the cylinder and crankshaft bearings. The other engine parts are arranged in proper alignment on this crankcase. The crankcase provides protection to the parts from dirt and also it acts as a lubricant sump.

9 Flywheel: Flywheel is a larger solid wheel mounted on the crankshaft. This acts as an energy reservoir to store excess energy during power stroke and delivers

The difference between the two-stroke and four-stroke engine cycles

Two Strokes	Four Strokes
It has one revolution of the crankshaft during one power stroke.	It has two revolutions of the crankshaft during one power stroke.
It generates high torque.	It generates less torque.
It uses a port for the fuel's outlet and inlet.	It uses valves for the fuel's outlet and inlet.
Its engines result in lesser thermal efficiency.	Its engines result in higher thermal efficiency.
It has a larger ratio in terms of power to weight.	It has a lesser ratio in terms of power to weight.
It generates more smoke and shows less efficiency.	It generates less smoke and shows more efficiency.
Requires more lubricating oil as some oil burns with the fuel.	Requires less lubricating oil.
Due to poor lubrication, more wear and tear occurs.	Less wear and tear occurs.
Engines are cheaper and are simple to manufacture.	Engines are expensive due to lubrication and valves and are tough to manufacture.
Engines are basically lighter and noisier.	Engines are basically heavier because their flywheel is heavy and less noisy.

(C) Difference between SI Engine and CI Engine:

Sl No.	SI Engine (Petrol)	CI Engin (Diesel)
1.	SI engine is known as the Spark Ignition engine.	CI engine is known as the Combustion Ignition engine.
2.	The fuel used here is Gasoline or Petrol.	In CI engine the fuel used is Diesel.
3.	The compression ratio is 6 to 9.	The compression ratio is high around 15 to 20.
4.	This is light in weight because of the low pressure developed here.	This is heavy in weight because of the high pressure developed here.
5.	Low vibration and Noise here.	Here more vibration and noise.
6.	SI engine works on the Otto cycle.	CI engine works on the Diesel cycle.
7.	The speed is higher in the SI engine.	The speed is low in the CI engine.
8.	Thermal efficiency is low or average.	Thermal efficiency is high.
9.	Air and fuel are used during the intake process	But here only air is used during the intake process.
10.	This is kind of cheaper in price.	This we get higher in price.
11.	This is also called a constant volume cycle.	This is called a constant pressure cycle.
12.	Petrol fuel has a high self-ignition temperature.	Diesel fuel has a self-ignition temperature but it’s low.

(D) Otto Cycle:

An Otto cycle explains the procedure through that a **petrol engine** extracts energy from the working medium (i.e., petrol) and converts it into useful mechanical work.

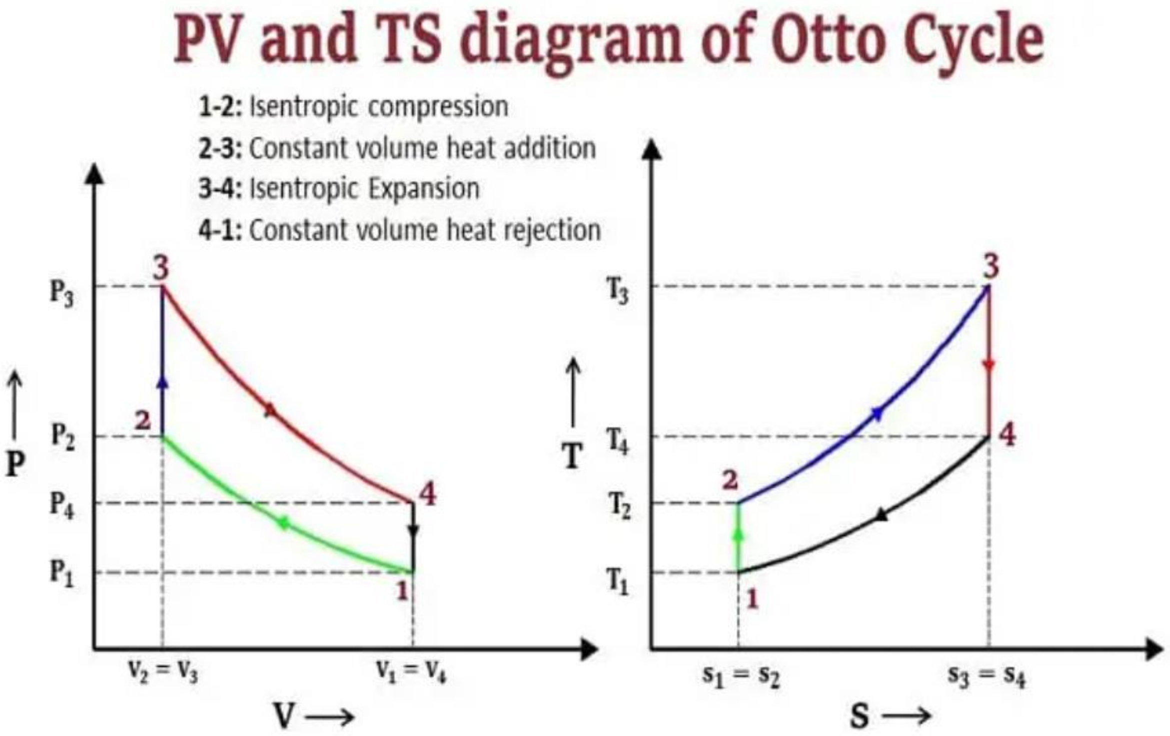
In simple words, this cycle describes how an IC engine (i.e., a gasoline engine) first converts the fuel's chemical energy into thermal energy and then thermal energy into mechanical power, which further uses to move a vehicle.

In **1876**, **Nicolas Otto** invented the **Otto cycle**. The Otto cycle is most commonly used in SI engines (i.e., gasoline engines) for their proper operation.

Almost all the latest gasoline engines work on the base of the Otto cycle. This cycle completes a working stroke in four steps (i.e., Two reversible adiabatic processes and two isochoric processes). Otto cycle has a compression ratio range between 7:1 to 10:1, which is less than the compression ratio of the Diesel cycle.

The Otto cycle and diesel cycle are two main types of the cycle used for engines.
It consists of four stages:

- Suction
- Compression
- Expansion
- Exhaust



The above-given **PV diagram** clearly represents that when the piston performs work on the air-fuel mixture, the volume of the gas decreases (compresses), and pressure increases. Similarly, after combustion, the released heat by the mixture performs work on the piston due to that it expands (expansion process) and moves the vehicle.

The main differences between the Diesel cycle and the Otto cycle are given below:

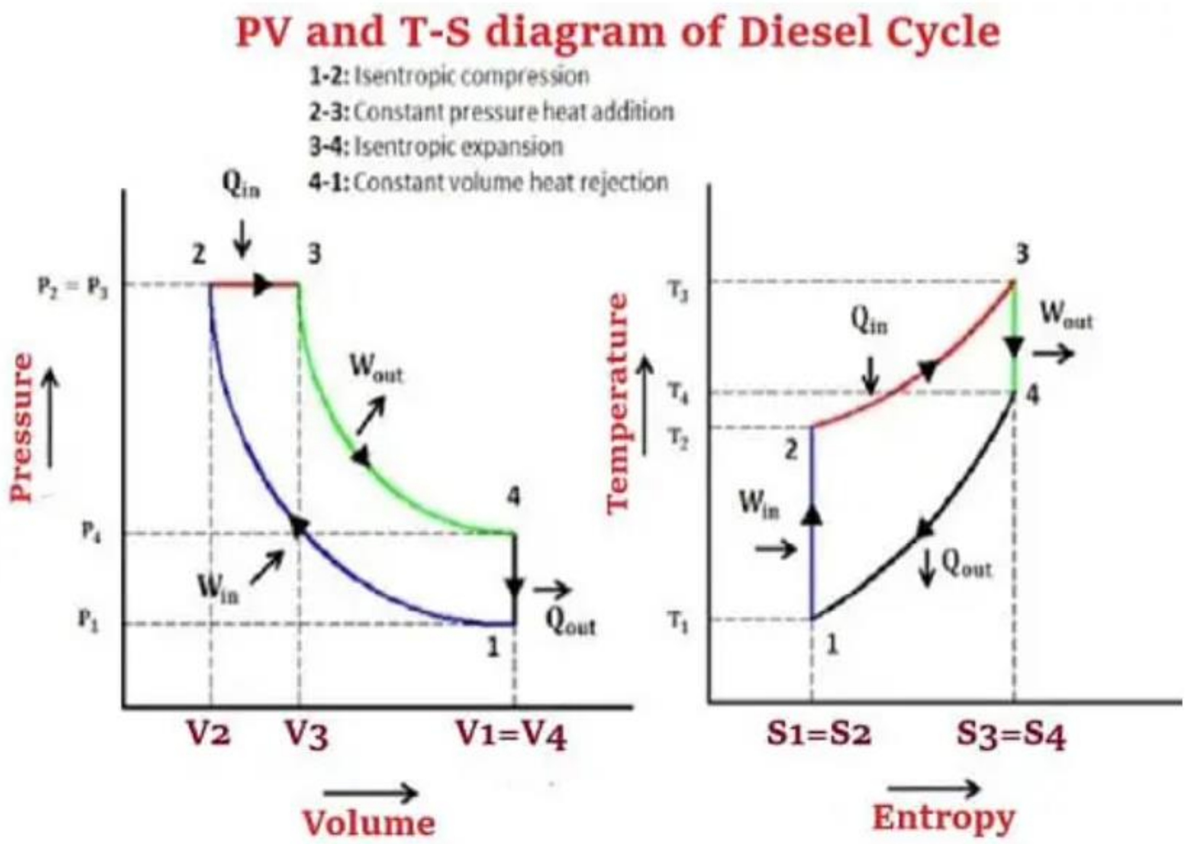
Otto Cycle	**Diesel Cycle**
In 1876, Nicolas Otto invented the Otto cycle.	In 1897, Dr. Rudolph Diesel invented the Diesel cycle.
Otto cycle is designed for gasoline engines.	The diesel cycle is designed for diesel engines.
The thermal efficiency of the Otto cycle is more compared to the Diesel cycle.	The diesel cycle has less thermal efficiency.
It has less compression ratio (up to 14:1).	It has a higher compression ratio (uP to 23:1).
This thermodynamic cycle requires a spark plug to burn the fuel-air mixture.	This cycle doesn’t require an extra spark plug for ignition. The air-fuel mixture ignites itself because of high compression.
In this cycle, the mixture of the fuel and air is sucked inside the combustion chamber during the intake stroke.	In the Diesel cycle, fuel injects into the combustion chamber at the end of the compression stroke.
In this cycle, the heat addition process happens at a constant volume.	In the diesel cycle, the heat addition process occurs at constant pressure.
The fuel (i.e., petrol) used in this cycle has a low price.	The fuel (i.e., diesel) used in this cycle has a high price.
The petrol engine has low weight.	The diesel engine has a heavyweight.
Otto cycle has lower efficiency.	The diesel cycle is most efficient than the Otto cycle.
As the piston reaches at TDC, the heat addition process occurs.	The heat addition takes place when the piston moves downward (i.e., BDC).

Diesel Cycle:

An engine in which diesel fuel is ignited due to high compression of air in the combustion chamber is known as a diesel engine. A diesel engine is also known as a compression ignition engine because, in this engine, ignition occurs due to the high compression of air.

In this engine, there is no use of a spark plug for ignition. In 1893, Rudolph Diesel invented the first diesel engine.

The diesel engine completes a power stroke in two or four strokes of the piston. An explanation of the Diesel engine cycle working is given below with the help of the T-S and P-V diagrams:



1) Suction Process (0-1): –

- For the suction of air, the engine piston moves from TDC to BDC (downward stroke). As it moves downward, the fresh air starts entering the engine cylinder from the atmosphere.
- During this process, the exhaust valve remains closed, and the suction valve opens.

2) Isentropic Compression (1-2): –

- After suction, the suction valve closes, and the piston moves up (from BDC to TDC).
- During the piston's upward motion, it compresses the air inside the cylinder.
- During the compression process, the temperature of the air increases from T_1 to T_2, the volume reduces from V_1 to V_2, and pressure rises from P_1 to P_2.
- However, during this whole process, there is no change in enthalpy ($S_1 = S_2$).

- This process is known as Isentropic because there is no change of enthalpy.
- In isentropic compression, the air is compressed up to such high temperature and pressure that the air-fuel mixture ignites itself, and it doesn't need any extra external heat source or spark plug.

3) Heat Addition at Constant Pressure (2-3): –

- When highly compressed air reaches at point 2 (as shown in the PV and TS diagram), a fuel injector injects diesel fuel into the cylinder, which mixes with the compressed air.
- As the diesel fuel touches the compressed air, the air-fuel mixture ignites due to the high compression of air. This ignition process adds heat to the compressed air-fuel mixture.
- During this process, the piston becomes constant, and pressure also remains constant (P_2=P_3). However, enthalpy increases from S_2 to S_3, temperature increases from T_2 to T_3, and also volume increases from V_2 to V_3.

4) Isentropic Expansion (3-4): –

- In this process, the mixture expands into the cylinder.
- Due to the expansion, the heat of the ignited air-fuel mixture works on the piston and forces it to move down, which rotates the crankshaft. This rotation of the crankshaft further moves the car.
- During this whole process, the pressure of the mixture falls from P_3 to P_4, volume increases from V_3 to V_4, and temperature also reduces from T_3 to T_4. However, entropy doesn't change S_3=S_4.

5) Constant Volume Heat Rejection (4-1): –

- After the expansion process, the piston further moves downward to remove the waste heat from the cylinder.
- In this process, entropy falls from S_4 to S_1, temperature up to T_1, and pressure falls further to P_1. However, volume remains unchanged (i.e.V4 = V1).
- After the removal of all waste heat, the piston again sucks air, and the whole process repeats.

(E) Refrigeration and Air-conditioning cycles:

What is refrigeration and air conditioning?

Refrigeration keeps the cold air close, air conditioning pushes it away. Refrigeration uses coolant alone, air conditioning also uses the air from outside. Refrigeration deals with cooling and freezing, air conditioning deals with cooling and dehumidifying the air

What do you mean by refrigeration?

Refrigeration, or cooling process, is the removal of unwanted heat from a selected object, substance, or space and its transfer to another object, substance, or space.

What is air conditioning?

Air-conditioning is that process used to create and maintain certain temperature, relative humidity and air purity conditions in indoor spaces. This process is typically applied to maintain a level of personal comfort.

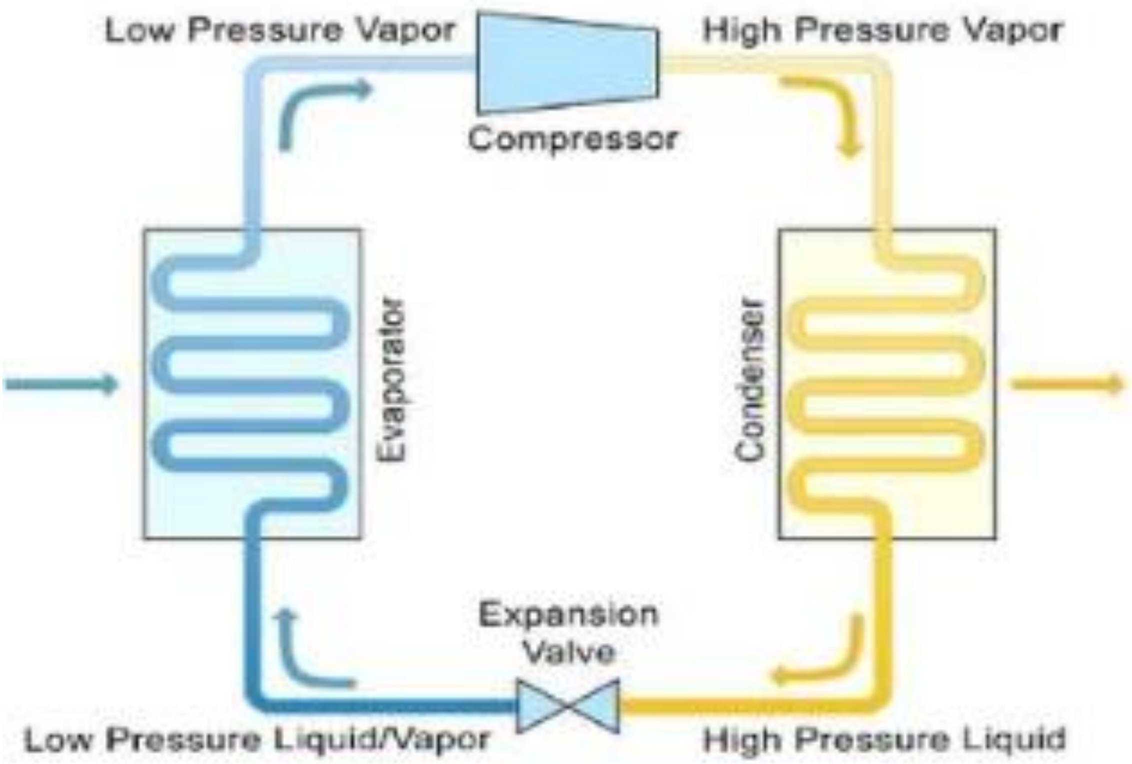
What is the air refrigeration cycle called?

Air refrigeration systems belong to the class of gas cycle refrigeration systems, in which a gas is used as the working fluid. The air refrigeration system works on the Joule cycle or reverse Brayton cycle or Bell-Coleman Cycle.

In simple terms, a refrigeration cycle's mission is heat absorption and heat rejection. The refrigeration cycle, sometimes called a heat pump cycle, is a means of routing heat away from the area you want to cool. This is accomplished by manipulating the pressure of the working refrigerant (air, water, synthetic refrigerants, etc.) through a cycle of compression and expansion.

Four fundamental elements of a basic cycle are as follows:

- The compressor
- The condenser
- The expansion device
- The evaporator



The compressor: Compression is the first step in the refrigeration cycle, and a compressor is the piece of equipment that increases the pressure of the working gas. Refrigerant enters the compressor as low-pressure, low-temperature gas, and leaves the compressor as a high-pressure, high-temperature gas.

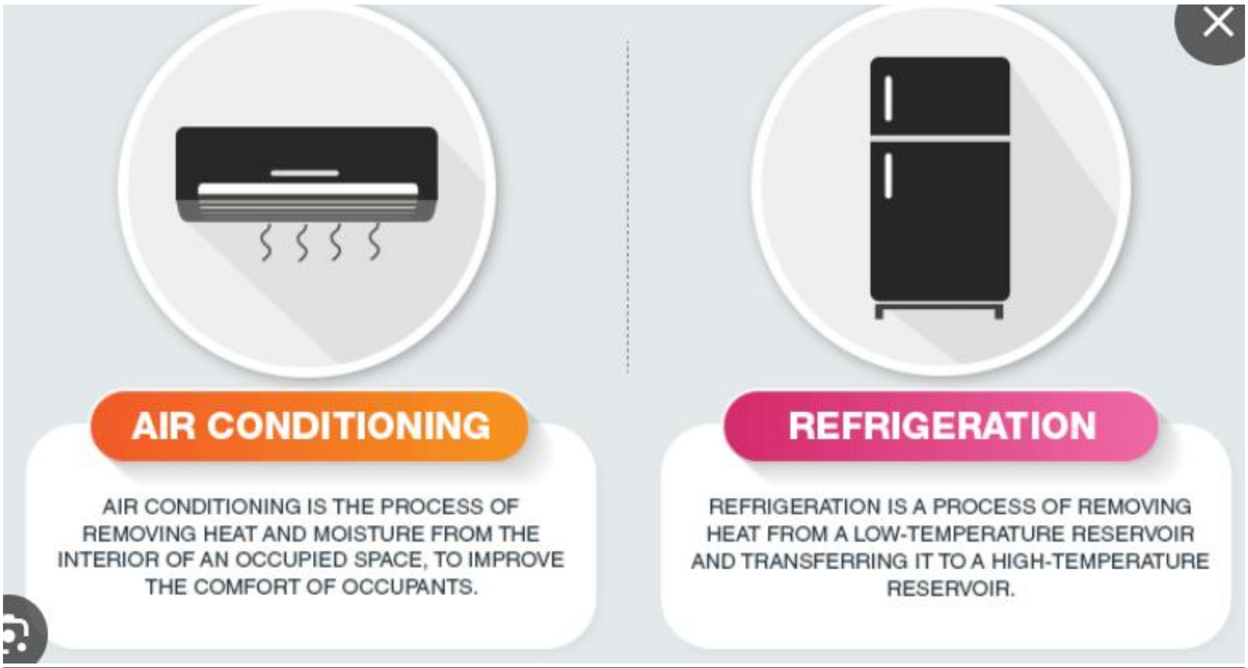
The condenser: The condenser, or condenser coil, is one of two types of heat exchangers used in a basic refrigeration loop. This component is supplied with high-temperature high-pressure, vaporized refrigerant coming off the compressor. The condenser removes heat from the hot refrigerant vapor gas vapor until it condenses into a saturated liquid state ie., condensation.

After condensing, the refrigerant is a high-pressure, low-temperature liquid, at which point it's routed to the loop's expansion device.

The expansion device: It create a drop in pressure after the refrigerant leaves the condenser. This pressure drop will cause some of that refrigerant to quickly boil, creating a two-phase mixture.

The evaporator: In refrigeration, an evaporator is the heat exchanger where the refrigerant circulating inside the refrigeration circuit absorbs the thermal energy from the environment, which is then cooled. This is how the state of the refrigerant changes from liquid to vapour, giving it its name

Air Conditioning:



Refrigeration is the process of removal of unwanted heat from a selected object, substance, or space and its transfer to another object, substance, or space. Naturally, thermal energy is seen flowing from a hotter place to a colder place.

An air conditioning process has an indoor and outdoor unit connected with a pipe. The air is heated, compressed, condensed and liquified. The liquid gas evaporates and is cooled with the help of a condenser.

Difference Between Air Conditioning and Refrigeration	
Air Conditioning	**Refrigeration**
The circulation system is designed to keep the cooled air out of the unit	The circulation system is designed to keep the cool air within the unit
Two individual units are present. One unit for the evaporator and the other unit houses the compressor and the condenser.	One single unit encompasses the evaporator, compressor and condenser
The in-built chemicals within the unit absorb air into the system	The air is supplied to the unit through pipes
Fan is required	No fan is required
They are used to cool the room to maintain humidity	They are used to cool the food for food preservation

(F) Components of Electric and Hybrid Vehicles

What is the concept of electric vehicles?

An EV includes both a vehicle that can only be powered by an electric motor that draws electricity from a battery (all-electric vehicle) and a vehicle that can be powered by an electric motor that draws electricity from a battery and by an internal combustion engine (plug-in hybrid electric vehicle).

What is the principle of electric cars?

Power is converted from the DC battery to AC for the electric motor. The accelerator pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor. The motor connects and turns the wheels through a cog.

What are 3 types of electric cars?

There are three types of electric vehicles available on the market:

- Battery Electric Vehicles (BEVs) ...
- Plug-In Hybrid Electric Vehicles (PHEVs) ...

- Fuel Cell Electric Vehicles (FCEVs) ...

What is an electric vehicle example?

On-road electric vehicles include electric cars, electric trolleybuses, electric buses, battery electric buses, electric trucks, electric bicycles, electric motorcycles and scooters, personal transporters, neighborhood electric vehicles, golf carts, milk floats, and forklifts.

What are 3 advantages of electric cars?

- No fuel required so you save money on gas. Paying $0.10 per kW is the equivalent of driving on gasoline that costs less than $1 per gallon. ...
- Environmental friendly as they do not emit pollutants. ...
- Lower maintenance due to an efficient electric motor. ...
- Better Performance.

What are the applications of electric vehicle?

- Consumer Electronics.
- Public Transportation.
- Aviation.
- Electricity Grid.
- Renewable Energy Storage.
- Military.
- Spaceflight.
- Wearable Technology.

What is a hybrid vehicle?

Hybrid electric vehicles are powered by an internal combustion engine and one or more electric motors, which uses energy stored in batteries. A hybrid electric vehicle cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the internal combustion engine.

What are the 4 different types of hybrid vehicles?

- Mild Hybrids. One of the newest innovations in hybrid technology is that of a “mild” hybrid system. ...
- Full Hybrids. ...
- Plug-In Hybrids. ...
- Electric Vehicles with Range Extender Hybrids.

Does hybrid car need petrol?

What is a hybrid vehicle? A hybrid vehicle can run on both petrol/diesel and electric power. They are a cheaper alternative to a fully electric vehicle and provide the benefits of having better fuel economy and reduced impact on the environment than a standard car with only a petrol or diesel motor.

Which is better EV or hybrid?

Summary. When all the factors are taken together—purchase price, range, refueling costs, maintenance and experience—EVs are simply a better investment. Their net emissions are lower, they require less maintenance, they actually cost less over the lifetime of the vehicle, and they're just more fun to drive

What are hybrid cars advantages and disadvantages?

Hybrid cars may be cheaper to run, thanks to their improved fuel economy, but they are also more expensive to buy initially. Due to the complex nature of their powertrain and advanced technology, hybrid prices are typically higher than comparative petrol or diesel cars.

Comparison of ICE (IC Engine ie., regular type), Hybrid & Electric Vehicles:

Parameters	ICE Vehicles	Hybrid Vehicles	Electric Vehicles
Efficiency	Converts 20% of the energy stored in gasoline to power the vehicle	Converts 40% of the energy stored in gasoline to power the vehicle	Converts 75% of the chemical energy from the batteries to power the vehicle.
Speed (Average Top Speed)	199.5 km per hour (kmph)	177 km per hour (kmph)	48-153 km per hour (kmph)
Acceleration (average)	0-96.5 kmph in 8.4 seconds	0-96.5 kmph in 6-7 seconds	0-96.5 kmph in 4-6 seconds
Maintenance	High maintenance owing to more number of moving parts	Same as an ICE vehicle	Maintenance is minimal due to lesser number of moving parts.
Mileage (average)	Can go over 480-500 kms before refuelling. Typically achieves 10-12 kmpl	Typical achieves 20-25 kmpl	Can travel 120-200 kms before recharging.
Cost (average)	INR 0.7-1.1 million	INR 1.2-2 million	INR 0.9-6 million

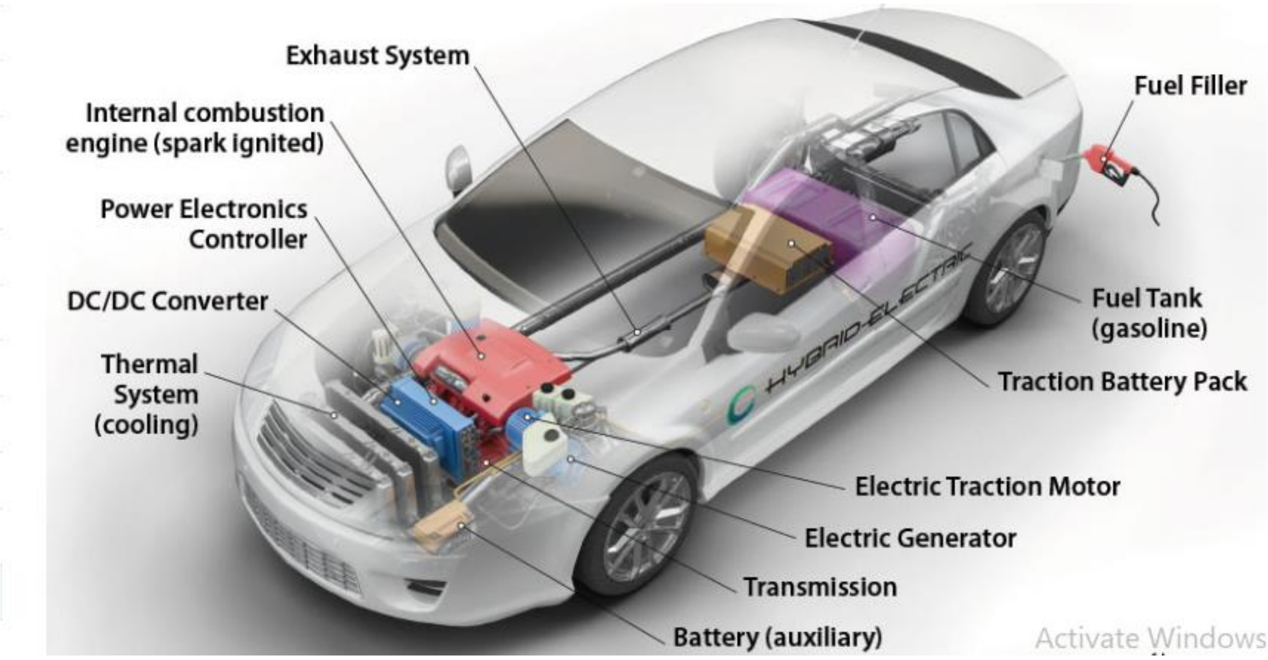


Fig.: Components of Electric and Hybrid Vehicles

Components of a Hybrid Electric Vehicles

Battery (auxiliary): In an electric drive vehicle, the low-voltage auxiliary battery provides electricity to start the car before the traction battery is engaged; it also powers vehicle accessories.
DC/DC converter: This device converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed to run vehicle accessories and recharge the auxiliary battery.
Electric generator: Generates electricity from the rotating wheels while braking, transferring that energy back to the traction battery pack. Some vehicles use motor generators that perform both the drive and regeneration functions.
Electric traction motor: Using power from the traction battery pack, this motor drives the vehicle's wheels. Some vehicles use motor generators that perform both the drive and regeneration functions.
Exhaust system: The exhaust system channels the exhaust gases from the engine out through the tailpipe. A three-way catalyst is designed to reduce engine-out emissions within the exhaust system.
Fuel filler: A nozzle from a fuel dispenser attaches to the receptacle on the vehicle to fill the tank.
Fuel tank (gasoline): This tank stores gasoline on board the vehicle until it's needed by the engine.
Internal combustion engine (spark-ignited): In this configuration, fuel is injected into either the intake manifold or the combustion chamber, where it is combined with air, and the air/fuel mixture is ignited by the spark from a spark plug.
Power electronics controller: This unit manages the flow of electrical energy delivered by the traction battery, controlling the speed of the electric traction motor and the torque it produces.

Thermal system (cooling): This system maintains a proper operating temperature range of the engine, electric motor, power electronics, and other components.
Traction battery pack: Stores electricity for use by the electric traction motor.
Transmission: The transmission transfers mechanical power from the engine and/or electric traction motor to drive the wheels.