# GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN

NEAR DAIRY CIRCLE, HOSUR ROAD, BENGALURU-560029, KARNATAKA
AFFILIATED TO VTU., BELAGAVI, RECOGNIZED BY GOVERNMENT OF KARNATAKA & A.I.C.T.E., NEW DELHI


Dr. NAVEED
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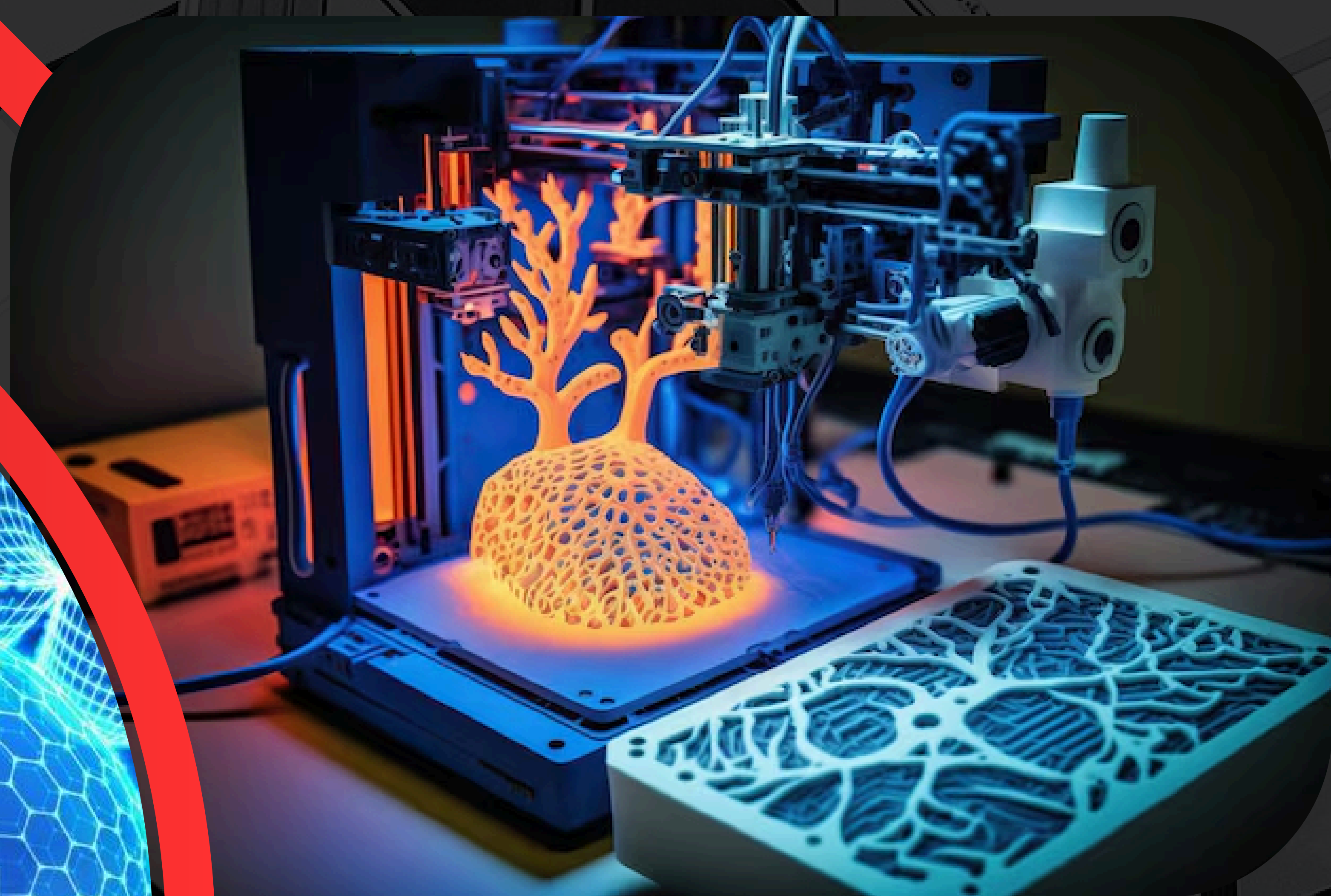
Mechanical engineering is vital because it forms the backbone of modern industry and technology. It encompasses the design, development, and maintenance of machines and systems that drive industries like manufacturing, automotive, aerospace, and energy. Mechanical engineers innovate solutions that enhance efficiency, improve energy sustainability, and create advanced technologies such as robotics and automation. Their contributions are critical in building infrastructure, optimizing production processes, and developing renewable energy solutions, making mechanical engineering essential for societal advancement and economic growth.

## Introduction to Mechanical Engineering/BESCK104D_204D




FIRST/SECOND
SEMESTER B.E DEGREE
2024

**GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN**

**Department of Mechanical Engineering**

**Near Dairy Circle, Bengaluru , Karnataka 560029**

# INTRODUCTION TO MECHANICAL ENGINEERING

# (BESCK104D/204D)

As per New Syllabus Prescribed by V.T.U. (CBCS System)

**For**

**FIRST / SECOND SEMESTER**

**(Bachelor of Engineering)**

## MODULE-01

**Introduction and Energy**

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# MODULE-01

*Syllabus:*

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

**Energy:** Introduction and applications of Energy sources like Fossil fuels, Nuclear fuels, Hydel, Solar, wind, and bio-fuels, Environmental issues like Global warming and Ozone depletion.

## Role of Mechanical Engineering in Industries and Society:

Mechanical Engineering is one of the basic branches of engineering and its fundamental principles are used in the design, development and construction of nearly all of the physical devices and systems we see around us including but not limited to automobiles, machines in all kind of factories, machinery used in building construction, road construction, agriculture, etc.

Mechanical Engineers in the energy sector are responsible to design and operate various power plants related to fossil fuel, hydroelectric, nuclear etc., They are involved in all aspects of the production and conversion of energy from one form to another. Mechanical Engineers are also involved in exciting projects such as developing alternatives to thermal energy, power cycle devices, fuel cells, gas turbines, and innovative uses of coal, wind, and tidal flow.

Mechanical Engineering plays a critical role in manufactured technologies, from cars to airplanes to refrigerators. It enables us to do many daily activities with ease, as it brings helpful technologies to our modern society. It is one of the most important subdivisions of engineering, because without it, many of the technologies we use every day would not be available.

Mechanical Engineers are involved with the design, construction and operations of all kinds of machinery. They conceptualize design for any product to be manufactured. They also develop, test and manufacture the state-of-the-art machinery. Manufacturing sector encompasses a set of industries to make or produce anything in a factory and therefore, it requires a great deal of specialized knowledge.

Without Mechanical Engineering, we would not have things like engines, generators, elevators or even air conditioning. While we might not even realize it, we most likely use something that has been mechanically engineered every day.

## Emerging Trends and Technologies in Energy Sector:

The renewable energy industry has seen impressive, global growth over the last decade and mechanical engineers have played a key role in enabling the world's transition to clean energy and more sustainable practices. To reduce $CO_2$ emissions and local air pollution, the world needs to rapidly shift towards low-carbon sources of energy – nuclear and renewable technologies.

The time has come to find suitable and better replacements for fossil fuels. Scientists are constantly researching newer and greener sources of energy that have limited impact on the environment and reduce their contribution to global warming, which is believed to be caused by the release of carbon dioxide while burning fossil fuels.

The renewable energy sector has benefitted from considerable growth — both from advances in technology that make it possible to harness new sources of energy and from global pressure to shift to clean energy. One such example is E-Vehicles.

Some of the energy sectors subjected to latest technologies are:

- Atomic energy (nuclear energy)
- Solar energy

- Hydel energy
- Wind energy
- Bio fuels etc.,

These are just a few of the promising alternatives for a cleaner and greener future. Other relatively new sources of energy such as fuel cells, geothermal energy, and ocean energy are also being explored.

**Emerging Trends and Technologies in Manufacturing Sector:**

The manufacturing industry has always had an appetite for technology. From big data analytics to advanced robotics, the game-changing benefits of modern technologies are helping manufacturers reduce human intervention, increase plant productivity and gain a competitive edge.

Sophisticated technologies, such as artificial intelligence, the internet of things(IoT) and 3-D printing among others, are shaping the future of manufacturing by lowering the cost of production, improving the speed of operations and minimizing errors.

For several decades, robotics and mechanization have been employed by manufacturers to increase productivity and minimize production costs per unit. Artificial intelligence (AI) and machine learning seem to be the next wave in manufacturing. AI is helping production teams analyze data and use the insights to replace inventory, reduce operational costs and offer seamless quality control over the entire manufacturing process. AI and machine learning are making it possible for robots and humans to collaborate with each other, creating agile manufacturing processes that learn, improve and make smart manufacturing decisions.

The capabilities of the internet of things (IoT) are rapidly being implemented in the industrial and manufacturing domain, providing plant owners with a way to increase productivity and decrease the complexities of processes. The industrial internet of things (IIoT) is an amalgamation of various technologies, such as machine learning, big data, sensor data, cloud integration and machine automation. These technologies are being employed in areas like predictive and proactive maintenance, real-time monitoring, resource optimization, supply-chain visibility, cross-facility operations analysis, and safety, enabling plant managers to minimize downtime and enhance process efficiency. For instance, regular maintenance and repair are essential for smooth plant operations. However, not all equipment and devices need maintenance at the same time. The IoT allows plant managers to employ condition monitoring and predictive maintenance of the equipment.

The 3-D printing or additive layer manufacturing technology is set to make a huge impact on high-end industries such as aerospace, mining machinery, automobiles, firearms, commercial and service machinery, and other industrial equipment. This revolutionary technology allows manufacturers to create physical products from complex digital designs stored in 3-D computer-aided design (CAD) files. Unlike the traditional manufacturing process, 3-D printers can create complex shapes and designs at no additional cost, offering greater freedom for designers and engineers.

## Emerging Trends and Technologies in Automobile Sector:

The automobile sector is adopting new technologies in its operations at an unprecedented scale. In addition to technologies such as artificial intelligence (AI) and big data & analytics that have been around for while, newer technologies such as the internet of things (IoT), autonomous vehicles, vehicle to vehicle communication, Electrification and block chain also find numerous applications in automotive sector. Looking at the rate of depletion of the fossil fuel reserves and the amount of harm caused to the environment due to their use introduces us to electric vehicles(EVs).

The future of mobility is electric. It is largely accepted that EVs are the best option available for the environment. EVs are a zero-emission mobility solution that can significantly drive down air pollution in cities and towns with saturated commuter traffic. Not only does this reduce our carbon footprint, but it also helps us breathe easier and live healthier lives. So, by choosing EVs, we choose a better world for everyone.

Artificial Intelligence (AI) technologies like deep learning, machine learning, and computer vision discover robotic automation applications inside the future trends of the automotive industry. AI guides the self-driving or Autonomous cars, helps the drivers in terms of safety, manages the fleet, and enhances services like vehicle insurance and inspection. Artificial intelligence further finds applications in automotive manufacturing, the rate of production, acceleration and helps to bring down the costs.

Internet of Things (IoT) allows secure interactions between the vehicle to vehicle and its infrastructure components in the vast automotive industry. This technology helps to a great extent in improving the road's safety, reducing pollution, solving traffic congestion, and spending energy with better management of the fleet. Furthermore, it enables the car to understand and comprehend its surroundings.

## Emerging Trends and Technologies in Aerospace Sector:

Aerospace industry has not just revolutionized the way we travel but has shrunk the world into few hours. Some of the emerging trends and technologies found in aerospace sector are: Artificial Intelligence, IoTs, Block chain Technology, Augmented Reality & Virtual Reality (AR&VR), Beacons Technology, Robotics, Biometrics, Mobile Communication etc.,

The airline is using AI to make sense of all the available data and use these insights to create offers and services personalized for individual travelers. The airline also has a recognition tool that reads passports and fills out all the information for flyers-easing out the data entry and data management tasks more manageable.

With the help of IoT, over the course of the next decade, it is likely that all "things" on board will be connected and the health of everything, from engine performance to the passenger safety, will be monitored in real-time. Sensors will automatically detect and report faults to maintenance teams on the ground through IoT, removing the need for the crew to manually report faults. Moreover, the addition of sensors to aircraft seats will enable the crew to monitor individual passenger health and wellbeing, and to proactively respond to their needs.

## Emerging Trends and Technologies in Marine Sector:

Advances in shipbuilding, propulsion, smart shipping, advanced materials, big data and analytics, robotics, sensors and communications in conjunction with an increasingly skilled workforce are all having monumental shifts in how the maritime industry are approaching new challenges and opportunities.

Design of freedom, efficient customization, waste reduction and managing virtual inventory will drive the development for future shipbuilding technologies.

IT infrastructure will be upgraded to retrieve, store, and process data in real time. These systems will combine machine learning and natural language processing to offer an intuitive interface between a person and a machine.

Developing advanced materials for ship applications will be a critical component of improving future ship performance. New features will be introduced, and multi-functional materials can be created.

## Gross Domestic Product (GDP):

GDP is important because it gives information about the size of the economy and how an economy is performing. The growth rate of real GDP is often used as an indicator of the general health of the economy. In broad terms, an increase in real GDP is interpreted as a sign that the economy is doing well. When real GDP is growing strongly, employment is likely to be increasing as companies hire more workers for their factories and people have more money in their pockets. When GDP is shrinking, as it did in many countries during the recent global economic crisis, employment often declines.

In some cases, GDP may be growing, but not fast enough to create a sufficient number of jobs for those seeking them. But real GDP growth does move in cycles over time. Economies are sometimes in periods of boom, and sometimes in periods of slow growth or even. GDP  is the monetary value of all the finished goods and services produced within a country's borders in a specific time period and includes anything produced within its borders by the country's citizens and foreigners.

It is primarily used to assess the health of a country's economy. The GDP of a country is calculated by adding personal consumption, private investment, government spending and exports. The above sectors such energy sector, manufacturing, automobile, aerospace and marine sectors are highly influential sectors governing the GDP of a country.

## Energy Sources and Power Plants:

### Review of Energy Resources:

The energy resources that are produced continuously in nature and which will not get exhausted eventually in future are called renewable energy resources. For example: Wind energy, solar energy, hydel energy, geothermal energy, tidal energy, ocean thermal energy, biomass energy etc.

While, the energy resources that gets exhausted eventually in future & which cannot be recovered any more are called non-renewable energy resources. For example: Fossil fuels like coal, petroleum oil, coal gas, natural gas etc & nuclear fuel like uranium.

Based on usage of the energy resources they can also be classified into conventional and non-conventional energy resources. The energy resources that are being used from a very long time are called conventional energy resources. For example: Fossil fuels, nuclear fuels, hydel energy etc.

While, the  alternative energy resources on which attention has been focused in the recent past which uses advanced technologies are called non-conventional energy resources. For example: Solar energy, fuel cells, wind energy, tidal energy, geothermal energy, biomass energy, ocean thermal energy etc. Some of the differences between them are listed in the table.

| S.N | Feature | Renewable (Non Conventional) | Non-Renewable ( Conventional) |
|---|---|---|---|
| 1. | Technologies | Commercially weak | Established |
| 2. | Plant size | Small (kW range) | Large (MW range) |
| 3. | Main power plants | Not sufficient | Suitable |
| 4. | Energy density of source | Low | High |
| 5. | Pollution problem | Less | More |
| 6. | Energy reserves | Renewable | Limited |
| 7. | Storage | Uneconomical | Easy |
| 8. | Cost of generation | High | Low |

## Fossil Fuel:

A fuel is a combustible substance which generates heat when burnt in the presence of oxygen. Carbon & hydrogen are major constituents of fuel in addition to other components. This heat energy is converted into mechanical energy which can be used for electrical power generation in thermal power plants and for propelling ships, automobiles and locomotives etc.

A natural fuel formed deep under the earth from the prehistoric remains of plants and animals is called fossil fuel. Fossil fuel is a hydrocarbon-containing material formed naturally in the Earth's crust from the remains of dead plants and animals that is extracted and burned as a fuel.

Fossil fuels are formed from the decomposition of buried carbon-based organisms that died millions of years ago. They create carbon-rich deposits that are extracted and burned for energy. They are non-renewable and currently supply around 80% of the world's energy.

They provide electricity, heat, and transportation, while also feeding the processes that make a huge range of products, from steel to plastics.

Coal, crude oil and natural gas are the three major types of fossil fuels found.

Coal is a combustible black or brownish-black sedimentary rock and is is formed when dead plant matter decays into peat and is converted into coal by the heat and pressure of deep burial over millions of years.

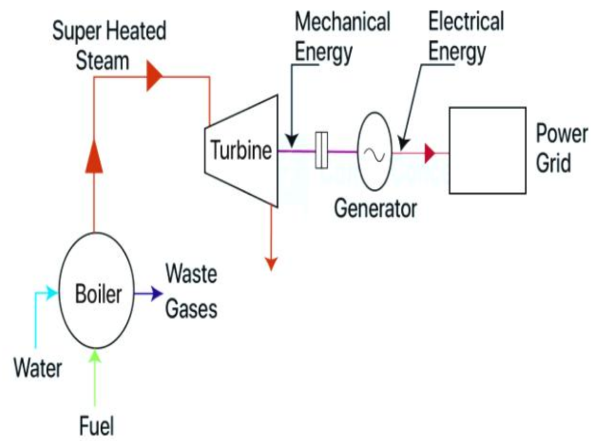
Petroleum, also known as crude oil, or simply oil, is a naturally occurring yellowish-black liquid mixture of mainly hydrocarbons. It is formed when large quantities of dead organisms, mostly zooplankton and algae, are buried underneath sedimentary rock and subjected to both prolonged heat and pressure. It is primarily recovered by oil drilling. Once extracted, oil is refined and separated, most easily by distillation, into innumerable products for direct use or use in manufacturing. Products include fuels such as gasoline (petrol), diesel, kerosene and jet fuel among many others.

Natural gas (also called fossil gas or simply gas) is a naturally occurring mixture of gaseous hydrocarbons consisting primarily of methane in addition to various smaller amounts of other higher alkanes. It is formed when layers of organic matter (primarily marine microorganisms) decompose under anaerobic conditions and are subjected to intense heat and pressure underground over millions of years.

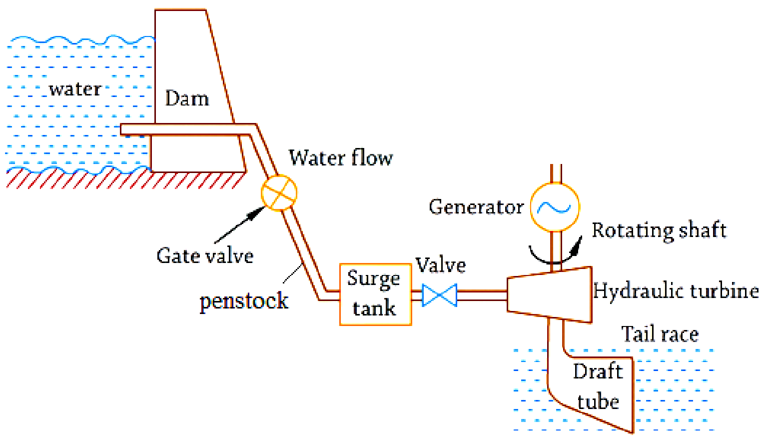
Fossil fuels even though they are major source of energy provider but they are very much harmful for the nature as it produces gases such as carbon dioxide that causes global warming and air pollution resulting in climatic changes and health issues.

## Construction and Working of Thermal Power Plant

A thermal power station is a power station in which heat energy is converted into electrical energy.
It consists of combustion chamber for heating fossil fuel such coal to produce heat energy, boiler and power house containing steam turbine with electric generator.
In principle of operation, the super heated steam from the boiler hits the rotor blades of the steam turbine due to which the rotor starts rotating because of the impulse or reaction effects and thereby steam energy is converted into mechanical energy (in the form of rotation of shaft). The rotor shaft is connected to the generator shaft through gear drives to produce electrical power.




## Construction and Working of Hydel Power Plant.

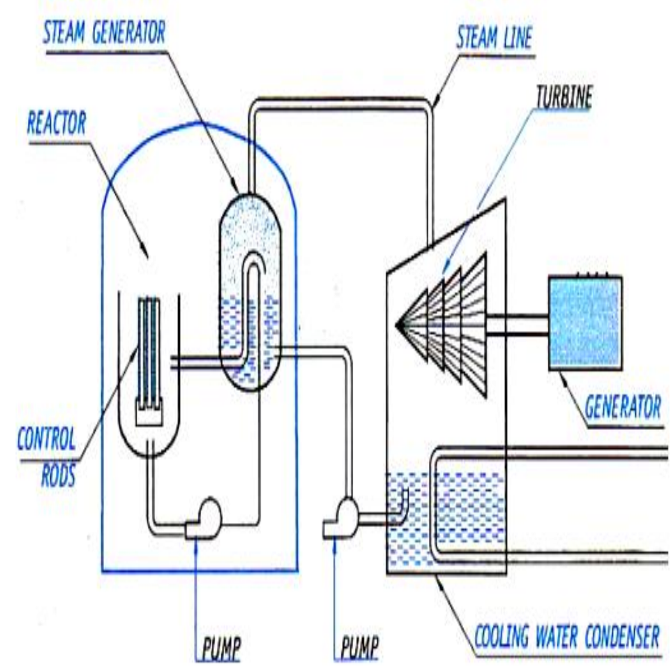



Hydel energy is the kinetic energy of the water which can be utilized for operating hydraulic turbine. It consists of dam, penstock, valves, nozzle and power house containing hydraulic turbine.
In principle of operation, the high velocity of jet hits the rotor blades due to which the rotor starts rotating because of the impulse or reaction effects and thereby hydraulic energy is converted into mechanical energy (in the form of rotation of shaft). The rotor shaft is connected to the generator shaft through gear drives to produce electrical power.

Hydropower plants can generate power to the grid immediately; they provide essential backup power during major electricity outages or disruptions. Hydropower provides benefits beyond electricity generation by providing flood control, irrigation support, and clean drinking water. Approximately 71% of all of the renewable electricity generated on Earth is from hydropower.

## Construction and Working of Nuclear Power Plant.

In nuclear power plant nuclear energy in the form of heat energy is utilized to generate huge quantity of steam which can be used to operate prime mover. It involves either fission or fusion chemical reaction which changes the structure of the nucleus to produce heat energy. In nuclear fission (splitting) reaction the nucleus of heavy atoms like uranium, plutonium is made to split (bombarded) in controlled continuous manner which results in generation of huge amount of heat energy. The break-up of $U^{235}$ when subjected to neutron bombardment yields fission products, neutrons and the release of a large amount of energy as heat ($8.2 \times 10^7$ kJ per g of$U^{235}$).



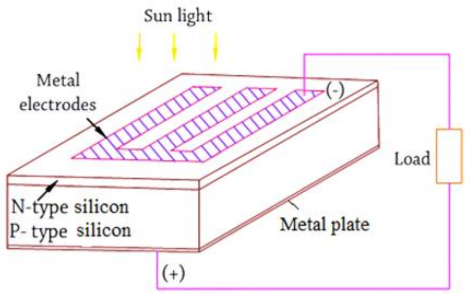

While, in nuclear fusion (adding) reaction when light masses of nuclei are added in presence of very high temperature, it releases neutron or proton or helium with huge amount of het energy.

A nuclear power plant consist of reactors where reaction take place, control rods to control the reaction, steam generator to generate steam for running steam turbine.

In principle of operation, the super heated steam generated from the heat energy of nuclear reaction hits the rotor blades of the steam turbine due to which the rotor starts rotating because of the impulse or reaction effects and thereby steam energy is converted into mechanical energy (in the form of rotation of shaft). The rotor shaft is connected to the generator shaft through gear drives to produce electrical power.

There are many applications of nuclear energy beyond electricity generation. These applications, which require heat, include seawater desalination, hydrogen production, district heating and process heating for industry (glass and cement manufacturing, metal production), refining and synthesis gas production

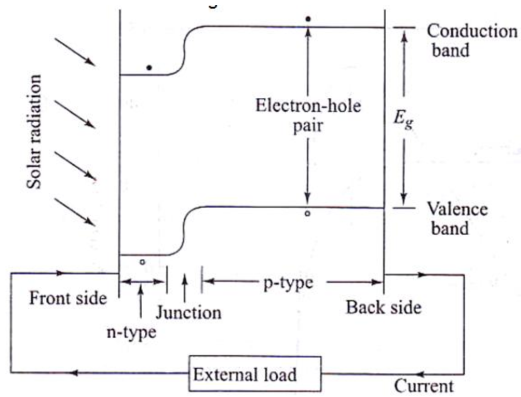
## Construction and Working of Solar Power Plant.




Solar Energy is one the important natural source of renewable energy. Today it is used as an alternate source of energy to produce electric power and for heating of water. Examples: liquid flat plate collector (solar water heater), solar cell, solar pond etc.,

A solar cell is a device which converts solar energy directly into electrical energy (DC) as shown in fig. It consists of Metal electrodes and metal plate which act conductors to conduct the electrical current. It consist of N-type silicon and P-type silicon semiconductors which act as impurities to change the current carrying behavior of semiconductors.

When solar rays with energy greater than the band gap energy are absorbed in the cell material, some of the electrons get excited & jump across the band gap from the valence band to the conduction band leaving behind holes in the valence band. This results in electron hole pair creation. The n-type silicon has excess electrons, while the p-type has excess holes. As these two materials are joined together, excess electrons from the n-type diffuse to recombine with the holes in the p-type. Similarly excess holes from the p-type diffuse to the n-type. As a result, the n-type material becomes positively charged, while the p-type is negatively charged. This creates a 'built-in' potential at the junction. The consequent electric field is adequate to separate the electrons and holes and cause a direct electric current to flow in the externals load.

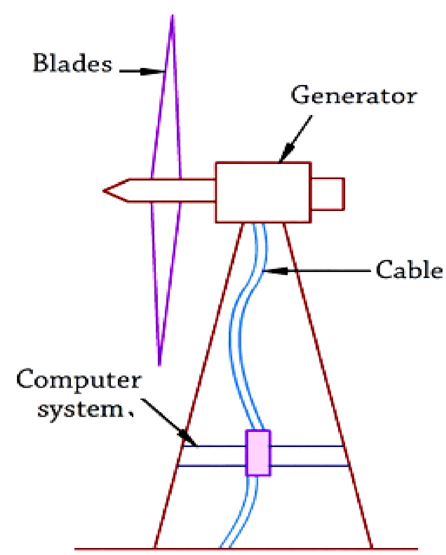



## Wind Energy :

Wind energy is the kinetic energy of large masses of air moving over the earth's surface which can be converted into mechanical work by 'wind mills' or 'wind turbines' as illustrated in the fig

It consists of blades, rotor, shaft, generator and computer system for advanced operations.

In principle of operation, the high velocity jet of air resulting from the wind hits the rotor blades of the wind turbine due to which the rotor starts rotating because of the impulse effects and thereby wind energy is converted into mechanical energy (in the form of rotation of shaft). The rotor shaft is connected to the generator shaft through gear drives to produce electrical power The rotor shaft is connected to the generator shaft through gear drives to produce electrical power.



Apart from providing electric power, wind mills are also used for pumping water, saw-milling of timber, milling grains, drainage-pumping, oil extraction from seeds, machining etc.,

## Bio Fuels:

Unlike other renewable energy sources, biomass (organic matter produced by plants) can be converted into liquid fuels called bio fuels by a wet process like digestion or fermentation. There are three different types of bio fuels used as explained below

### Types and applications of biofuels with advantages.

| Solid bio fuel | Liquid bio fuel | Gaseous bio fuel |
|---|---|---|
| **1. Wood:** It is in the form of cut logs, wood chips and sawdust and currently used for domesting heating & to provide process heat in the timber and furniture industries. | **1. Alcohols & vegetable oil:** Theses are replacing petrol and diesel as transport fuel in several countries & this is likely to accelerate as oil prices rise. Methanol & Ethanol can be blended with unleaded petrol in the present day internal combustion engines. | **1.Biogas:** It is mixture of methane & carbon dioxide with traces of hydrogen sulphide. It is compressed, stored & its quality can be improved by removing $CO_2$ by subjecting it to some chemical treatment. It is the most economical fuel used so far especially for cooking & water heating purposes. |
| **2. Straw**: Straw burning stoves and furnaces are becoming increasingly common in many countries. They burn various sizes of baled or chopped & compressed straw, and provide heat for crop drying & water heating. | **2.Vegetable oils:** vegetable oils from crushed seeds & nuts can be burnt in unmodified diesel engines. They can also be blended with diesel or even can be used directly. | |
| **3.Municipal Refuse:** It is far from an ideal fuel. It is messy to handle & has a low and variable energy content on average only about one-third that of coal. | **3. Biodiesel:** It is domestically produced from vegetable oils, animal fats, waste cooking oil etc., It is non-toxic, clean , biodegradable and can be used to replace petrol | |
| **Advantages of bio fuels:** | They have high calorific value and storage life cycle, can be easily handled and burned. In future it may be able to replace the existing expensive fuel systems. | |

### Comparison of Bio Fuels with Petroleum Fuels:

| Parameter | Bio Fuel | Petroleum Fuel |
|---|---|---|
| Calorific Value | 30 to 37.27 MJ/kg | 43 to 48 MJ/kg |
| Emission | • Greenhouse gas emissions are less<br>• About 17.9 pounds of $CO_2$ is produced by burning 1 gallon of B20 Biodiesel | • They are more.<br>• About 22.38 pounds of $CO_2$ is produced by burning 1 gallon of diesel. |
| Biodegradability | They are biodegradable. | They are not biodegradable. |
| Toxity | Non toxic | Toxic as well as carcinogic causing cancer. |
| Renewability | Renewable | Most of them are non renewable |
| Safety | Safe to produce | Not safe to produce involves lot of mining & drilling activities. |

## Global Warming:

Global warming is a phenomenon of climate change characterized by a general increase in average temperatures of the Earth, which modifies the weather balances and ecosystems for a long time. It is directly linked to the increase of greenhouse gases in our atmosphere, worsening the greenhouse effect. It refers to the observed and continuing increase in average air and ocean temperatures since 1900 caused mainly by emissions of greenhouse gases. Greenhouse gases are those that absorb and emit infrared radiation in the wavelength range emitted by Earth. The primary greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide and ozone. Without greenhouse gases, the average temperature of Earth's surface would be about −18 °C (0 °F), rather than the present average of 15 °C (59 °F).

### Causes:

The world's leading climate scientists believe that human activities are very likely the main cause of global warming since the mid-twentieth century, mostly because of: The massive use of fossil fuels is obviously the first source of global warming, as burning coal, oil and gas produces carbon dioxide - the most important greenhouse gas in the atmosphere - as well as nitrous oxide. The exploitation of forests has a major role in climate change. Trees help regulate the climate by absorbing $CO_2$ from the atmosphere. When they are cut down, this positive effect is lost and the carbon stored in the trees is released into the atmosphere. Another cause of global warming is intensive farming, not only with the ever-increasing livestock, but also with plant protection products and fertilizers. In fact, cattle and sheep produce large amounts of methane when digesting their food, while fertilizers produce nitrous oxide emissions. Waste management methods like landfills and incineration emit greenhouse and toxic gases - including methane - that are released into the atmosphere, soil and waterways, contributing to the increase of the greenhouse effect. Modern life is highly dependent on the mining and metallurgical industry. Metals and minerals are the raw materials used in the construction, transportation and manufacturing of goods. From extraction to delivery, this market accounts for 5% of all greenhouse gas emissions. Finally, overconsumption also plays a major role in climate change. In fact, it is responsible for the overexploitation of natural resources and emissions from international freight transport, which both contributes to global warming.

### Effects:

The increase of temperatures and the climate upheavals disturb the ecosystems, modify the conditions and cycles of plant reproduction. The scarcity of resources and climate change are changing life habits and migratory cycles of animals. We are already witnessing the disappearance of many species - including endemic species - or, conversely, the intrusion of invasive species that threaten crops and other animals. Because of global warming, permafrost and ice are melting massively at the poles, increasing the sea level at a rate never known before. In a century, the increase reaches 18 cm (including 6 cm in the last 20 years). The worst case scenario is a rise of up to 1m by 2100. Human beings are not spared by these upheavals. Climate change is affecting the global economy. It is already shaking up social, health and geopolitical balances in many parts of the world. The scarcity of resources like food and energy gives rise to new conflicts. Rising sea levels and floods are causing population migration. Small island states are in the front line. The estimated number of climate refugees by 2050 is 250 million people. For decades now, meteorologists and climatologists around the world have been watching the effects of global warming on the weather phenomena. And the impact is huge: more droughts and heatwaves, more precipitations, more natural disasters like floods, hurricanes, storms and wildfires, frost-free season, etc.

**Ozone Depletion:**

The ozone layer is mainly found in the lower portion of the stratosphere, about 20 to 30 km (12 to 19 miles) above the earth, though the thickness varies seasonally and geographically. The ozone layer protects living things from harmful ultraviolet rays from the sun; without the protection of the ozone layer, millions of people would develop skin cancer and weakened immune systems. Ozone ($O_3$) is a highly reactive gas whose molecules are comprised of three oxygen atoms. Its concentration in the atmosphere naturally fluctuates depending on seasons and latitudes.

The main cause of ozone depletion and the ozone hole is manufactured chemicals, especially manufactured halocarbon refrigerants, solvents, propellants andfoam-blowing agents (chlorofluorocarbons (CFCs), HCFCs, halons), referred to as ozone-depleting substances (ODS). These compounds are transported into the stratosphere by turbulent mixing after being emitted from the surface, mixing much faster than the molecules can settle. Once in the stratosphere, they release halogen atoms through photo dissociation, which catalyze the breakdown of ozone ($O_3$) into oxygen ($O_2$). Both types of ozone depletion were observed to increase as emissions of halocarbons increased.

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Department of Mechanical Engineering

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# INTRODUCTION TO MECHANICAL ENGINEERING

# (BESCK104D/204D)

As per New Syllabus Prescribed by V.T.U. (CBCS System)

## For

## FIRST / SECOND SEMESTER

## (Bachelor of Engineering)

## MODULE-02

### Machine Tools and Advanced Manufacturing System


**Dr.NAVEED** M.Tech., PhD.

**Assistant Professor**

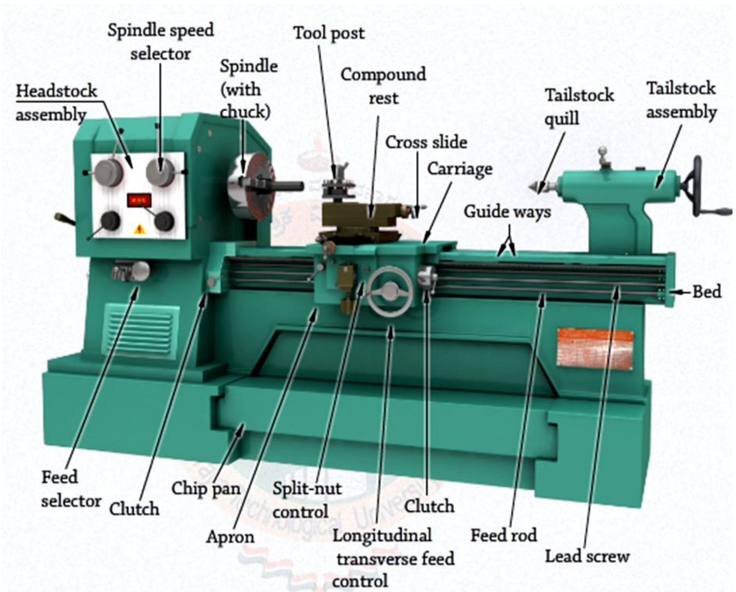
**Department of Mechanical Engineering**

# MODULE-02 MACHINE TOOL OPERATIONS & ADVANCED MANUFACTURING SYSTEMS

**Module-02/Syllabus:**

Machine Tool Operations: Working Principle of lathe, Lathe operations: Turning, facing, knurling. Working principles of Drilling Machine, drilling operations: drilling, boring, reaming. Working of Milling Machine, Milling operations: plane milling and slot milling. (No sketches of machine tools, sketches to be used only for explaining the operations).

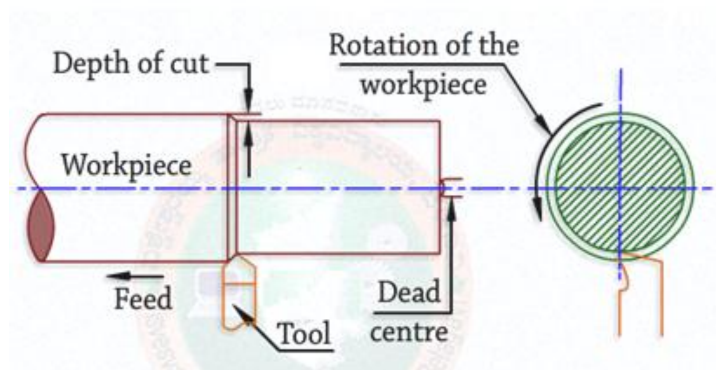
Introduction to Advanced Manufacturing Systems: Introduction, components of CNC, advantages and applications of CNC, 3D printing.

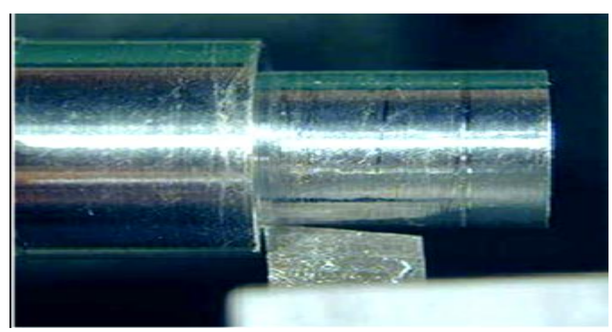



**Lathe Machine**: A lathe is a machine tool employed generally to produce circular objects. It is one of the oldest, most common, most basic, most versatile and most widely used machine tool. Engine lathe is the most commonly used general purpose lathe, it is small in size, inexpensive and can perform many operations. Engine Lathe is so called because the lathe of this type was driven by a steam engine. Today these lathes are equipped with the motor for the lathe driven mechanism, it is also called as center lathe or simply Lathe.

## Principle of Working of a Center Lathe:

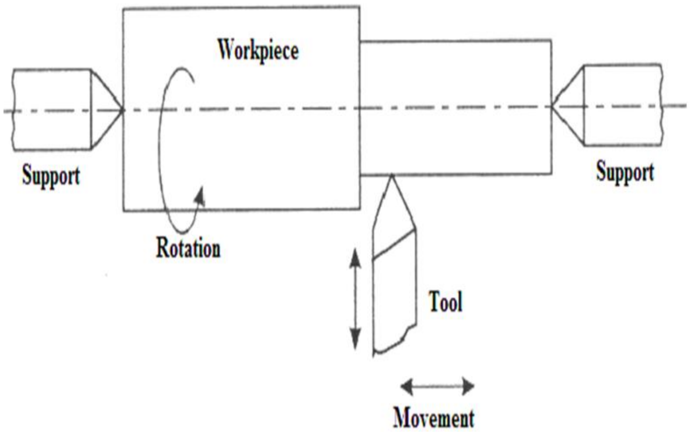
A lathe, basically turning machine works on the principle that, when a cutting tool is moved against a rotating work piece, the excess material is removed in the form chips. The figure illustrates principle of working of a center lathe.



In operation, the work piece is placed between the two centers of the lathe, that is the live center (head stock) and the dead center (tail stock). The cutting tool is mounted on the tool post at the compound rest. As the work piece is turned or rotated on the lathe, the cutting tool is moved on the work piece and the desired amount of material is removed in the form of chips. Based on the operation, the cutting tool can be selected, the most commonly used tool in the lathe are High Speed Steel (HSS), Cemented Carbide, Cemented Oxide, Diamond, etc.

In lathe the amount of cut given to the job is termed as depth of cut where as the direction in which the tool is traveling is called feed. The cutting tool is usually made up of material which is harder than the work piece.




**Lathe Operations:** These are the various operations which can be carried out on the cylindrical work piece using the lathe machine with different types of cutting tools. Examples: Turning operation, facing operation, knurling operations , thread cutting operation, taper turning etc.,

**Turning Operation:**

Turning is an operation on a lathe in which the work piece is reduced to the cylindrical section of required diameter as shown in the fig.

From the fig, the work piece is supported in between the two centers which permit the rotation of the work piece.

A single point cutting tool is moved perpendicular to the axis of the work piece to a known predetermined depth of cut& is then moved parallel to the axis of the work piece. The excess material is removed in the form of chips. With this operation the diameter of the work piece can be reduced to the required dimension.

**Facing Operation:**

Facing is an operation on lathe for generating flat surfaces at the ends of the work piece as shown in the fig.

In this operation, the cutting tool is moved perpendicular to the axis of rotating work piece. It removes excess material on the face of the work piece. It is very helpful in removing the burrs present on the face of the work piece which if not removed may be harmful to the operator. It is also carried out to reduce/cut the work piece to the required length.

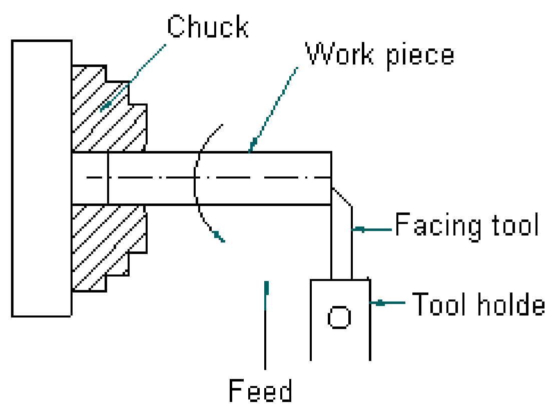
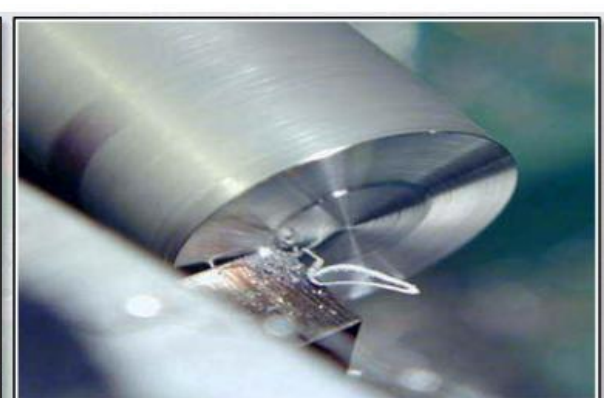



Fig: Facing operation



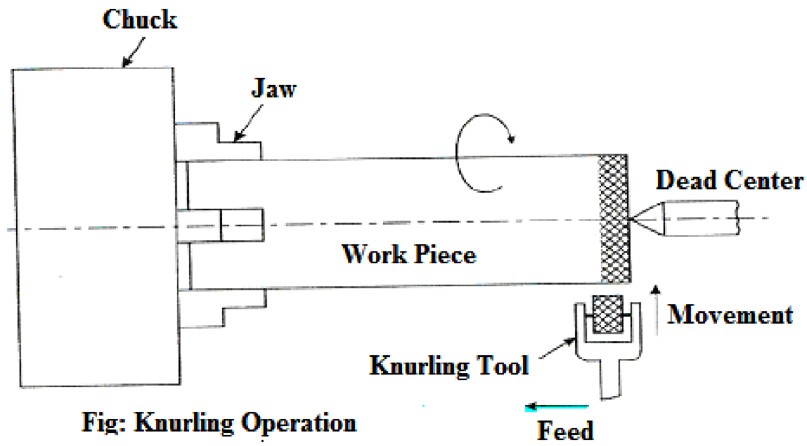
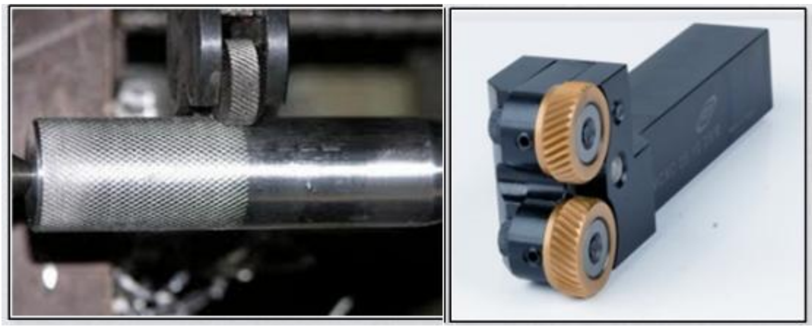



Fig: Knurling Operation



## Knurling Operation:

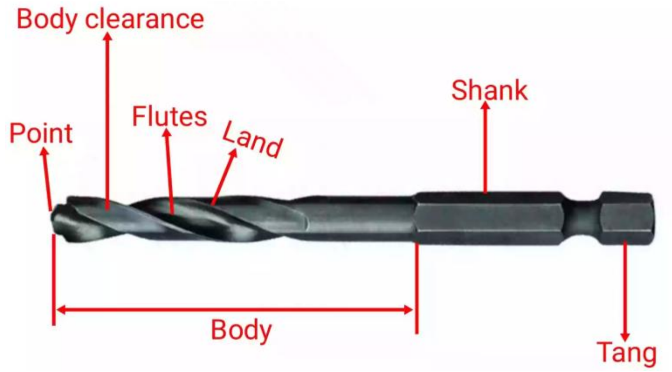
Knurling is an operation on the lathe to generate serrated surfaces on work pieces by using special tool called knurling tool, which impresses its pattern on the work piece as shown in the fig.

From the fig, in operation, the work piece is rotated at a low speed. The knurling tool is pressed against the rotating work piece and pressure is slowly increased until the knurling tool produces a pattern on the surface of the work piece. Knurling operation is preferred where grip is required which will increase the friction to hold the work piece.

## Drilling:

Drilling is a metal cutting process carried out by a rotating cutting tool to make circular holes in solid materials. The cutting tool is also called 'twist drill', since it has sharp twisted edges formed around a cylindrical body.

Drilling machine is a power operated machine tool, which holds the twist drill bit in its spindle, rotating at high speeds & when manually actuated to move linearly against the work piece produces a circular hole.

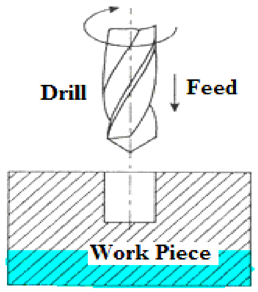



Fig: Principle of Drilling Operation

## Working Principle of Drilling Machine/Drilling Operation

In drilling machine the drill bit is rotated while the stationary work piece is brought in contact with the rotating drill bit to carry out drilling operation as shown in the fig.

In operation the work piece is rigidly clamped & the rotating drill bit is brought closer to it. The hole is generated by the sharp edges of the rotating drill bit, which is forced to move against the rigidly clamped work piece. The excess material is removed in the form of chips which get curled and escapes through the helical grooves provided in the drill bit. In drilling, while cutting action takes place inside the work piece a lot of heat is generated during the operation which is carried away by the use of coolants.

Drilling operation is carried out to drill holes on metal, wood or concrete surface of different diameter depending on the size of the drill bit.

## Boring Operation:

Boring is an operation of enlarging a previously drilled hole, by means of a boring tool having only one cutting edge as shown in the fig.

From the fig, in operation, initially a hole is drilled to the nearest size. the hole is then enlarged using a boring tool. The operation is continued till the lower surface of the work piece upto the required level.

Boring operation is helpful particularly when a drill bit of the required diameter is not available. By adjusting the cutting tip of the boring tool the diameter of the hole can be increased to the desired dimension.

It is also helpful to enlarge the top portion of the hole either in the form of square type or conical type to fit the head of the bolts and screws.

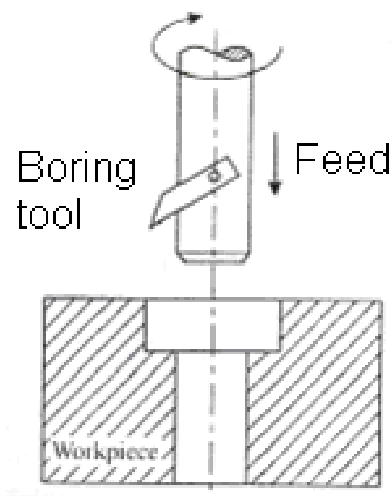



Fig: Boring operation

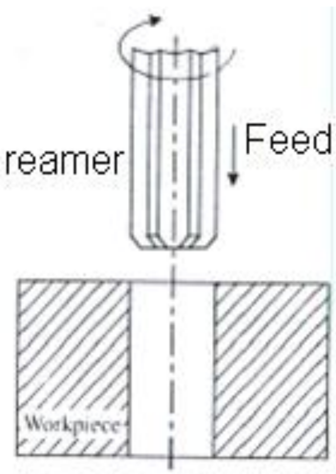



Fig: reaming operation

**Reaming Operation:**

Reaming is the process of smoothing the surface of the drilled holes using a reamer tool as shown in the fig.

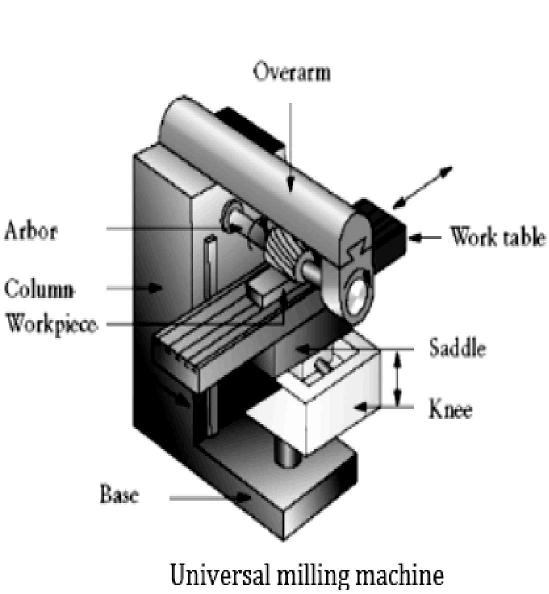
From the fig, reaming operation is carried out by means of a multi tooth revolving tool called 'reamer' which is similar to the twist drill, but has straight flutes.

While reaming, the speed of the spindle is reduced to half of that of the drilling.

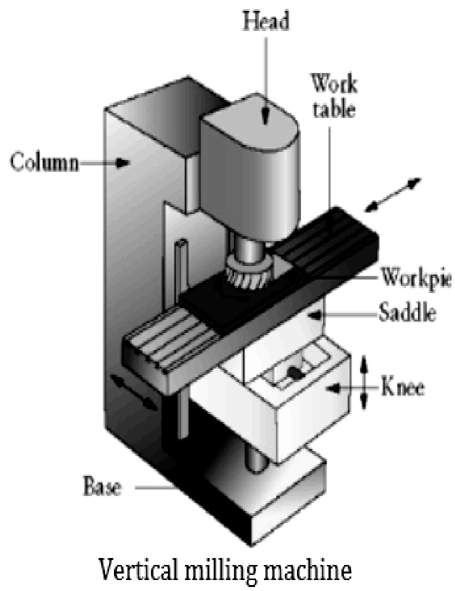
The material removed is very less and hence the drilled hole surfaces are finished with high accuracy.

## Applications of Drilling Machine Tool:

- Drill is a machine tool used for drilling the holes in solid equipment like metal, wood or concrete with drill bit or driver bit.
- Drills are used in wide variety of applications in metal working, constructions and wood working industries.
- Drilling machine is widely being used in different industries including construction, medical equipment, transportation and electronic equipment.
- Different kinds of drills are using in particular applications that can construct holes in numerous sizes in various kinds of materials.
- Drills powered by electricity are the most common tools in wood working and machining shops
- Drills are also used in surgery to remove or create holes in bone.




Universal milling machine

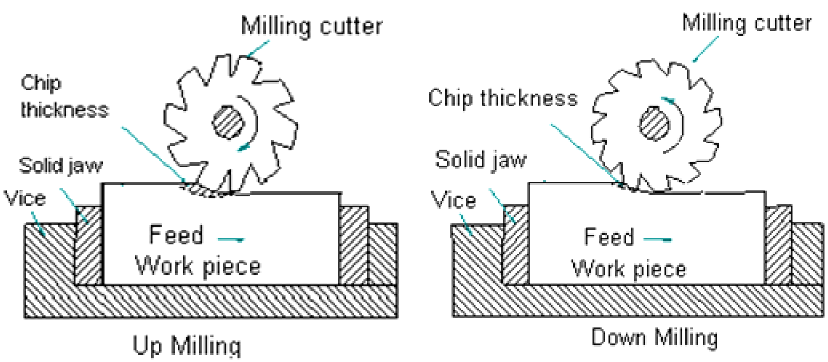



Vertical milling machine

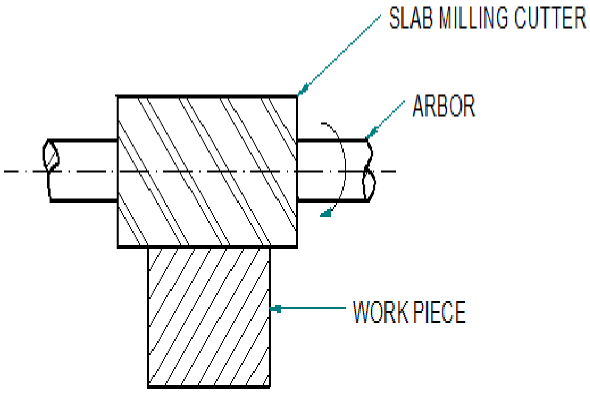
**Milling Machine:**

Milling is a process of removing excess material from the work piece in which the operating tool is called as milling cutter or just cutter. The milling cutter is a multipoint cutting tool having cutting teeth formed on its periphery. In milling, the work piece is fed against a revolving milling cutter. A milling machine is a power operated machine tool in which the milling operation is carried out. It can be horizontal type /universal or vertical/radial type.

**Principle of Milling:** Milling is carried out in two basic ways namely, Up Milling & Down Milling as shown in fig & explained in table




| Up Milling | Down Milling |
|---|---|
| The work piece is fed in the direction opposite to that of the rotating cutter | The work piece is fed in the same direction as that of the rotating cutter. |
| Thickness of chip is minimum at the beginning of cut and reaches to the maximum when the cut ends. | Thickness of chip is maximum at the beginning of cut and reaches to the minimum when the cut ends. |
| The cutting force is directed upwards and this tends to lift the work piece from the table. Hence greater clamping force is necessary | The cutting force acts downwards that tends to keep the work piece firmly on the table, thereby permitting lesser clamping forces. |
| During up milling, the chip gets accumulated at the cutting zone. These chips interfere with the revolving cutter, thereby impairing the surface finish. | The chips do not interfere with the revolving cutter as they are disposed easily by the cutter. Hence there is no damage to the surface finish. |
| Difficult for efficient cooling since the cutter rotates in the upward direction carrying away the coolant from the cutting zone | Efficient cooling can be achieved since the coolant can easily reach the cutting edge |
| Used for machining hard surfaces such as castings and forgings | Used for finishing operations and small works |




## Plain Milling / Slab Milling:

Slab/Plain milling is a process used to mill flat surfaces of work pieces in such a way that the milling cutter axis is made parallel to the surface of the work piece that is being milled as shown in the fig.

The operation is carried out in a horizontal/universal milling machine with the milling cutter mounted on the standard milling arbor.

The milling cutter has straight or helical teeth on its periphery.

When the work piece is brought in contact with the rotating milling slab cutter and moved horizontally, the excess material from the flat work piece is removed.

## Slot Milling:

Slot milling is the process of milling slots using different types of slot cutters.

The operation can be performed by means of plain milling cutter, end milling cutter, T-slot cutter etc. The cutter to be used is chosen according to the shape of the slot to be produced

A typical T-slot milling is as shown in the figure. To obtain a T-slot, initially end slot will be obtained using an end-slot milling cutter. Then to this end slot a suitable T-slot milling cutter will be used to obtain a T-slot profile. It is carried out on a vertical type of milling machine. When the work piece is brought in contact with the rotating milling slot cutter and moved horizontally, the excess material from the flat work piece is removed.

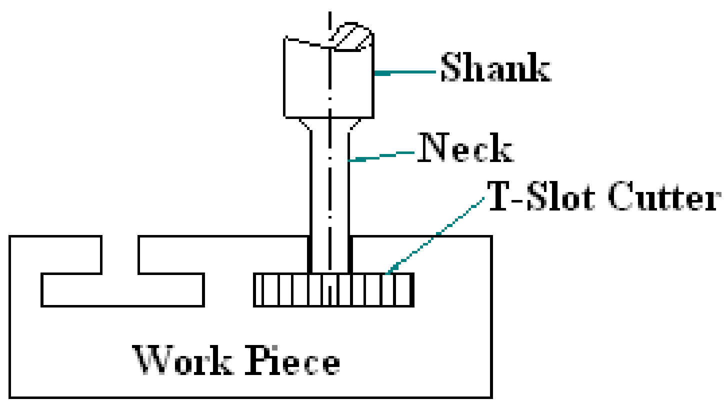
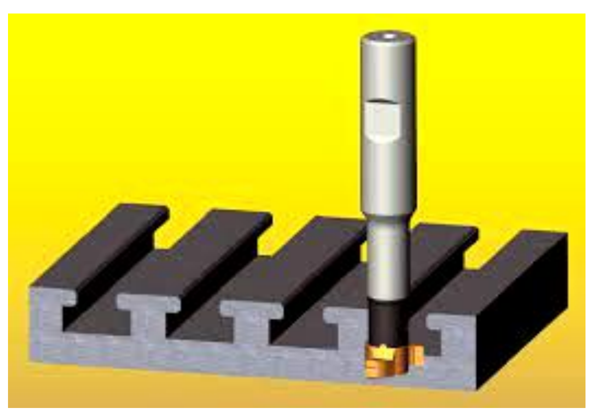



Fig: Slot Milling Opertion



### Applications of Milling Machines:

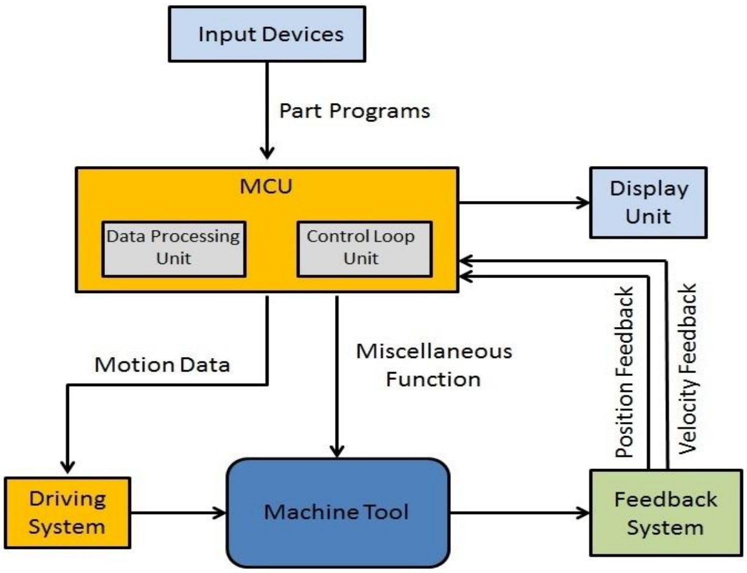
- The milling machine is used for making various types of gears.
- It is generally used to produce slot or groove in work pieces.
- It can able to machine flat surface and irregular surfaces too.
- It is used in industries to produce complex shapes.
- Milling machines can be used for a variety of complicated cutting operations – from slot cutting, threading, and rabbeting to routing, planning, and drilling.
- They are also used in die sinking, which involves shaping a steel block so that it can be used for various functions, such as moulding plastics or coining.
- Milling machines are used mainly for shaping and cutting solid materials such as metal, wood, plastics or even brass.

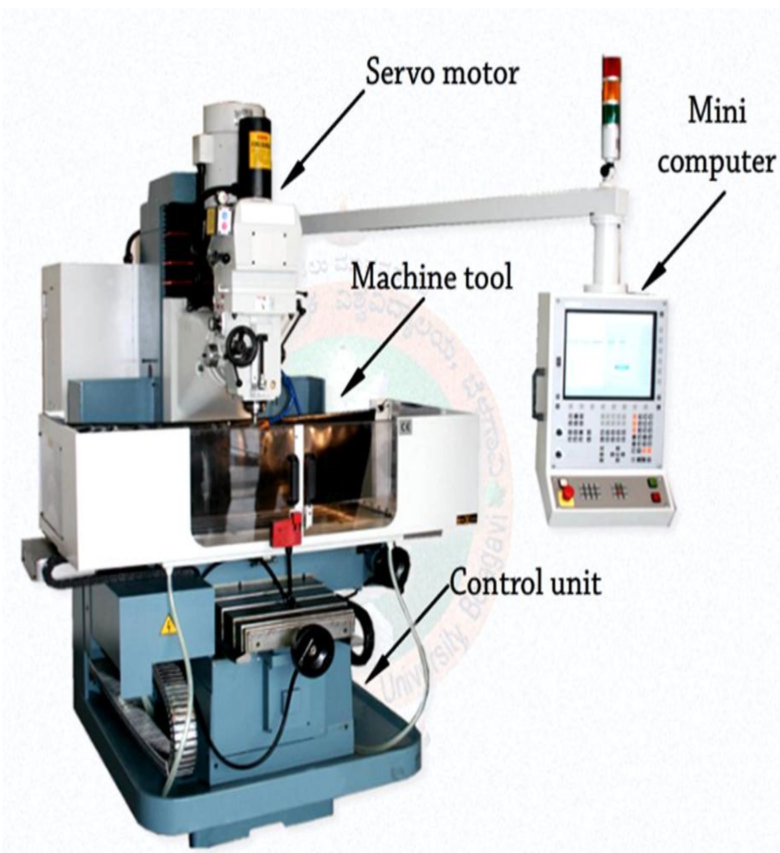
### Introduction to Advanced Manufacturing System:

Advanced manufacturing is the use of innovative technology to improve products or processes. It is also referred as Smart Manufacturing. Automation is one of the key elements of Advanced Manufacturing.
Automation from the point of industrial context may be defined as "A technology that is concerned with the use of mechanical, electrical/electronics and computer based system to control the various production processes in a systematic manner".
Examples: Numerically controlled machines (NC Machines), Computer Numerical Control (CNC), Transfer lines, Mechanized assembly machines, Feedback control systems etc. Robots & Automation are two closely related technologies. Robots assist in industrial automation.

### Components of CNC Machines:

Computer Numerical Control (CNC) is a system in which a microcomputer or microprocessor is made an integral part of the control panel of a machine or equipment. It may also defined as "An NC system with a microcomputer or microprocessor using software to implement control algorithms". The basic elements of CNC machine are shown in fig .




**Input Devices:** These are the devices which are used to input the part program in the CNC machine.

**Machine Control Unit (MCU):** It is the heart of the CNC machine. It is just like CPU of a computer. It involves several actions to perform in a CNC machine. Then, it helps to send the proper instruction to every part of the machine. It can recognize interpolations (circular, straight, and helical) to form axis transfer commands. In this part programming is typed & entered into the computer memory. It can be used again and again. A typical CNC may need only the drawing specifications of a part to be manufactured and the computer automatically generates the part program for the loaded part. The CNC machines have the facility for proving the part program without actually running it on the machine tool. It is connected to Display Unit which acts just like monitor of a computer.

**Driving System:** Basic function of a CNC machine is to provide automatic and precise motion control to its elements such work table, tool spindle etc for this driving systems are used to provide such kinds of controlled motion to the elements of a CNC machine tool. It consists of drive motors and ball lead-screws.

**Machine Tool:** Depending on the type of machining carried out, a specific machine tool like lathe, milling etc with be interconnected to the MCU and feedback system. Based on the programming the part will be finished inside the machine tool.

**Position feedback package:** CNC control unit allows compensation for any changes in the dimensions of the cutting tool. With CNC control systems, it is possible to obtain information on machine utilization which is useful to the managements. It uses feedback providing components like sensors.

## Advantages of CNC Machines:

- Greater flexibility
- Reduced data reading error
- Conversion of units possible
- CNC machines can diagnose program and can detect the machine malfunctioning even before the part is produced.
- High repeatability & precision manufacturing
- High volume of production
- Complex contours & surfaces can be easily obtained
- Flexibility in job change, automatic tool settings, less scrap
- Less paper work, more safe & better quality products

## Disadvantages of CNC Machines:

- Higher investment cost
- Unsuitable for long run applications
- Requires planned support facilities
- Setup is expensive
- Requires skilled operators with knowledge of computer programming
- High maintenance & service required

## Applications of CNC Machines:

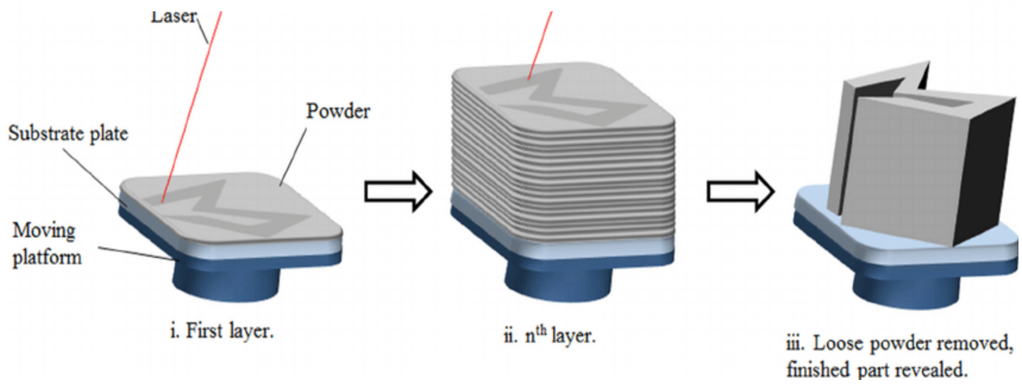
- CNC machining prototype productions are not tied to any single sector. People use it virtually everywhere. It helps to create everything from aircraft parts to surgical tools.
- The aerospace industry has a long-shared history with CNC machining. The machining of metal aircraft components occurs at the highest level of precision. Some of the machinable aerospace components include engine mounts, fuel flow components, landing gear components, and fuel access panels.
- The automotive industry regularly enjoys the uses of CNC milling machine for both prototyping and production. Extruded metal can be machined into cylinder blocks, gearboxes, valves, axels, and various other components. On the other hand, CNC machines plastics into components like dashboard panels and gas gauges.
- CNC machining also helps in the prototyping and production of consumer electronics. These electronics include laptops, smart phones, and many others.
- The military sector frequently turns to CNC machining for the prototyping of rugged and reliable parts.
- CNC machining offers its use on various medically safe materials. CNC machinable medical parts include surgical instruments, electronic enclosures, orthotics, and implants.

## 3D Printing/Additive Manufacturing:

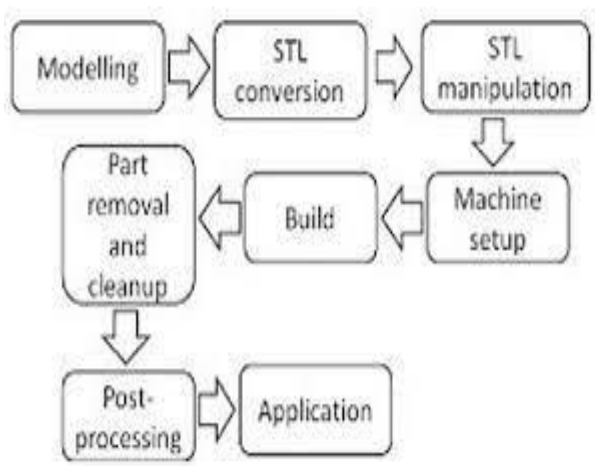

Additive Manufacturing (AM) is an appropriate name to describe the technologies that build 3D objects by adding layer-upon-layer of material, whether the material is plastic, metal, concrete or one day even it may be human tissue.

It is also referred by other words such as rapid prototyping, direct digital manufacturing and additive manufacturing.

The raw material used may be in the form of liquid, powder, semi solid etc.,




### Stages in 3D Printing:




**1. 3D CAD Modelling :**

All AM parts must start from a software model that fully describes the external geometry. This can involve the use of almost any professional CAD solid modeling software, but the out put must be a 3D solid or surface representation.

**2. STL convertion:**

Nearly every AM machine accepts the .STL file format, which has become a defacto standard, and nearly every CAD system can output such a file format. This file describes the external closed surfaces of the original CAD model and forms the basis for calculation of the slices.

**3. STL manipulation:**

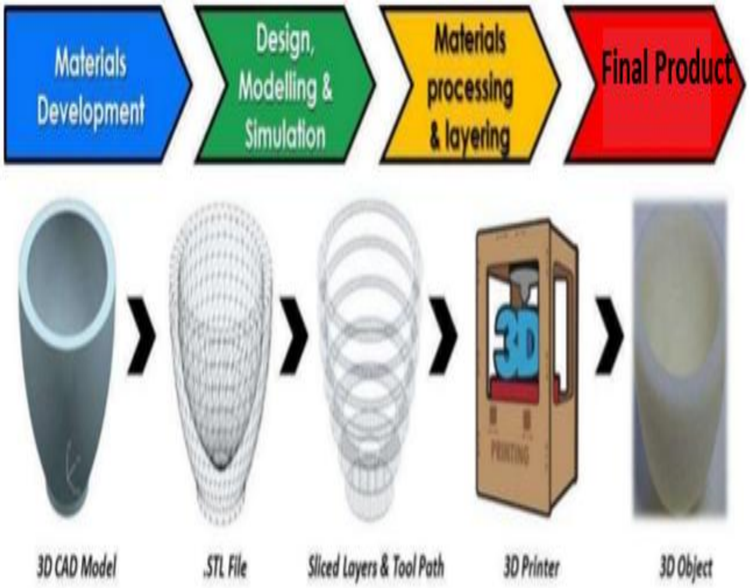
The STL file describing the part before it is transferred to the AM machine can also be manipulated for any changes in design and dimensions.

**4. Machine setup:**

The AM machine must be properly set up prior to the build process. Such settings would relate to the build parameters like the material constraints, energy source, layer thickness, timings, etc.

**5. Build:**

Building the part is mainly an automated process and the machine can largely carry on without supervision. Only superficial monitoring of the machine needs to take place at this time to ensure no errors have taken place like running out of material, power or software glitches,etc.




**6. Part removal & clean up:**

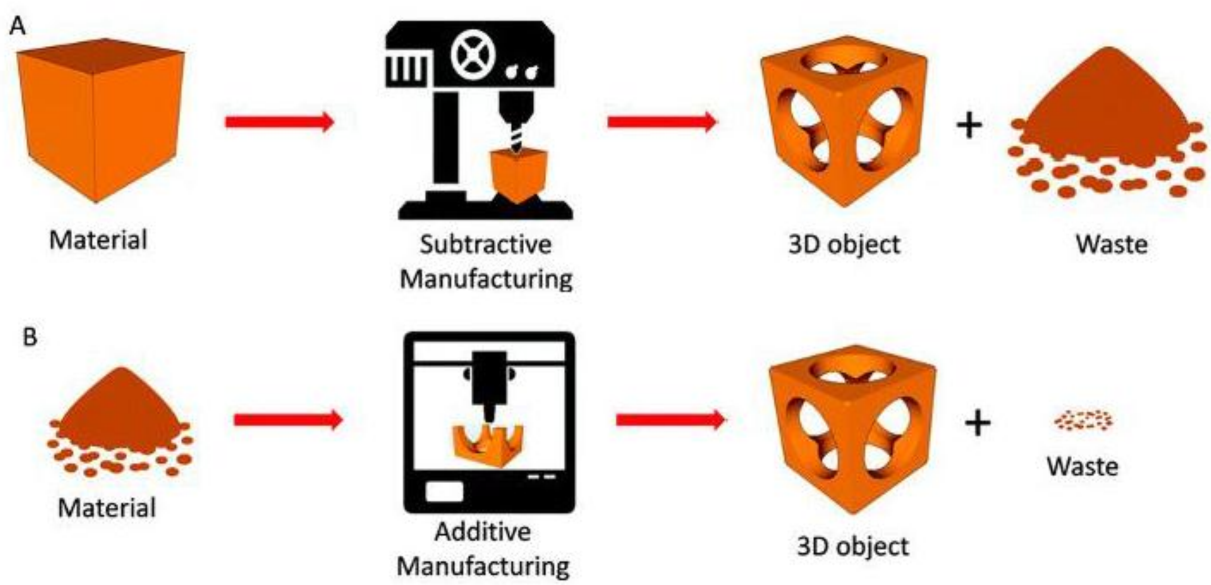
Once the AM machine has completed the build, the parts must be removed. This may require interaction with the machine, which may have safety interlocks to ensure for example that the operating temperatures are sufficiently low or that there are no actively moving parts.

**7. Post-process:**

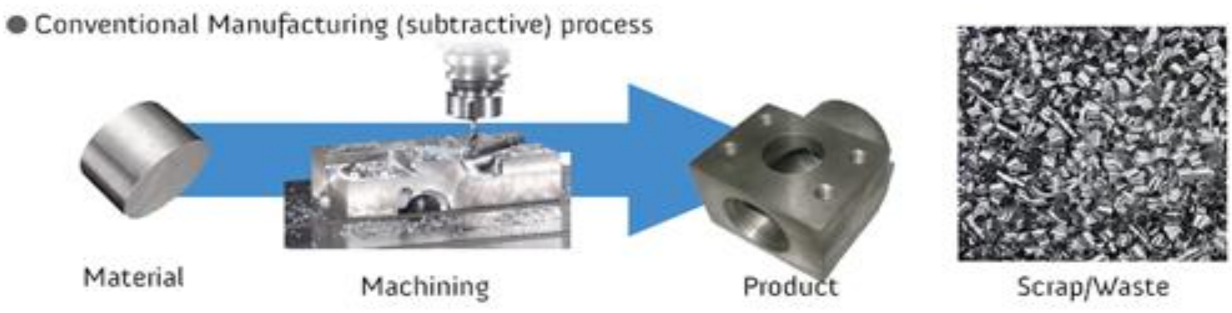
Once removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. Parts may be weak at this stage or they may have supporting features that must be removed. This therefore often requires time and careful, experienced manual manipulation. Parts may now be ready to be used. However, they may also require additional treatment before they are acceptable for use.

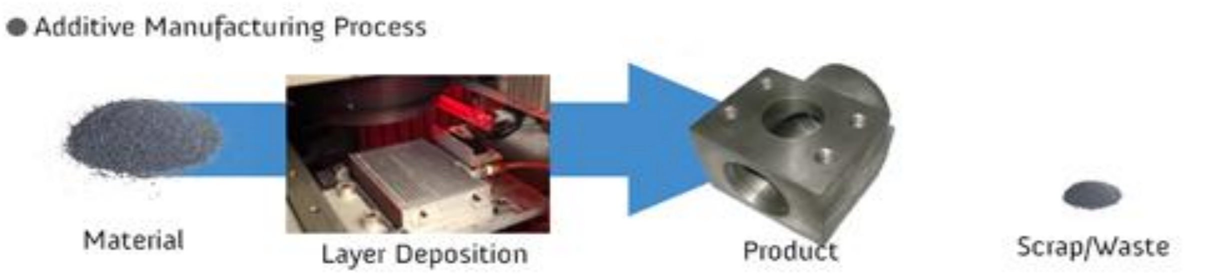
For example, they may require priming and painting to give an acceptable surface texture and finish. Treatments may be laborious and lengthy if the finishing requirements are very demanding

## Difference between 3D printing and CNC Machines




- The key difference between 3D printing and CNC machining is that 3D printing is a form of additive manufacturing, while the CNC machining is subtractive manufacturing.
- This means CNC machining starts with a block of material (called a blank), and cuts away material to create the finished part. To do this, cutting tools are used to shape the piece.
- Both 3D printing and CNC machining are compatible with a wide variety of materials, including both plastics and metals.




### Advantages of AM

- Freedom of design
- Complexity for free
- Potential elimination of tooling
- Lightweight design
- Elimination of production steps

### Disadvantages:

- Slow build rates
- High production cost
- Limited component size
- Considerable effort required for design of model


### Applications of AM

AM has been used across a diverse array of industries, including;

- Automotive
- Aerospace
- Biomedical
- Consumer goods and many others



**Classification of 3D Printing:** Based on the type of raw materials used, 3D printing may be classified into the following four types.

1. Liquid Polymer System (Stereo Lithography)
2. Discrete Particle System (Selective Laser Sintering & Direct Metal Laser Sintering)
3. Molten Material System (Fused Deposition Modeling, FDM)
4. Solid Sheet System

**Liquid Polymer System** (Stereo Lithography): A polymer is a large molecule composed of many repeated subunits called monomers. They are prepared by polymerization reactions, in which simple molecules are chemically combined into a long chain molecules or three-dimensional structures. They have low specific gravity and good strength. Plastics & synthetic rubbers are termed as organic polymers. There are two important classes of organic polymers such as thermoplastics & thermosetting plastics.

Stereo Lithography is a type of most commonly used Liquid Polymer System. It was the first process ever developed in Additive Manufacturing during 1986. It builds plastic parts or plastic objects layer by layer with the help of laser beam. It uses those plastic materials which get quickly solidified when it comes in contact with laser beam.

**Discrete Particle Systems:** Discrete particle systems are also known as Powder Based Systems. In this the raw material is used in POWDER FORM of very fine size in terms of microns. It uses high power LASER light for melting raw material. It builds up the part layer by layer.

The TWO major types of Discrete Systems are:

1. Selective Laser Sintering (SLS) and
2. Direct Metal Laser Sintering (DMLS)

Selective Laser Sintering is an additive manufacturing technique that uses a high power laser to fuse small particles of plastic, metal, ceramics, or glass powders into a mass that has a desired 3D shape. While Direct Metal Laser Sintering uses the same above process for powdered metal.

**Molten Material System:** Molten material systems are characterized by a pre-heating chamber that raises the material temperature to melting point so that it can flow through a delivery system. The most well-known method for doing this is the Fused Deposition Modeling (FDM) material extrusion technology developed by the US company Stratasys. This approach extrudes the material through a nozzle in a controlled manner. Two extrusion heads are often used so that support structures can be fabricated from a different material to facilitate part cleanup and removal.

**Solid Sheet System:** One of the earliest AM technologies was the Solid Sheet System which used a laser to cut out profiles from sheet paper, supplied from a continuous roll, which formed the layers of the final part. Layers were bonded together using a heat-activated resin that was coated on one surface of the paper. Once all the layers were bonded together the result was very much like a wooden block.

**GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN**

**Department of Mechanical Engineering**

**Near Dairy Circle, Hosur Road, Bengaluru , Karnataka 560029**

# INTRODUCTION TO MECHANICAL ENGINEERING

# (BESCK104D/204D)

As per New Syllabus Prescribed by V.T.U. (CBCS System)

**For**

**FIRST / SECOND SEMESTER**

**(Bachelor of Engineering)**

## MODULE-03

**IC Engines & Electric Vehicles**

**Dr.NAVEED** M.Tech., PhD.

**Assistant Professor**

**Department of Mechanical Engineering**

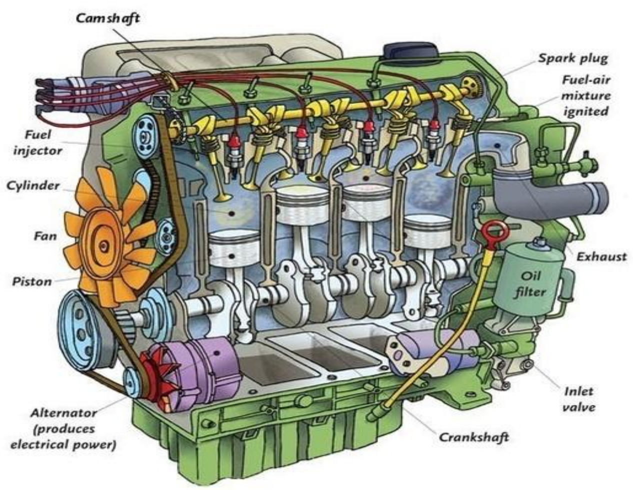
**MODULE-03** **IC ENGINES & E-VEHICLES**

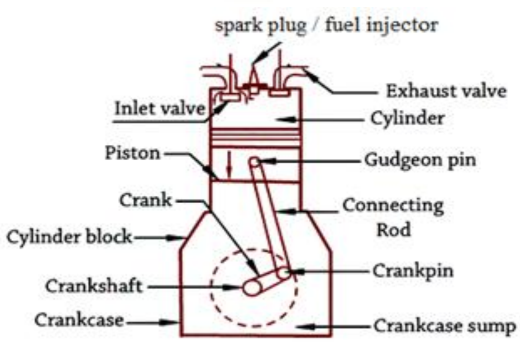
*Syllabus:*

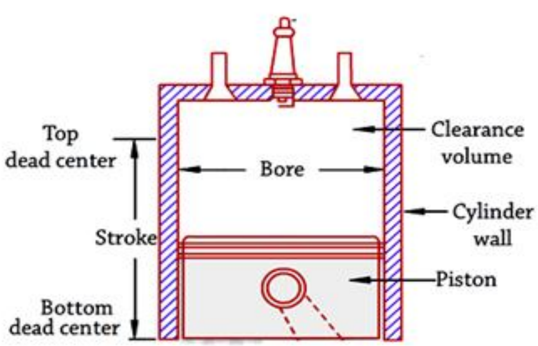
**Introduction to IC Engines:** Components and Working Principles, 4-Strokes Petrol and Diesel Engines, Application of IC Engines.
**Insight into Future Mobility:** Electric and Hybrid Vehicles, Components of Electric and Hybrid Vehicles. Advantages and disadvantages of EVs and Hybrid vehicles.

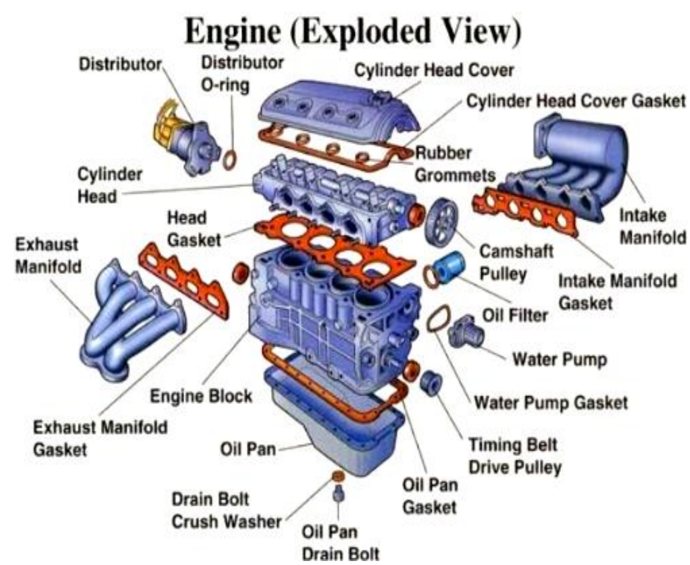
## IC Engines:

An IC Engine (internal combustion engine) is a Prime mover which converts heat energy released by the combustion of the fuel taking place inside the engine cylinder in to mechanical energy in the form of rotary motion of crank shaft. Example: Petrol engines, Diesel engines, Gas engines, etc.




## Parts of an IC Engine:

Cylinder: It is the Heart of the Engine where fuel combustion & piston reciprocation take place. The inside diameter is called bore & to prevent wearing of the cylindrical block, a sleeve is tightly fitted in the cylinder

Piston: It is a close fitting hollow-cylindrical plunger moving to-&-fro in the cylinder. The power developed by the combustion of fuel is transmitted by the piston to the crankshaft through the connecting rod.

Piston rings: These are metallic rings inserted into the circumferential grooves provided at the top of the piston to maintain a gas-tight joint between the piston & the cylinder while the piston is reciprocating in the cylinder.

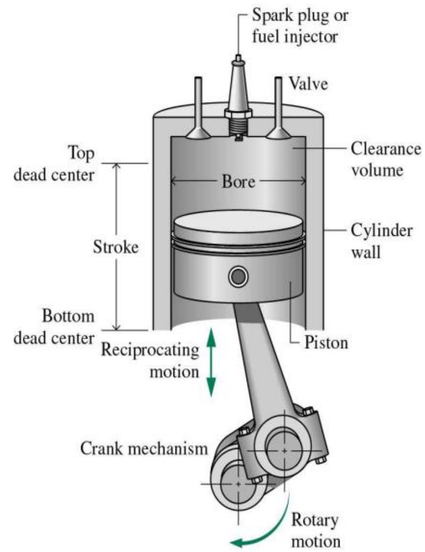
Connecting rod: It is a link that connects the piston and the crank by means of a pin joint & converts the reciprocating motion of the piston into rotary motion of the crankshaft.

Crank & Crankshaft: The Crank is a lever that is connected to the end of connecting rod by a pin joint with its other end connected rigidly to the crankshaft from which the required Mechanical power is obtained.

Crank case: It serves as an enclosure for the crank shaft

Valves & cams: Valves which are also known as poppet valves are used to control the flow of the intake & the exhaust gases to & from the engine cylinder & are operated b means of cams driven by the crankshaft through a timing gear.

Flywheel: It is a heavy wheel mounted on the crankshaft to maintain uniform rotation of the crankshaft.

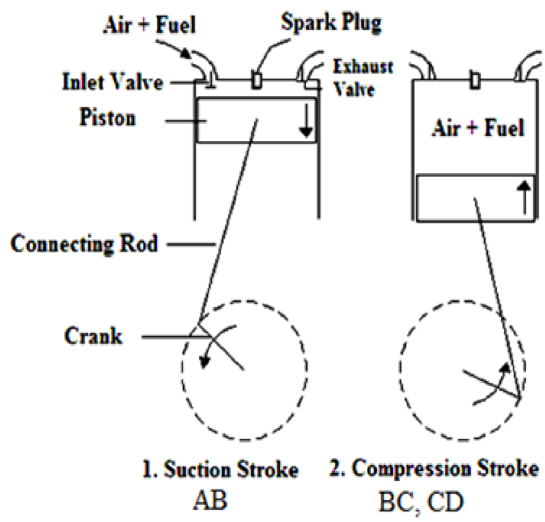


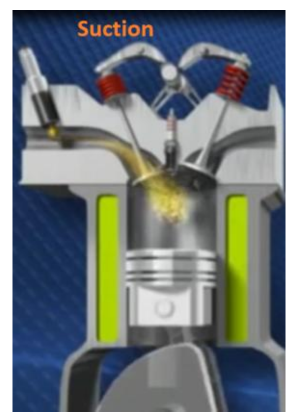


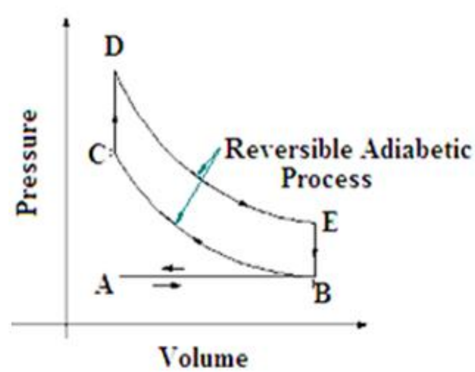
**Construction & operating principle of 4 stroke petrol engine (Otto cycle, Constant volume cycle, S.I engine)**

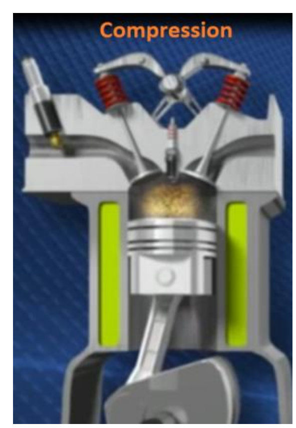
**Suction stroke:** During suction stroke the inlet valve opens with outlet valve closed & the piston travels from (Top Dead Center) TDC to (Bottom Dead Center) BDC & the crankshaft revolves by half rotation, causing the suction of air and fuel mixture from a carburetor. The energy required to perform this stroke is supplied by' cranking' only during the first cycle at the time of starting, while running, the flywheel supplies the mechanical energy. This stroke is represented by a line AB on the P-V diagram.

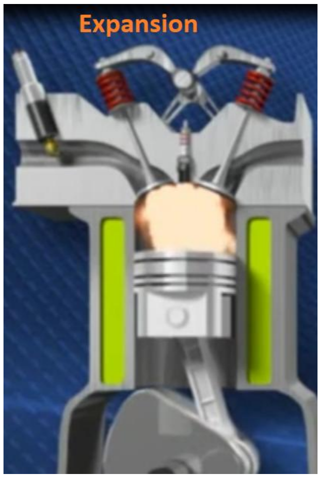
**Compression stroke**: During the compression stroke both inlet and exhaust valves are closed and the piston travels from the BDC to TDC & the crankshaft revolves further by half rotation, causing the compression of air and fuel mixture. This stroke is represented by a line BC on the P-V diagram. At the end of this stroke a spark is produced by a sparkplug, resulting in the combustion of the fuel and air & is represented by a line CD on P-V diagram.

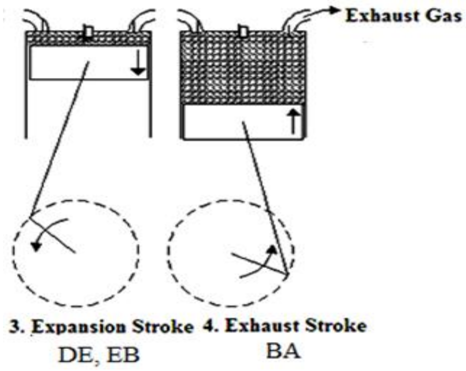


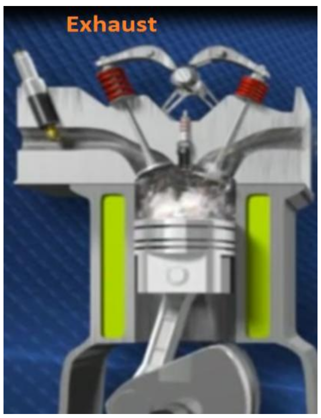



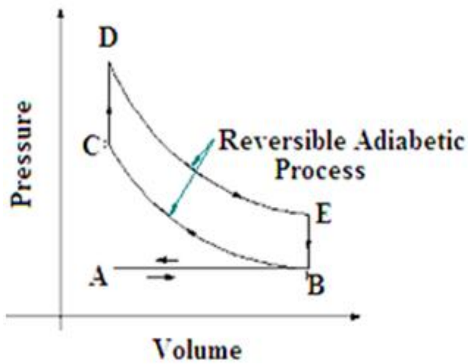





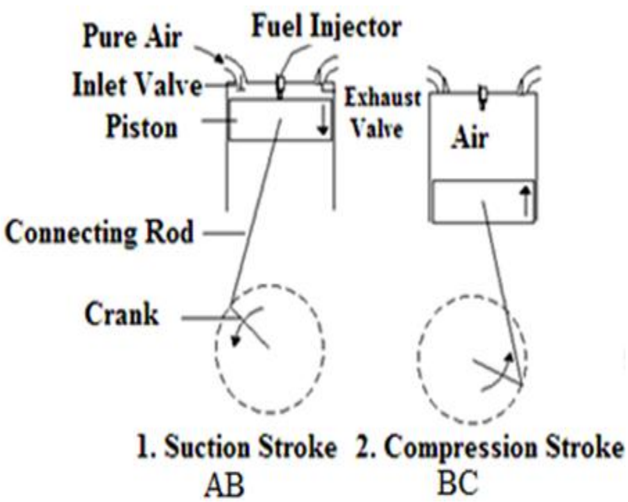



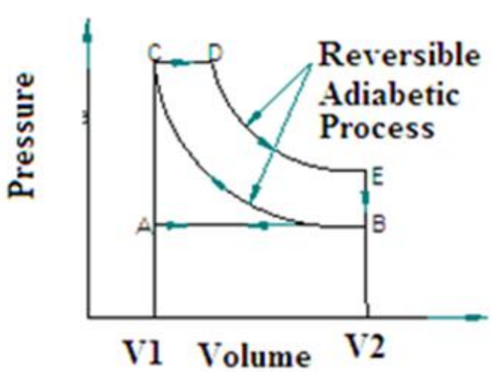




**Working stroke/Power stroke/Expansion stroke:** In this stroke the piston travels from TDC to BDC with both the valves remain closed & the crankshaft revolves half rotation. The piston is forced due to the expansion of the burnt gases .This linear motion of the piston is transmitted to the crankshaft through the connecting rod to produce mechanical power. This stroke is called as power stroke as the mechanical power is produced during this stroke. It is represented by the curve DE on a P-V diagram. As the piston moves further, the pressure of the hot gases gradually decreases at constant volume as represented by the line EB in PV diagram.

**Exhaust stroke:** During Exhaust stroke the exhaust valve opens with inlet valve closed and the piston travels from BDC to TDC, causing the exhaust of burnt gases from the cylinder & the crankshaft revolves half rotation. This stroke is represented by a line BA on the P-V diagram.

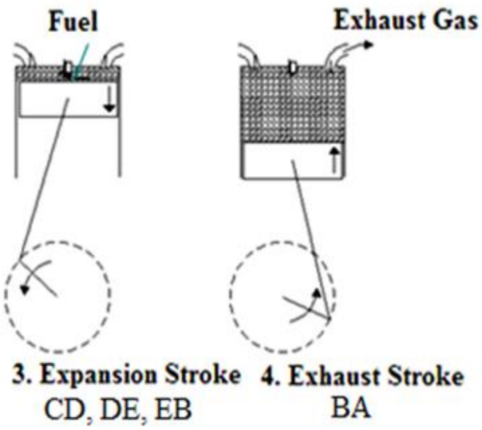


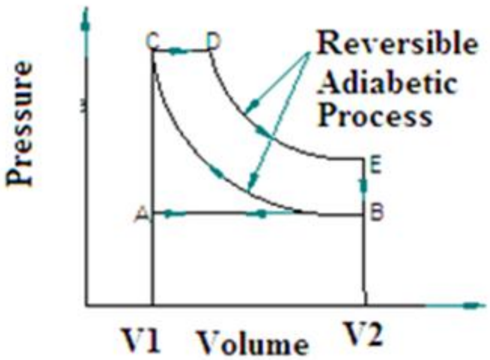




## Construction & operating principle of 4 stroke diesel engine (Diesel cycle, Constant Pessure, C.I engine)

***Suction stroke:*** During suction stroke the inlet valve opens with outlet valve closed & the piston travels from (Top Dead Center) TDC to (Bottom Dead Center) BDC & the crankshaft revolves by half rotation, causing the suction of pure air. The energy required to perform this stroke is supplied by 'cranking' only during the first cycle at the time of starting, while running, the flywheel supplies the mechanical energy. This stroke is represented by a line AB on the (Pressure -Volume) P-V diagram.

**Compression stroke:** During the compression stroke both inlet and exhaust valves are closed and the piston travels from the BDC to TDC & the crankshaft revolves further by half rotation, causing the compression of air. This stroke is represented by a line BC on the P-V diagram.At the end of this stroke a metered quantity of fuel is injected through the fuel injector, the high temperature of the air ignites the fuel as soon as it is injected. This is called Auto-ignition or Self-ignition




**Working stroke/Power stroke/Expansion stroke:** In this stroke the piston travels from TDC to BDC with both the valves remain closed & the crankshaft revolves half rotation. The burnt gases released by the combustion of the fuel that is continuously injected into the cylinder, force the piston to perform earlier part of this stroke at constant pressure till the injection of the fuel is completed. This constant pressure expansion with simultaneous combustion is represented by the line CD on PV diagram. The piston is forced further during the remaining part of this stroke due to the expansion of the burnt gases .This linear motion of the piston is transmitted to the crankshaft through the connecting rod to produce mechanical power. This stroke is called as power stroke as the mechanical power is produced during this stroke. It is represented by the curve DE on a P-V diagram. As the piston moves further, the pressure of the hot gases gradually decreases at constant volume as represented by the line EB in PV diagram.

**Exhaust stroke:** During Exhaust stroke the exhaust valve opens with inlet valve closed and the piston travels from BDC to TDC, causing the exhaust of burnt gases from the cylinder & the crankshaft revolves half rotation. This stroke is represented by a line BA on the P-V diagram.

## Comparisons between Petrol Engine & Diesel Engine.

| Particulars | Petrol Engine | Diesel Engine |
|---|---|---|
| Theoretical cycle of operation | Works on Otto cycle also known as Constant volume cycle | Works on Diesel cycle also known as Constant pressure cycle |
| Fuel used | Petrol | Diesel |
| Admission of fuel | Petrol mixed with air is admitted during suction stroke itself | Only air is drawn during suction stroke while, at the end of compression stroke pressurized diesel is injected through the fuel injector. |
| Ignition of fuel | Petrol mixed with air is ignited by the spark plug | Diesel is ignited by the high temperature compressed air. |
| Compression ratio | Low compression ratio ranging from 7:1 to 12:1 | High compression ratio ranging from 16:1 to 20:1 |
| Engine speed | High engine speed of about 3000 rpm | Low engine speed of about 500 to 1500 rpm |
| Output power capacity | Low, due to low compression ratio | High, due to high compression ratio |
| Thermal efficiency | Lower, due to low compression ratio | Higher, due to high compression ratio |
| Noise & vibration | It is almost nil, due to low operating pressure | More, due to higher operating pressure |
| Applications | Used in Scooter, Motor cycle, Cars etc. | Used in trucks, Tractors, Buses etc. |

## Application of IC Engines in Power Generation:

I.C engines are heat engines which converts heat energy from the combustion of fuel to mechanical energy in the form of crank shaft rotation which can be connected to the generator shaft through the power transmission system to produce electrical energy.

The IC engines used for the electric power generation may be classified into different types such as

- Compression Ignition (CI) IC Engine: In this compressed air is used to ignite diesel to produce heat energy. It also uses piston cylinder arrangement to operate the crank shaft.
- Spark Ignition (SI) IC Engine: In this the petrol is ignited by the electrical sparks to produce heat energy. It uses piston cylinder arrangement to operate the crank shaft.
- Gasoline IC Engine: It is a kind of internal-combustion engine that generate power by burning a volatile liquid fuel (gasoline or a gasoline mixture such as ethanol) with ignition initiated by an electric spark.
- Gas Engines: A gas engine is an internal combustion engine which runs on a gas fuel, such as coal gas, producer gas, bio-gas, landfill gas or natural gas.
- Gas Turbine: A gas turbine is an internal combustion engine that can convert natural gas or other liquid fuels to mechanical energy. This energy then drives a generator that produces electrical energy.

## Application of IC Engines in Agriculture:

Today, diesel engines power the majority of agricultural equipment in and around the world necessary to plant cultivate and harvest crops and transport them to markets or for processing and then delivered ultimately to the consumer. In addition to the farm machineries which are needed to grow and harvest crops, trucks and tractors are required to transport fertilizer, herbicides and pesticides, and even water to fields to help prepare them for planting and keeping the crop healthy while it is growing. Tractors allowed the entire agricultural industry to change. The use of engine-powered tractors allowed for faster planting and harvesting, along with the ability to manage pests and water crops in the event of droughts. This allowed for more farmland to be used and more food to be produced. In addition, farms did not have to maintain teams of horses, oxen, or mules specifically for use in the fields. Efficiency and crop yields rose exponentially.

## Application of IC Engines in Marine Propulsion:

Propulsion means to push forward or drive an object forward. A propulsion system is a machine that produces thrust to push an object forward. Today ship propulsion is not just about successful movement of the ship in the water. It also includes using the best mode of propulsion to ensure a better safety standard for the marine ecosystem along with cost efficiency. Diesel propulsion system is the most commonly used marine propulsion system converting mechanical energy from thermal forces. Diesel propulsion systems are mainly used in almost all types of vessels along with small boats and recreational vessels. Marine engines on ships are responsible for propulsion of the vessel from one port to another. Whether it's of a small ship plying in the coastal areas or of a massive one voyaging international waters, a marine engine of either 4-stroke or 2-stroke is fitted onboard ship for the propulsion purpose. The engines used onboard ships are internal combustion engines (a type), in which, the combustion of fuel takes place inside the engine cylinder and the heat is generated post the combustion process. A 4 stroke engine can be installed on the ship to produce electrical power and also to propel the ship (usually in small size vessel). The 2 stroke engines are used for vessel propulsion and are bigger in size as compared to the 4 stroke engines.

**Application of IC Engines in Aircraft Propulsion:**

An internal-combustion piston engine is normally used especially for smaller planes while for larger planes jet engines are used for propulsion. Jet engines are typical IC engines which use a number of rows of fan blades to compress air which then enters a combustion chamber where it is mixed with fuel and then ignited. The burning of the fuel raises the temperature of the air which is then exhausted out of the engine creating thrust. In simplest terms, a jet engine ingests air, heats it, and ejects it at high speed. For example in a turbojet engine which is a type of jet engine which consist of rotating elements similar to that of a turbine, ambient air is taken in at the engine inlet (induction), compressed about 10 to 15 times in a compressor consisting of rotor and stator blades (compression), and introduced into a combustion chamber where igniters ignite the injected fuel (combustion). The resulting combustion produces high temperatures (760 to 1,040 °C). The expanding hot gases pass through a multistage turbine, which turns the air compressor through a coaxial shaft, and then into a discharge nozzle, thereby producing thrust from the high-velocity stream of gases being ejected to the rear (exhaust). A turbojet engine is far simpler than a reciprocating engine of equivalent power, weighs less, is more reliable, requires less maintenance, and has a far greater potential for generating power.

**Application of IC Engines in Automobile:**

Internal combustion engines are the most common form of heat engines, as they are used in vehicles, boats, ships, airplanes, and trains. Automobiles are the vehicles designed primarily for passenger transportation as well for transporting goods from one place to another and commonly propelled by an internal-combustion engine using a volatile fuel. Reciprocating piston engines are by far the most common power source for land and water vehicles, including motorcycles, cars, buses, trucks, ships and to a lesser extent, locomotives (some are electrical but most use diesel engines). Two stroke petrol engines are normally used for operating very light vehicles while four stroke diesel engines are widely used for driving medium to heavy vehicles. The automobiles have become an integral part of our life without which we cannot perform our day to day activities in a simple easy way.

## Numericals on IC Engine:

**A gas engine working on a four stroke cycle has a cylinder of 250mm diameter, length of stroke 450mm & is running at 180rpm.Its Mechanical efficiency is 80% When the mean effective pressure is 0.65Mpa, Find 1. Indicated power 2. Brake power 3. Friction power 4. Break thermal efficiency if Cv = 42000 Kj/kg for fuel consumption of 3 kg/hr**

Given: 4 stroke engine.

$D = 250mm = 0.25m$ $\quad L = 450mm = 0.45m$

$N = 180$ rpm $\quad \eta_{mech} = 80\%$

$P_m = 0.65$ Mpa $= 0.65\times10^6$ N/m$^2$

$C_v = 42000$ KJ/Kg

$m = 3$ Kg/hr $= 3/3600$….Kg/s

IP ? BP? FP? $\eta_{Bth}$ ?

$$\mathbf{IP = \frac{P_m\,LAn}{60000}\ldots.KW}$$

$$A = \frac{\pi D^2}{4} \ldots . m^2$$

$$A = \frac{\pi 0.25^2}{4} = 0.049 \ldots . m^2$$

* For 4 stroke engine: n = N/2 180/2 = 90cycles/min

$$IP = \frac{0.65x10^6x0.45x0.049x90}{60000} = 21.5 \ldots . KW$$

$$\eta_{mech} = \left(\frac{BP}{IP}100\right)\%$$

$$80 = \left(\frac{BP}{21.5}100\right)\%$$

**BP = 17.2….KW**

**FP = IP - BP = 21.5 - 17.2 = 4.3….KW**

$$\eta_{Bth} = \left(\frac{BP}{C_V.m}100\right)\%$$

$$\eta_{Bth} = \left(\frac{17.2}{42000x3/3600}100\right) = \mathbf{49.14}\%$$

**The following observations were obtained during a trial on a four stroke diesel engine**

**Cylinder diameter = 25cm; Stroke of the piston = 40cm**

**Crankshaft speed = 250rpm; Brake load = 70kg**

**Brake drum diameter = 2m; Mean effective pressure = 6bar**

**Diesel oil consumption = 0.1 ltrs/min; Specific gravity of diesel = 0.78**

**Cv = 43900 Kj/kg**

**Find 1.BP 2. IP 3. FP 4. Mechanical efficiency 5. Brake thermal efficiency 6.Indicated thermal efficiency**

**Given:** 4 stroke engine:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| D | = | 25 cm | = | 0.25m | L | = | 40 cm | = | 0.4m |
| N | = | 250 rpm | | | W | = | 70 Kg | | |
| R | = | 2/2 | = | 1m | $P_m$ | = | 6bar | = | $6x10^5$ N/m$^2$ |
| V | = | 0.1 | ltr/min | | | | | | |

$$V = \frac{0.1x10^{-3}}{60} = 1.666x10^{-6} \ldots . m^3/s$$

Specific gravity of fuel = 0.78 Cv = 43900 KJ/Kg

IP ? BP? FP ? $\eta_{mech}$ ? $\eta_{Bth}$ ? $\eta_{Ith}$ ?

$$\mathbf{IP = \frac{P_m\,LAn}{60000} \ldots . KW}$$

$$A = \frac{\pi D^2}{4} \ldots . m^2$$

$$A = \frac{\pi 0.25^2}{4} = 0.049 \ldots . m^2$$

* For 4 stroke engine: n = N/2 = 250/2 = 125 cycles/min

$$IP = \frac{6x10^5x0.4x0.049x125}{60000} = 24.5 \ldots . KW$$

$$\mathbf{BP = \frac{2\pi NT}{60000} \ldots . KW}$$

**T = 9.81 W R…..Nm**

= 9.81x 70x1 = 686…. Nm

$$BP = \frac{2\pi 250x686}{60000} = 17.95 \ldots . KW$$

**FP = IP - BP =** 24.5 - 17.95 = 6.55….KW

$$\eta_{mech} = \left(\frac{BP}{IP}100\right)\%$$

$$\eta_{mech} = \left(\frac{17.95}{24.5}100\right) = 73.26\%$$

$$\eta_{Bth} = \left(\frac{BP}{C_V.m}100\right)\%$$

**Mass flow rate of the Fuel: m = Volume flow rate x Density of fuel…..Kg/s**

$$\text{Density of Fuel} = 1000 \text{ x Specific gravity of fuel}$$

$$\text{Density of Fuel} = 1000 \text{ x } 0.78 = 780 \ldots \text{Kg/m}^3$$

**Mass flow rate of the Fuel: m** = $1.666 \times 10^{-6} \times 780 = 1.3 \times 10^{-3}$….Kg/s

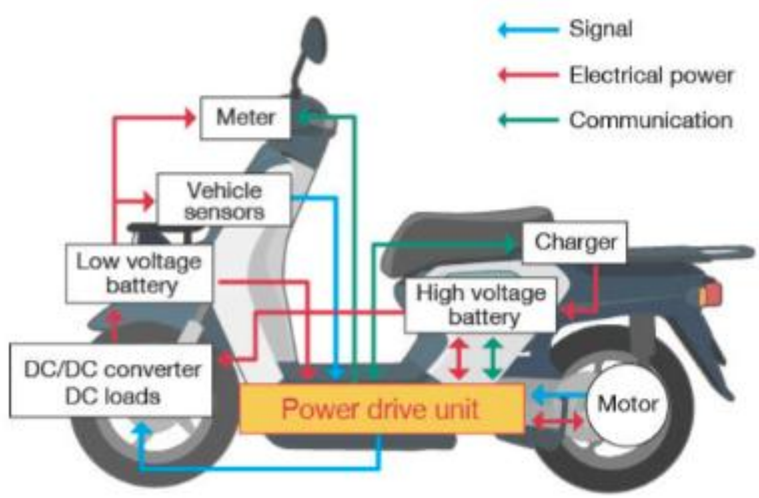
$$\eta_{Bth} = \left(\frac{17.95}{43900 \text{x} 1.3 \text{x} 10^{-3}}100\right) = 31.45\%$$

$$\eta_{Ith} = \left(\frac{IP}{C_V.m}100\right)\%$$

$$\eta_{Ith} = \left(\frac{24.5}{43900 \text{x} 1.3 \text{x} 10^{-3}}100\right) = \mathbf{42.92}\%$$

## ELECTRIC AND HYBRID VEHICLES:

Electric Vehicles (EVs) are vehicles that are either partially or fully powered on electric power. Hybrid electric vehicles (HEVs) are powered by an internal combustion engine in combination with one or more electric motors that use energy stored in batteries. A hybrid vehicle combines any two power (energy) sources. Typically, one energy source is storage, and the other is conversion of a fuel to energy. The combination of two power sources may support two separate propulsion systems.




The main difference between hybrid vehicles and an electric vehicle is that the hybrid combines an internal combustion engine and electric motor(s) to send power to its wheels while the electric vehicles draws power from a single source of the electric motor(s) to propel the vehicle

## Advantages & Disadvantages of Electric Vehicles:

Electric vehicles have low running costs as they have less moving parts for maintaining and also very environmentally friendly as they use little or no fossil fuels & do not emit pollutants. Electric vehicles help drivers save more money than hybrid vehicles. Lower maintenance due to an efficient electric motor & better performance.

The main disadvantages of electric vehicles are it includes risks of fire, and that EVs are not safe. There is the case of too much high-tech wizardry, charger compatibility, vehicle costs, and financing of charging stations. Electric cars can be expensive to buy. There aren't enough charging points.

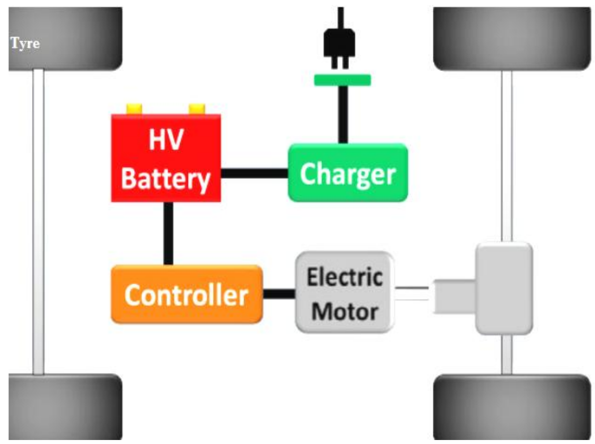
### Advantages & Disadvantages of Hybrid Vehicles:

Hybrid electric vehicles (HEVs) combine the benefits of high fuel economy. Comparatively it uses less fossil fuel and reduced $CO_2$ emission than traditional gas or diesel-engine vehicles. They are eco-friendly, have more financial benefits and higher resale value, are more lightly manufactured, and charge themselves through regenerative braking.

The major disadvantages are acceleration in hybrid vehicles is generally very poor, even if they are capable of a reasonable top speed, the batteries degenerate faster than one used in electric vehicles resulting in replacement of batteries much earlier stage, higher Maintenance costs.

## Components of Electric Vehicles:

The major components of an electric vehicle consist of

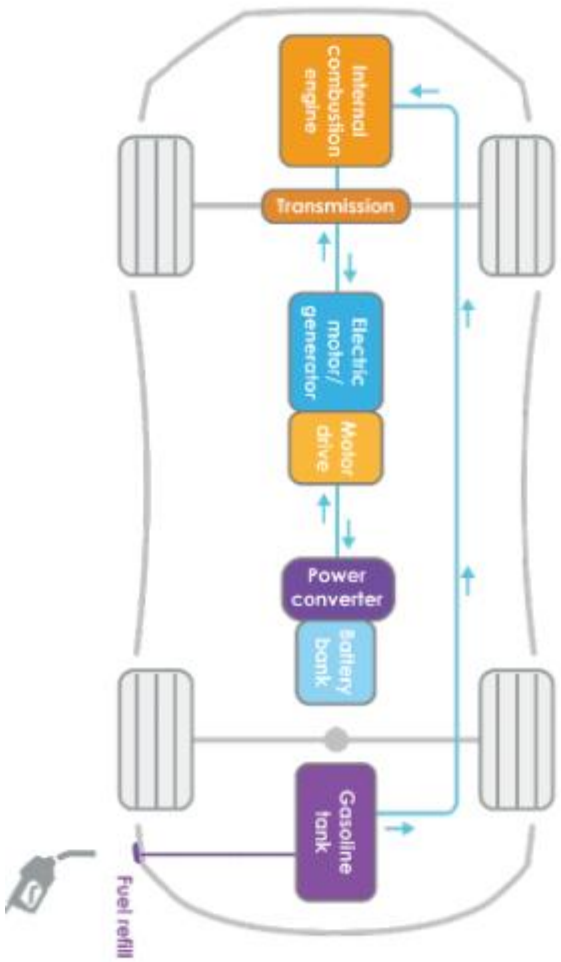



**Electric motor:** The motor converts electric energy into kinetic energy that moves the wheels of the vehicle. It reduces the noise and the vibration as well as a lot of space occupied by the conventional engine system to drive the crank shaft.In most of the vehicles the motor will act as a generator to produce electrical energy when the vehicle is in neutral gear which can be used to charge the battery.

**Controller:** It controls the flow of the electric power in the vehicle. It consists of the inverter, low voltage DC converter, Vehicle Control Unit (VCU) and reducer. The inverter converts the battery's DC into AC, which then is used to operate the motor. The device is also responsible for executing acceleration and deceleration, the low voltage DC converts the high voltage electricity from the EV's high-voltage battery into low-voltage(12V) and supplies it to the vehicle's various electronic systems. The VCU is arguably the most important component. It oversees nearly all the vehicle's power control mechanisms, including the motor control, regenerative braking control, A/C load management, and power supply for the electronic systems. The reducer reduces the speed of the motor to match the required speed of the vehicle.

**Battery:** The battery stores electrical energy and is the equivalent of a fuel tank in an internal combustion engine. The maximum driving distance of an EV is often determined by the battery capacity-the higher the capacity, the higher the driving distance.

**Charger:** It supplies the electric current required for charging the battery. It consists of converter to convert AC to DC for charging the battery in the house hold premises. In case of the charging stations it supplies direct DC for fast charging of the batteries.




## Components of Hybrid Vehicles:

A hybrid electric vehicle uses an electric motor/generator along with an internal combustion engine-offering high fuel economy. A hybrid vehicle combines any two power (energy) sources. Typically, one energy source is storage, and the other is conversion of a fuel to energy. These two power sources may be paired in series, meaning that the fuel engine charges the batteries of an electric motor that powers the vehicle, or in parallel, with both mechanisms driving the vehicle directly.

It consists of an IC engine, electric generator, control module, electric motor, controller, battery.

**IC Engine:** In most of the hybrid vehicles, IC engine acts as the main source of power. The parts of an IC engine are similar to that of the conventional IC engine.

**Electric Generator:** The function of an electric generator is to produce electricity when driven by an external power source (IC engine). It depends on the type of mode followed i.e., series, parallel or both.

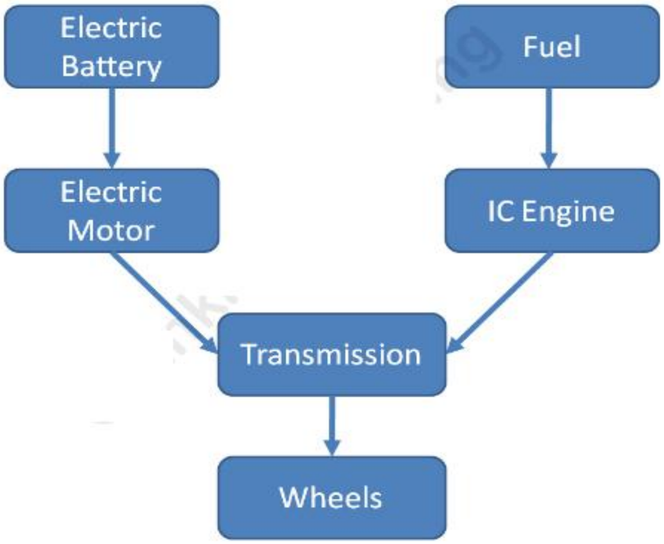
**Control Module:** It is the most important component of the hybrid vehicle. It controls the entire operation of the vehicle by synchronizing all the power sources employed.

The functions of rest of the components are similar as mentioned in the above topic of electric vehicles

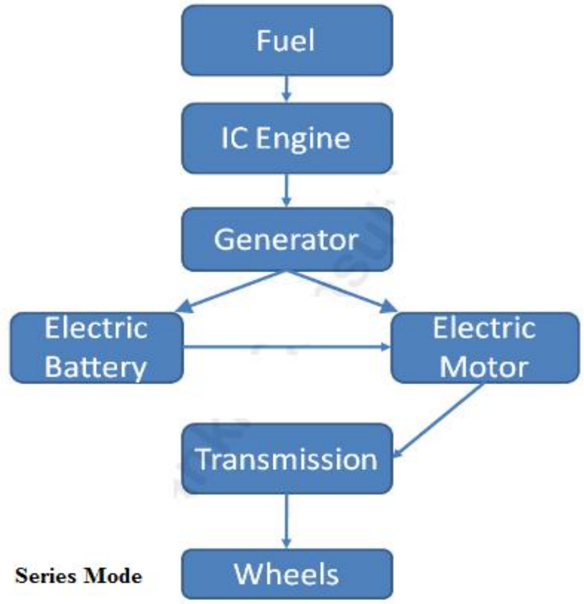
## Drives and Transmission in Hybrid Vehicles:

In electric vehicles the wheels are operated directly through the electric motor as explained in the above diagram of electric vehicle while in hybrid vehicles there are three possible modes of drive and transmission system such as parallel hybrid mode, series hybrid mode or combination of both.

In case of parallel mode, wheels get power from both the IC engine and an electric motor. However, the IC engine serves as the main source of power. As electric battery's role is only to support the engine, these vehicles need a smaller capacity battery. A parallel hybrid mode is more effective in high-speed driving.

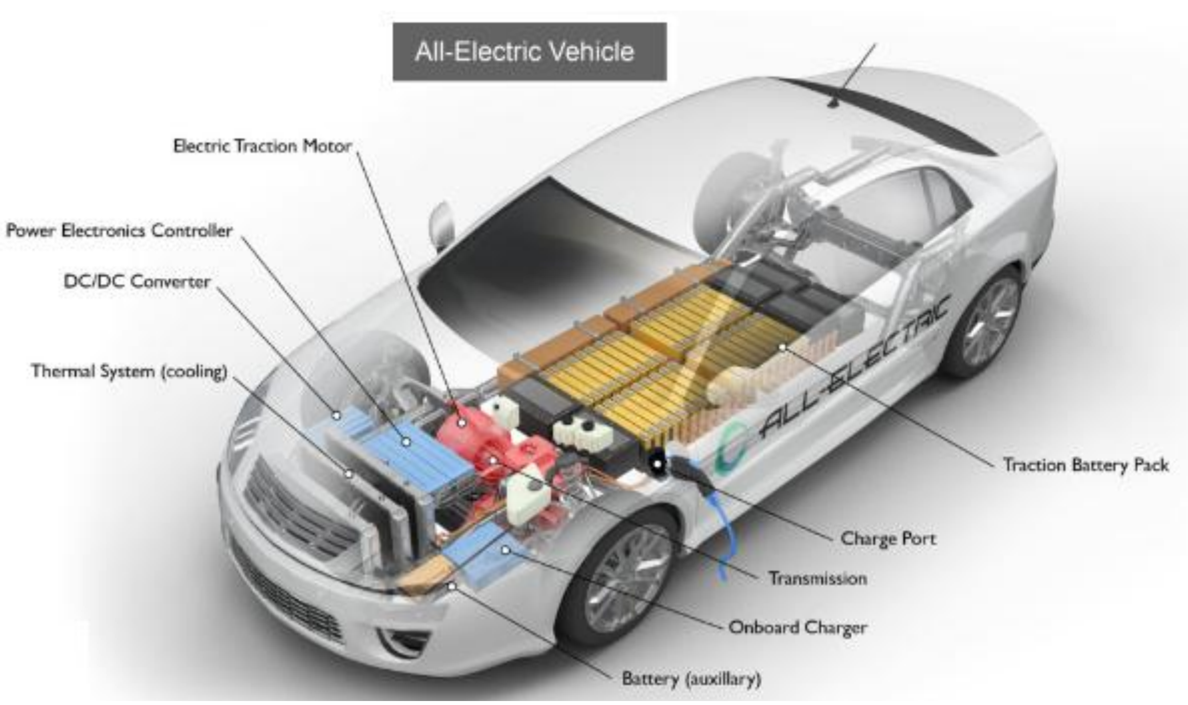


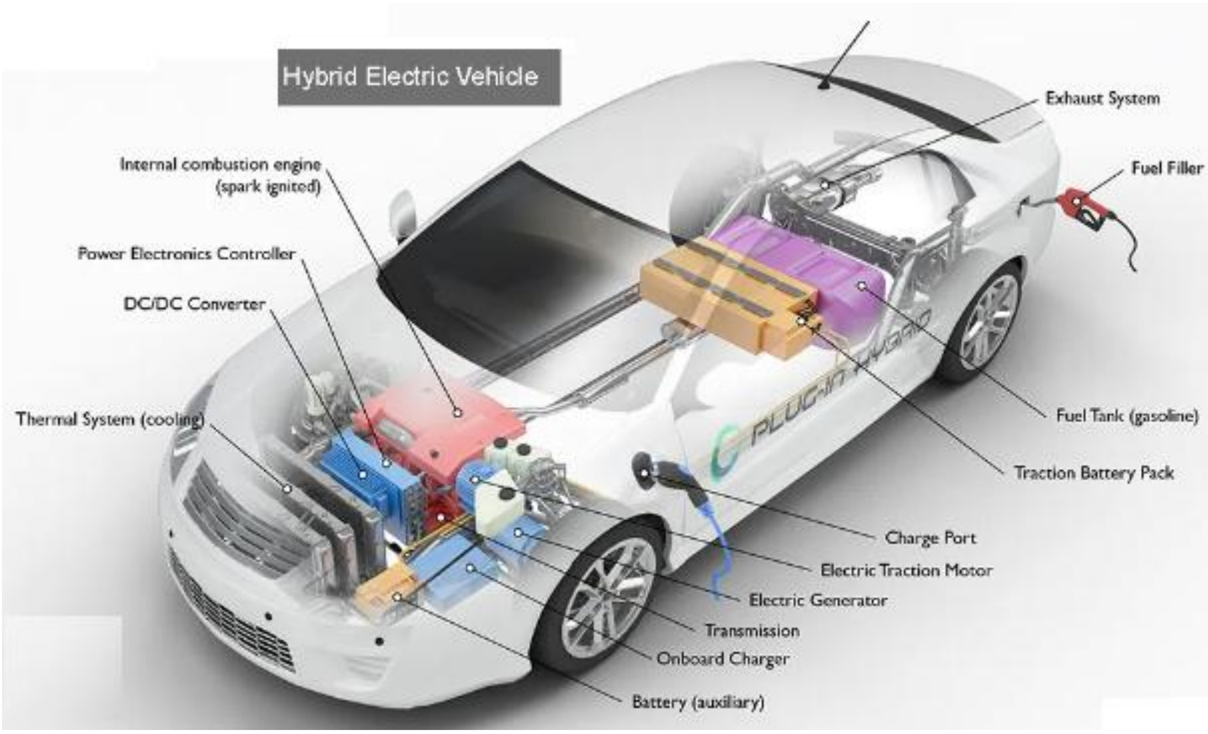

Parallel Mode




Series Mode

In series hybrid mode, wheels are powered only by an Electric motor which ultimately derives its power from the electric battery. The IC engine installed in the vehicle does not supply power to wheels directly. So, these vehicles need large capacity batteries. The series hybrid vehicle is more efficient in low-speed driving involving frequent start-stop.




Hybrid Electric Vehicle
Internal combustion engine (spark ignited)
Power Electronics Controller
DC/DC Converter
Thermal System (cooling)
Exhaust System
Fuel Filler
Fuel Tank (gasoline)
Traction Battery Pack
Charge Port
Electric Traction Motor
Electric Generator
Transmission
Onboard Charger
Battery (auxiliary)
PLUG-IN HYBRID

**GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN**

**Department of Mechanical Engineering**

**Near Dairy Circle, Hosur Road, Bengaluru , Karnataka 560029**

# INTRODUCTION TO MECHANICAL ENGINEERING

# (BESCK104D/204D)

As per New Syllabus Prescribed by V.T.U. (CBCS System)

**For**

**FIRST / SECOND SEMESTER**

**(Bachelor of Engineering)**

## MODULE-04

**Engineering Materials & Joining Processes**

**Dr.NAVEED** M.Tech., PhD.
**Assistant Professor**
**Department of Mechanical Engineering**

## MODULE-04 ENGINEERING MATERIALS & JOINING PROCESSES

*Syllabus:*

**Engineering Materials:** Types and applications of Ferrous & Nonferrous Metals, silica, ceramics, glass, graphite, diamond and polymer. Shape Memory Alloys. **Joining Processes**: Soldering, Brazing and Welding, Definitions, classification of welding process, Arc welding, Gas welding and types of flames.

### 4.1 ENGINEERING MATERIALS

Materials which are used in the engineering practice are called engineering materials. These have physical, mechanical and chemical properties. Engineering materials can be broadly classified into metals & non-metals, while metals are further sub-classified as ferrous and non-ferrous metals as discussed in table 4.1 and shown in figure 4.1

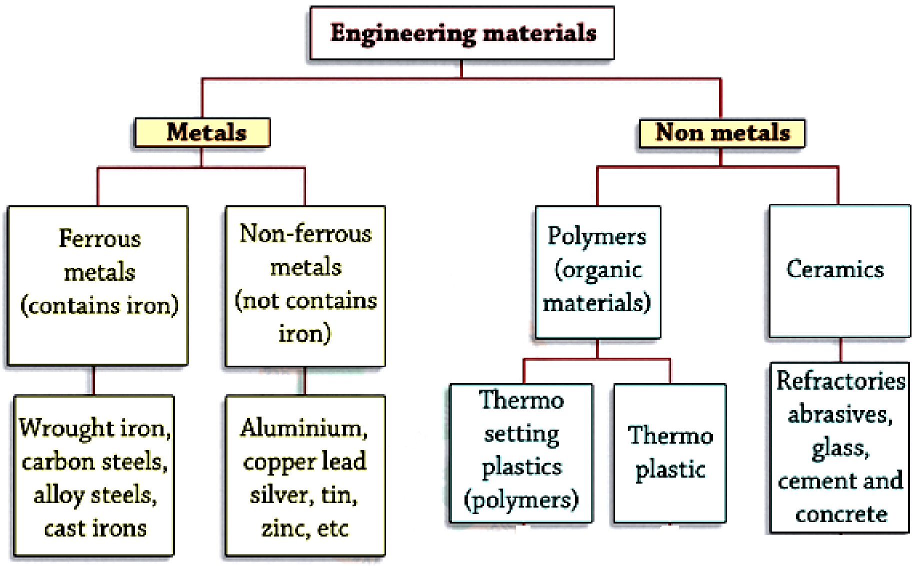



**Fig.4.1 Classification of engineering materials.**

**Table 4.1: Classification of engineering materials.**

| Engineering materials | Description |
|---|---|
| Metals | Metals are materials which are in solid form at room temperature except mercury which is in liquid form. They are opaque and good conductors of heat and electricity. They also possess high density, high melting temperature and most of them are elastic up to a limit. A metal can also exist in liquid and gaseous forms. |
| Non Metals | All materials which are not metals belong to this category. These may be in the form of liquids, gases or solids such as Wood, Stone, Rubber, Plastic, Ceramic, Concrete, Asbestos etc. |
| Ferrous Metals | Metals containing iron, such as pig Iron, wrought Iron, Cast Iron, Steel, Carbon Steel, nickel steel etc, are called Ferrous metals, these can be attracted by magnets and are susceptible to rusting. They are very widely used in engineering. |
| Non-Ferrous Metals | Metals like gold, silver, Copper, Aluminium, Tin, Platinum, Zinc, Manganese, Nickle, Antimony etc. which do not contain iron are non-Ferrous metals. These can neither rust nor can be attracted by magnets. |

Some of the basic types of ferrous materials are discussed in table 4.2 with their applications

**Table 4.2: Basic types of ferrous materials.**

| Ferrous materials | Description | Applications |
|---|---|---|
| Pig Iron | The metallic product coming out of blast furnace is known as pig iron. | For making wrought iron, cast iron, steel. |
| Wrought Iron (Pure Iron) | 99.8% Pure iron, 0.01 - 0.02% carbon with traces of phosphorus, sulphur, Silicon and Slag left behind is known as wrought iron. | For making steam & water pipes, engine bolts, rivets, chain links, crane hooks etc. |
| Cast Iron | Remelting of pig iron and refining it gives cast iron. In grey cast iron carbon is present in the form of graphite flakes, in white cast iron in the form of iron carbides, while in the form of nodules in nodular cast iron. The heat treatment of white cast iron for about $900^0$C for several days gives malleable cast iron. Products of cast iron obtained from chilling process(rapid cooling) gives chilled cast iron. | For making machine frames, columns, beds, plates flywheels, engine block, cylinder head etc., |
| Steel | It contains various alloying elements to enhance its properties. In addition to carbon it contains silicon, sulphur, manganese, phosphorous, nickel , chromium, tungsten . Steel with all these alloying elements is known as alloy steel, while ***tool steels*** exhibit good wear & abrasion resistance & can withstand hardness at elevated temperatures. ***Stainless steel*** is a type of steel with very good corrosive wear resistance unlike the ordinary steel. | Low carbon steel is used for making shafts, camshafts, gears and axles. Medium carbon steel is used for making connecting rods, couplings, spindles etc. High carbon steel is used for making hammers, chisels, knives, punches drills etc. |

Some of the basic types of non-ferrous materials are discussed in table 4.3 with their applications.

**Table 4.3: Non-ferrous materials with their chemical composition and applications**

| Non-ferrous materials | Description | Applications |
|---|---|---|
| Brass | Brass is an alloy of copper (Cu) and zinc (Zn). Brass has excellent resistance to seawater corrosion and is easy to machine and form. Brass is an excellent choice for components in which corrosion-resistance is important. | For making ornaments, electrical fittings, gears, pinions and other moving parts of a clock etc., |
| Bronze | Bronze is an alloy of copper and tin. It is highly corrosion-resistant because of its ability to with stand water and conducts heat and electricity, better than most steels | For making marine fittings, pumps, valves, bearings etc., |
| Aluminium | Aluminium is the most abundant metal on earth however, it doesn't come in its pure form. It has to be extracted from its ore, called bauxite. Aluminium is a silvery-white, light, strong, flexible, non-corrosive and infinitely recyclable metal. | For making bumpers, car body, connecting rod, golf clubs, tennis racket, aircraft structures, connecting rod of aero engines, .etc., It is used in the packaging foils, cans, frames, etc. due to its non-adsorbing and non-toxic nature. It is used in household items ranging from furniture to utensils. |

**4.2 NON METALS:** Non metals are generally those materials which lack the characteristics of metals. Commonly used nonmetals are polymers and ceramics.

**4.3 POLYMERS:** A polymer is a large molecule composed of many repeated subunits called monomers. They are prepared by polymerization reactions, in which simple molecules are chemically combined into a long chain molecules or three-dimensional structures. They have low specific gravity and good strength. Plastics & synthetic rubbers are termed as organic polymers. There are two important classes of organic polymers such as thermoplastics & thermosetting plastics. Brief description of thermoplastics & thermosetting plastics is highlighted in table 4.4

**Table: 4.4 Thermoplastics & thermosetting plastics**

| Thermoplastics | Thermosetting plastics |
|---|---|
| These are polymers which get soften on heating & get hardened on cooling and vice-versa. Hence it can be reshaped & reused. | These are polymers which get soften on heating & get hardened on cooling. But once it is hardened it will be permanently molded & cannot be soften on cooling. Hence it cannot be reshaped & reused. |
| Exmples: Nylon, polythene, Polyvinyl chloride(PVC) etc | Examples: Polyesters, urea formaldehyde , epoxy resin etc., |
| It consist of linear long chain polymers | It consist of three dimensional network structure |
| Theses have weak intermolecular forces between polymer chains | Theses have strong covalent bonds between polymer chains |
| It is synthesized by addition polymerization. | It is synthesized by condensation polymerization. |
| These have low molecular weight | These have high molecular weight |
| These have low melting point, low tensile strength, stiffness, brittleness, rigidity and durability. | These have high melting point, high tensile strength, stiffness, brittleness, rigidity and durability. |
| These are soluble in organic solvents | These are insoluble in organic solvents |
| They can be reclaimed from wastes | They cannot be reclaimed from wastes |


**Silica:** Silica, also called silicon dioxide($SiO_2$), is a compound of the two most abundant elements in Earth's crust such as silicon and oxygen. It is divided into two main groups, crystalline silica and amorphous silica (non-crystalline silica). The most common type of crystalline silica is quartz. Other types also exist, but they are less common. Silica compounds are found throughout the environment in rocks, sand, clay, soil, air, and water. Since sand is plentiful, easy to mine and relatively easy to process, it is the primary source of silicon.

Applications: About 95% of the commercial use of silicon dioxide (sand) occurs in the construction industry, e.g. for the production of concrete (Portland cement concrete). Certain deposits of silica sand, with desirable particle size and shape and desirable clay and other mineral content, were important for sand casting of metallic products. The high melting point of silica enables it to be used in such applications such as iron casting. Silica is the primary ingredient in the production of most glass. The majority of optical fibers for telecommunication are also made from silica. It is a primary raw material for many ceramics such as earthenware, stoneware and porcelain. Silicon dioxide is widely used in the semiconductor technology.

**4.4 CERAMICS:** Ceramics are inorganic, nonmetallic materials that are essential in our daily lifestyle. They are usually made by taking mixtures of clay, earthen elements, water and shaping them to desired forms. Once they are shaped, they are fired to high temperature inside an oven. In general, they are hard, corrosion-resistant and brittle. Ceramics can withstand high temperatures, are good thermal insulators, and do not expand greatly when heated. This makes them excellent thermal barriers, for applications that range from lining industrial furnaces to covering the space shuttle to protect it from high temperatures.They are often covered with decorative, water proof paint like material called glazes.

Applications: They are widely used as high voltage insulators, high temperature resistant cutting tool tips, dies, engine parts etc., Examples: silicon dioxide, aluminium oxide, zirconium oxide etc.,

**4.5 Glass:** It is a non-crystalline, amorphous solid that is often transparent and has widespread practical, technological and decorative applications. It is made from natural and abundant raw materials such as sand, soda ash, and limestones which are melted at very high temperature to form a new material called glass. At high temperature it behaves like liquid while at ambient temperature it behaves like solids. As a result of this it can be molded to any given shape.

Applications: Packaging such as jars, bottles. Tableware such as drinking glasses, plate, cups, bowls etc., Housing & buildings such as windows, doors and panels. Interior design and furniture, Electronic appliances, automotive & transport industries etc.,

**4.6 Graphite:** Graphite is a **non-metal** but has many properties of metals. It is an excellent conductor of heat and electricity and has the highest natural strength and stiffness of any material. Graphite is a crystalline form of the element carbon. It consists of stacked layers of graphene. Graphite occurs naturally and is the most stable form of carbon under standard conditions. Graphite can be divided into two main types—natural and synthetic. Natural graphite is a mineral composed of graphitic carbon. Natural graphite is an excellent conductor of heat and electricity, stable over a broad range of temperatures, and a highly refractory material with a high melting point of 3650 °C. Synthetic graphite can be produced from coke and pitch. Essentially, synthetic graphite has higher electrical resistance and porosity, and lower density.

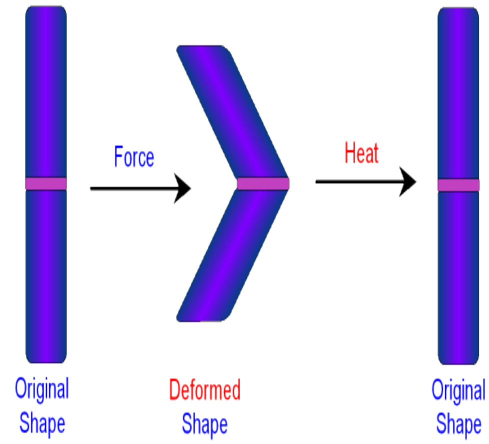
Applications: Graphite is used to produce crucibles, ladles, and molds for holding molten metals. Large amounts of high-purity electrographite are used for producing moderator rods and reflector components in nuclear reactors. Graphite is widely used as an engineering material across a variety of applications such as piston rings, thrust bearings, journal bearings, and vanes.

Graphite specimen

**4.7 Diamond:** Diamond is a mineral composed of pure carbon. It is the hardest naturally occurring substance known; it is also the most popular gemstone. The hardness of diamond is due to its tightly packed atomic structure. Diamond composed of carbon atoms that linked together in a strong, three-dimensional network. This network makes diamond very resistant to scratching and breaking. Diamond has the highest hardness and thermal conductivity of any natural material.

Applications: Because of their extreme hardness, diamonds have a number of important industrial applications.The most familiar uses of diamonds today are as gemstones used for adornment, and as industrial abrasives for cutting hard materials. Diamond can be used to polish, cut, or wear away any material, including other diamonds. Common industrial applications of this property include diamond-tipped drill bits and saws, and the use of diamond powder as an abrasive. The markets for gem-grade and industrial-grade diamonds value diamonds differently.

**4.8 Shape Memory Alloys:** Shape Memory Alloys (SMAs) are those smart materials that can be deformed at low temperature and recover their original shape upon heating. It is also defined as an alloy that can be deformed when cold but returns to its pre-deformed ("remembered") shape when heated. They have the ability to change its phase as a function of temperature. The two most prevalent shape-memory alloys are copper-aluminium-nickel (Cu-Al-Ni), and nickel-titanium (NiTi) alloys but SMAs can also be made by alloying zinc, copper, gold and iron. The special property that allows shape-memory alloys to revert to their original shape after heating is that their crystal transformation is fully reversible which is not seen in other materials. Shape-memory alloys are typically made by casting, using vacuum arc melting or induction melting.




Applications:SMAs are being explored as vibration dampers for launch vehicles and commercial jet engines. SMAs also exhibit potential for other high shock applications such as ball bearings and aircraft landing gears.

## 4.9. SOLDERING, BRAZING AND WELDING:

**Introduction:** There are various processes by which two or more parts can be joined together. The joints obtained by joining processes may be temporary or permanent. Among all the various joining processes, welding, brazing and soldering are different from the others in the sense that, in these processes, the parts are joined by the application of heat.

**4.10 Soldering:** Soldering is a method of joining similar or dissimilar metals by means of a filler metal whose melting temperature is below 450$^{o}$C. The filler metal usually called, solder is an alloy of tin and lead in various proportions.

## 4.11 Construction & operating principle of soldering iron method

It is the common and widely used method of soldering. The construction details & operating principle of soldering iron method is discussed in table 4.5 and shown in fig 4.2.

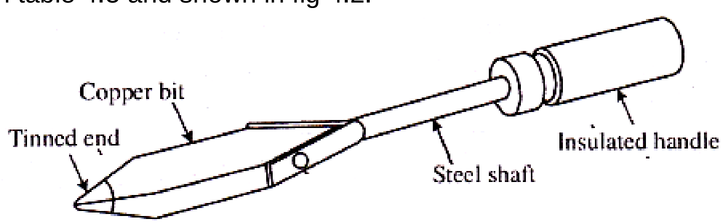



**Fig. 4.2 Soldering iron method.**

**Table 4.5: Construction & operating principle of soldering iron method.**

| Construction details | Description |
|---|---|
| Tinned end | It is the tip of the copper bit. It receives & stores heat from the copper bit. It conducts heat from the copper bit to the components being joined. |
| Copper bit | It is heated electrically or by oil or gas flame & supplies heat energy to the tinned end. |
| Steel shaft | It is connected to the copper bit through rivets & provides support to the copper bit. |
| Insulated handle | It is gripped by the operator & helps the operator to carry on soldering. |
| Flux material | The function of the flux is to wet the surface of the workpiece and to permit the molten solder to flow easily into the joint. It also prevents oxides from separating the solder from the surface. Zinc chloride & hydrochloric acid are some of the fluxes used in soldering. |
| In operation, the surface of the parts to be joined are first cleaned in order to remove dirt, grease and other oxides which is followed by application of 'flux' at the edges of the parts to be joined. The solder is heated by an electric source, usually a soldering iron and the molten solder is deposited at the joint. The solder is allowed to cool for some time and then the soldered joint is cleaned to remove any flux residues in order to avoid corrosion. | |

**4.12 BRAZING:** Brazing is a method of joining similar or dissimilar metals by means of a filler metal whose melting temperature is above 450$^0$C but below the melting point of the base metal. The filler metal used is called 'spelter'**-** a non-ferrous metal or alloy. Usually copper and copper alloys, silver and silver alloys and aluminum alloys are most commonly used spelters. Further the use of flux increases both the flow of filler metal and its ability to stick to the base metal. It also prevents the formation of oxides that are formed during the process. Borax, boric acid, fluorides or chlorides are the commonly used flux materials.

### 4.13 Construction & operating principle of torch brazing

The construction details & operating principle of torch brazing is discussed in table 4.6 and shown in fig 4.3

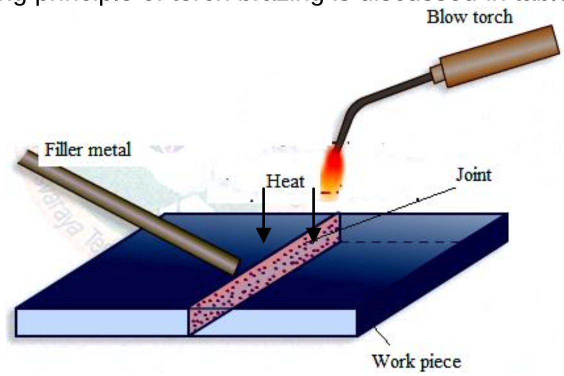



**Fig. 4.3 Torch brazing**

**Table 4.6: Construction & operating principle of torch brazing**

| Construction details | Description |
|---|---|
| Blow torch | It provides source of heat energy for carrying out brazing operation. It is operated through oxy-acetylene gas cylinders. It provides carburizing flame with excess acetylene for heating the components to be joined. |
| Filler metal | It is similar in chemical composition to that of the components to be joined. It is an additional material which provides sufficient molten metal to obtain the joint. |
| Flux material | The function of the flux is to wet the surface of the workpiece and to permit the molten solder to flow easily into the joint. It also prevents oxides from separating the solder from the surface. Zinc chloride & hydrochloric acid are some of the fluxes used. |
| In operation, the surface of the parts to be joined are first cleaned in order to remove dirt, grease and other oxides which is followed by application of 'flux' at the edges of the parts to be joined. The base metals are heated by an oxy-acetylene welding torch. The filler metal is then placed at the joint & is heated with a carburizing flame, which makes it to melt. The molten metal fills the joint by capillary action, forming a strong metallurgical bond between the two base metals | |

**4.14 WELDING:** Welding is a metallurgical process in which the parts to be joined are heated to a suitable temperature and then fused together either with or without the application of pressure. Since a slight gap usually exists between the work pieces, a 'filler metal' can be used to supply additional material to fill the gap.

### 4.15 METHODS OF WELDING

There are two methods of welding: Plastic welding & fusion welding as discussed in table 4.7

**Table 4.7: Comparison of plastic welding & fusion welding**

| Plastic welding / Pressure welding | Fusion welding |
|---|---|
| The metal parts to be joined are heated to the plastic state then fused together by applying external pressure without the use of filler metal. Example: Forge welding, Resistance welding etc. | In fusion welding process, the parts to be joined are heated above their melting temperature and then allowed to solidify by cooling. Example: Arc welding and Gas welding. |
| It requires heat & pressure | It requires only heat |
| Joint area is heated to plastic state | Joint area is heated to molten state |
| Requires lower temperature | Requires higher temperature |
| Composition is not much affected | Composition & structure are affected |
| No need of filer material | It requires filler material. |

## 4.16 CONSTRUCTION & OPERATING PRINCIPLE OF ARC WELDING

Arc welding process is fusion method of welding that utilizes the high intensity of the arc generated by the flow of current to melt the workpieces. The construction details & operating principle of arc welding is discussed in table 4.8 and shown in fig 4.4

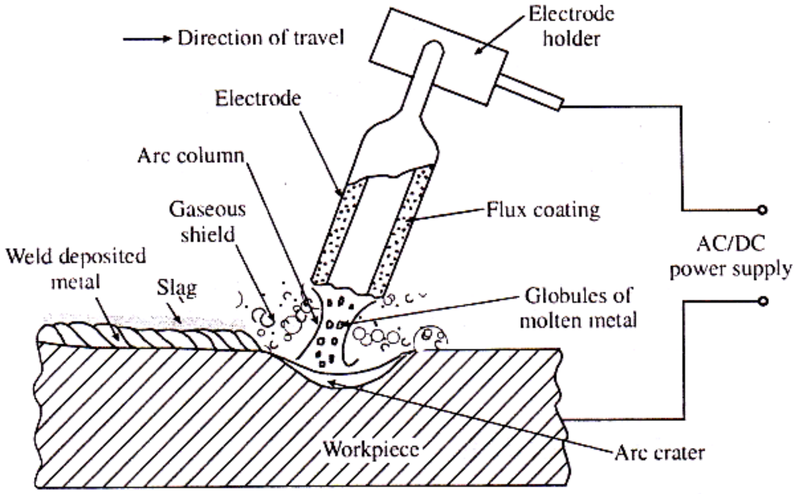



**Fig 4.4: Arc welding**

**Table 4.8 Construction & operating principle of arc welding**

| Construction details | Description |
|---|---|
| Electrode holder | It provides source of heat energy for carrying out welding operation. It is connected to either AC or DC transformer and helps in transferring electric current to the electrode which is connected to it. |
| Electrode | It is similar in chemical composition to that of the components to be joined. It is an additional material which provides sufficient molten metal to obtain the joint. One of its end is left uncoated with flux material & it connected to the electrode holder for passage of electric current. An electric circuit is formed between the electrode & workpiece to generate heat energy for welding. It can be consumable electrode or non-consumable electrode. In case of non-consumable electrode a separate filler material is used. |
| Flux material | The function of the flux is to provide a safer zone for welding operation. It removes impurities from the workpiece material in the form of slag. |
| In operation, an electric arc is produced by striking the electrode on the work piece. The electrode is momentarily separated from the work piece by a small gap such that the arc is still maintained between the workpiece and the electrode. The electrical energy is thus converted into heat energy & results in molten pool of electrode & the joint surface of the base metals. The tip of the electrode melts and combines with the molten metal of the workpiece thereby forming a homogenous joint as shown in the fig. Arc welding process is used for fabrication work, repair and maintenance work. Examples: Boiler and Pressure vessel fabrication, Ship building, Joining of large pipes and penstock, Building and Bridge constructions, Automotive and Aircraft industries etc. | |

## 4.17 Construction & operating principle of oxy-acetylene welding

In oxy-acetylene welding, mixture of oxygen and acetylene are most commonly used to produce a continuous flame for welding. The construction details & operating principle of gas welding is discussed in table 4.9 and shown in fig 4.5

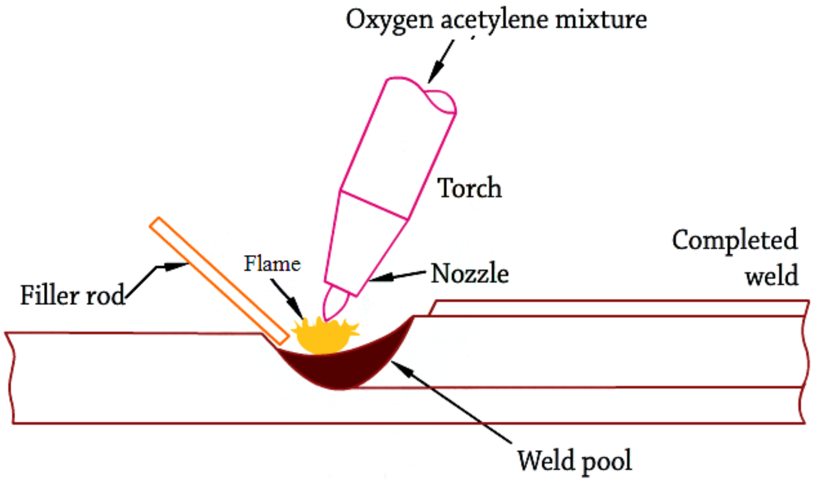



**Fig 4.5: Oxy-acetylene gas welding**

**Table 4.9: Construction & operating principle of oxy-acetylene gas welding**

| Construction details | Description |
|---|---|
| Two large cylinders | One cylinder contains oxygen at high pressure and the other contains acetylene gas. Different types of flames are obtained by adjusting the ratio of oxygen & acetylene gases. |
| Pressure regulators | These are used to control the pressure of the oxy-acetylene gas as per requirements. |
| Welding torch | It is used to mix both oxygen and acetylene gases in proper proportions and to burn the mixture at the tip. |
| In operation, the pressure regulator is adjusted to obtain suitable proportions of oxygen and acetylene gases entering into the welding torch. The temperature of the flame at the tip of the torch will be in the range of 3200$^0$C which is sufficient enough to melt the workpiece metal. Since a slight gap usually exists between the workpiece, a filler metal can be used to supply additional material so as to fill the gap & to obtain a strong weld joint. | |

## 4.18 Types of flames produced in gas welding

The construction details different types of gases produced in oxy-acetylene gas welding with their temperature is discussed in table 4.10 and shown in fig 4.6

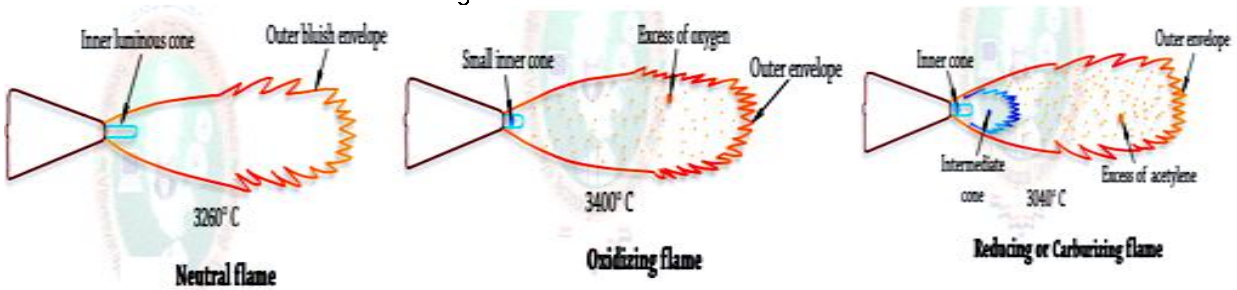



**Fig 4.6: Flames produced in oxy-acetylene gas welding.**

**Table 4.10: Flames produced in oxy-acetylene gas welding.**

| Flames | Description |
|---|---|
| Neutral flame | In this oxygen and acetylene are mixed in equal proportions & is characterized with inner whitish cone surrounded by a sharp blue flame. The temperature of the neutral flame is around 3260$^0$C. |
| Oxidizing flame | It has excess of oxygen & is characterized with a shorter inner white cone surrounded by narrow brightest flame. The temperature of the oxidizing flame is around 3400$^0$C. |
| Reducing or carburizing flame | It has excess of acetylene. In this the outer flame envelope is longer than that of the neutral flame and is usually much brighter in colour. The temperature of the reducing or carburizing flame is around 3040$^0$C |

### 4.19 Comparison of joining processes

Some comparisons of the joining processes are discussed in table 4.11

**Table 4.11: Comparison of joining processes**

| Parameters | Welding | Soldering | Brazing |
| --- | --- | --- | --- |
| Heating temperature | Base metals are heated above their melting point. | They are heated below their melting point. | They are also heated below their melting point. |
| Filler material | It is made up of same material as that of the base metals | It is not as same as that of the base metals | It is not as same as that of the base metals |
| Joint formation | It is formed by solidification of both molten filler metal and base metal. | It is obtained by diffusion of filler metal into the base metal. | It is obtained by diffusion of filler metal into the base metal. |
| Strength of the joint | It is much stronger than the base metal due to modification in grain structure. | It is weaker than that of brazing & welding. | It is stronger than soldering but weaker than welding. |
| Heat affected zone | It is affected to larger extent | It is almost negligible. | It is affected but not to the level of welding. |
| Finishing operations | It requires certain finishing operations like grinding, filing etc., | It doesn’t require & the joint can be used as it is. | In some cases finishing operations are needed. |
| Applications | In fabrication & structural applications | For joining thin sheet metals, pipes, wires, circuit board etc., | In arts, jewelry & also in industries. |

**GHOUSIA INSTITUTE OF TECHNOLOGY FOR WOMEN**

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# INTRODUCTION TO MECHANICAL ENGINEERING

# (BESCK104D/204D)

As per New Syllabus Prescribed by V.T.U. (CBCS System)

**For**

**FIRST / SECOND SEMESTER**

**(Bachelor of Engineering)**

## *MODULE-05*

## INTRODUCTION TO MECHATRONICS, ROBOTICS, AUTOMATION & IoT

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**Department of Mechanical Engineering**

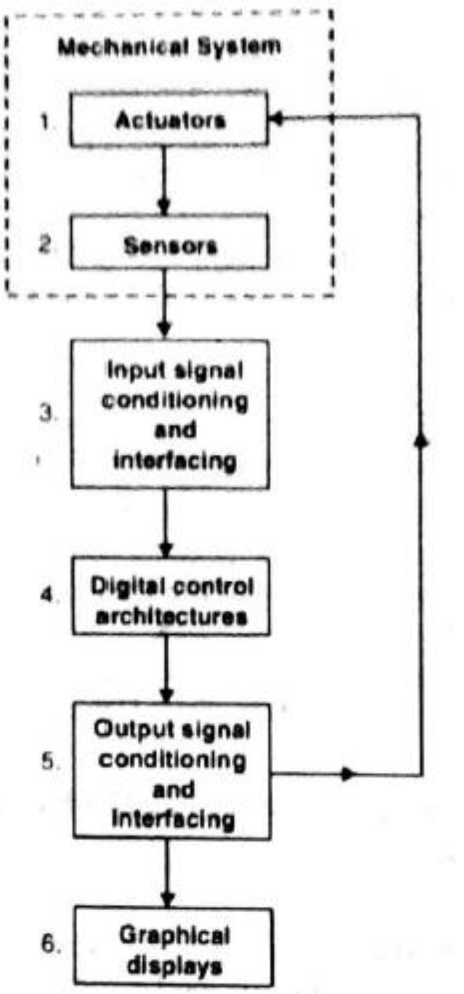
# MODULE-05 MECHATRONICS, ROBOTICS, AUTOMATION & IoT

*Syllabus:*

**Introduction to Mechatronics and Robotics**: open-loop and closed-loop mechatronic systems. Classification based on robotics configuration: polar cylindrical, Cartesian coordinate and spherical. Application, Advantages and disadvantages. **Automation in industry:** Definition, types – Fixed, programmable and flexible automation, basic elements with block diagrams, advantages. **Introduction to IOT:** Definition and Characteristics, Physical design, protocols, Logical design of IoT, Functional blocks, and communication models.

## MECHATRONIC SYSTEMS:

Mechatronics is an interdisciplinary area of engineering that combines mechanical, electrical engineering and computer science. A typical mechatronic system picks up signals from the environment, processes them to generate output signals, transforming them for example into forces, motions and actions. Mechatronics, also called mechatronics engineering, is an interdisciplinary branch of engineering that focuses on the integration of mechanical, electronic and electrical engineering systems. Mechatronics engineering technologists use a combination of mechanical, electrical, computer and software skills to work with smart technologies, such as robots, automated guided systems and computer-integrated manufacturing equipment.




A mechatronic system is composed of mechanical parts, electric devices, electronics components and it is operated and controlled under the supervisions and commands that are programmed through suitable software. The mechatronic components essentially consist of actuators, sensors, input signal conditioning and interfacing unit, digital control architecture, output signal conditioning and interfacing, and displays. The main application of the mechatronic system is to transform output signals which are obtained by processing the input data gathered from the surroundings and then turning them into useful energy, locomotions, and decisions. Examples of mechatronic systems are robots, digitally controlled combustion engines, machine tools with self-adaptive tools, contact-free magnetic bearings, automated guided vehicles, etc.

The various components of mechatronic system are explained in the following chart.

**Actuators:** produce motion or cause some action. Solenoids, voice calls, DC motors, Stepper motor, servomotor, hydraulic, pneumatic.

**Sensors:** detect the state of the system parameters, inputs and outputs. Switches, potentiometer, photoelctrics, digital encoder, strain gauge, thermocouple, accelerometer etc.

**Input/output Signal conditioning and interfacing**: provide connection between the control system circuits and the input/output devices.Discrete circuits, amplifiers, filters, A/D, D/A, power transistor etc.

**Digital devices**: controls the system. Logic circuits, micro controller, SBC, PLC etc.,

**Graphic Display**: provide visual feed back to users. LEDs, Digital Displays, LCD, CRT

**EXAMPLES:**

**1. Home appliances** (e.g. washing machines): Many of the home appliances that are in use today are mechatronic systems. They are manufactured in large numbers en masse and typically require small controllers to be “embedded” within them. An automatic washing machines have integrated sensors, controllers and a programmer to measure the load, fill with water and adjust the temperature. Various programmes are executed to agitate, wash, rinse and spin dry. In some cases they will even use hot air drying. This is a good example of mechatronics.

**2. ABS (anti-lock braking system) and many areas in automotive engineering:** An antilock braking system on a vehicle is a system that prevents the wheels from ceasing up or stopping to rotate when the brakes are suddenly pressed. Another good example of a mechatronic system from automotive engineering is the engine control unit (ECU).

Some other examples include: Elevators and escalators, Mobile robots and manipulator arms, Sorting and packaging systems in production lines, Computer Numerically Control (CNC) production machines, Aeroplanes and helicopters, Tank fluid level and temperature control systems, Temperature control system in an industrial oven etc.,

## Open Loop & Closed Loop Mechatronic Systems:

Mechatronic systems are equiped with control sysyetm to execute the program of instructions. It causes the process to accomplish its defined function, to carry out specific manufacturing operation.There are two types of mechatronic sysytems such as open loop & closed loop mechatronic systems as shown in fig & discussed in table

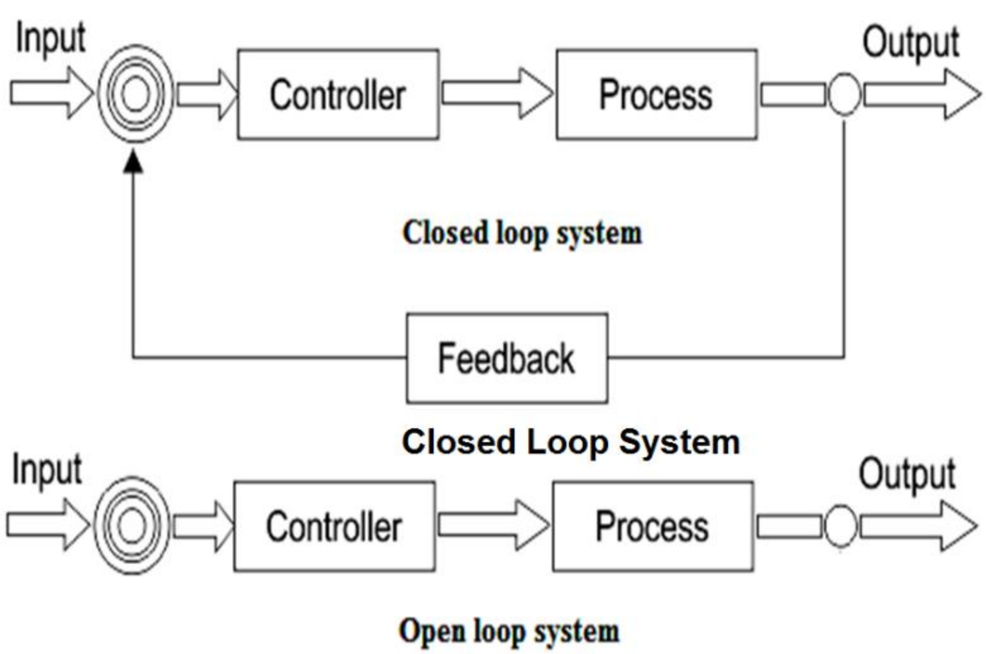



**Fig. Closed loop & open loop mechatronic system**

**Table: Closed loop & open loop mechatronic control system**

| Closed loop system (Feedback system) | Open loop system |
|---|---|
| It compares the output variables with input parameters with the help of feedback system such as sensors. If any difference between the two is found, then it drives the output variables into an agreement with the input parameters. | There is no such feedback system used & there is no comparison of input parameters to the out variables. It basically relies on the efficiency of the controller (such as actuators) |
| These are highly reliable | These are not reliable |
| They are more accurate because of feedback system | If calibrated periodically they are accurate. |
| They can be optimized | They cannot be optimized |
| They are difficult to build & less stable | They are easy to build & generally more stable |

**Robots:** According to the Robotics Industries Association (RIA) an industrial robot may be defined as a multifunctional manipulator designed to move materials, parts, tools, or special devices through variable programmed motion for the performance of a variety of tasks.

**Common Robot Configuration:** Based on robot configuration majority of commercially available industrial robots can be grouped into the four basic types as shown in fig & discussed in table

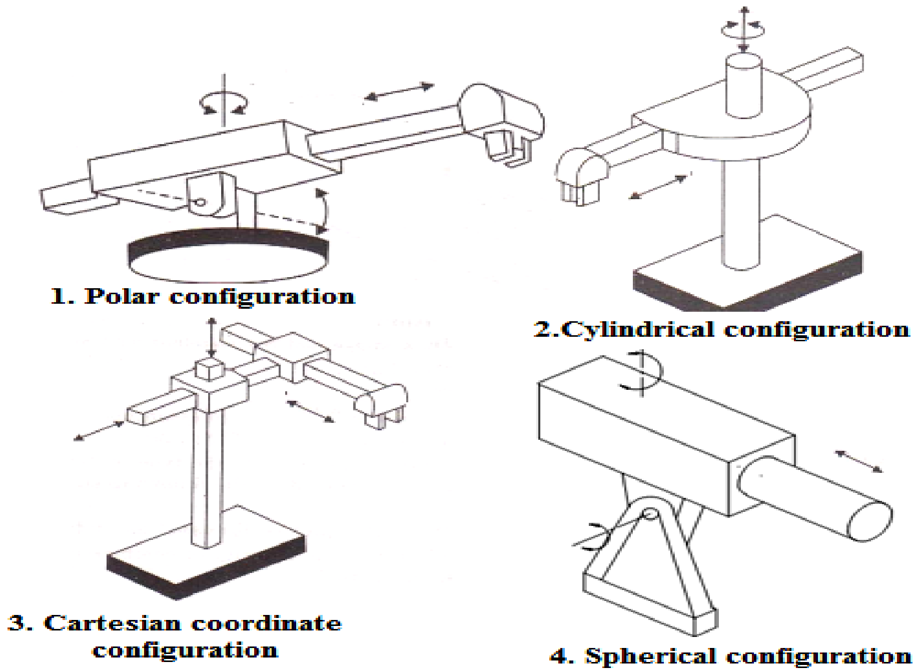



**Fig. Robot configuration**

**Table : Classification of robots**

| Robot Configuration | Description |
|---|---|
| Polar configuration | A robot in this configuration has a telescopic arm which pivots about a horizontal axis and also rotates about a vertical axis in addition to tilting of its body. |
| Cylindrical configuration | A robot in this configuration has a vertical column with the robot arm attached to a side which can move up and down the column. Simultaneously, the arm can move radially with respect to the column. |

| | |
|---|---|
| Cartesian coordinate configuration | It is also known as rectilinear or gentry robot. A robot in this configuration has three mutually perpendicular axes which define a rectangular work volume. |
| Spherical configuration. | A robot in this configuration has uses a telescopic arm that can be raised or lowered about a horizontal pivot point which is mounted on a rotating base and which gives the robot its vertical movement. These various joints provide the robot with the ability to move its arm within a spherical envelope. |

**Table : Advantages & disadvantages of robots**

| Advantages of robots | Disadvantages of robots |
|---|---|
| Lifting and moving heavy objects. | Robots are expensive & cannot be widely implemented in developing countries. The price of a single industrial robot cost about 5000 Dollars. |
| Working in hostile environments. | It eliminates large employment opportunities, thereby resulting in unemployment problems. |
| Providing repeatability and consistency. | It requires skilled programmers & operators to program & operate the robots for different applications. |
| Working during unfavorable hours. | High maintenance & service cost. |
| Performing dull or monotonous jobs. | Lesser mobility. |
| Reduces labor cost, material waste , capital cost & improves product quality | They are computer program dependent. |

**Table: Applications of robots**

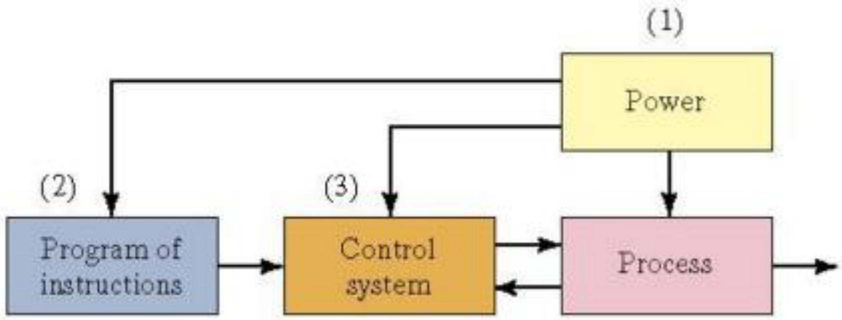
| Parameters | Applications |
|---|---|
| Processing & Assembly operation | In robotic processing operations, the robot manipulates a tool to perform a process on the work part. Examples of such applications include spot welding, continuous arc welding, and spray painting. Spot welding of automobile bodies is one of the most common applications of industrial robots. The robot positions a spot welder against the automobile panels and frames to complete the assembly of the basic car body. Arc welding is a continuous process in which the robot moves the welding rod along the seam to be welded. Spray painting involves the manipulation of a spray-painting gun over the surface of the object to be coated. Other operations in this category include grinding, polishing, and routing, in which a rotating spindle serves as the robots too. In robotic processing operations, they are used for uniting disassembled parts like screwing of studs & screws in threaded holes, inserting of shaft in holes etc., The use of robots in assembly is expected to increase because of the high cost of manual labour common in these operations |
| Material handling & transfer | Material-handling applications include material transfer and machine loading and unloading. Material-transfer applications require the robot to move materials or work parts from one location to another. Many of these tasks are relatively simple, requiring robots to pick up parts from one conveyor and place them on another. Other transfer operations are more complex, such as placing parts onto pallets in an arrangement that must be calculated by the robot. Machine loading |

| | |
|---|---|
| | and unloading operations utilize a robot to load and unload parts at a production machine. This requires the robot to be equipped with a gripper that can grasp parts. |
| Inspection | Inspection is another area of factory operations in which the utilization of robots is growing. In a typical inspection job, the robot positions a sensor with respect to the work part and determines whether the part is consistent with the quality specifications. |

**AUTOMATION:** Automation can be defined as a technology concerned with performing a process by means of programmed commands combined with automatic feedback control to ensure proper execution of the instructions. The resulting system is capable of operating without human intervention. It may also be defined as A technology concerned with the application of mechanical, electrical , electronics and computer based system to execute the process without human interference.

**Basic Elements of Automated System:**

An automated sysytem consist of some of the major elements as shown in the following flow chart.




Power: The principal source of power in automated systems is electricity. Electric power has many advantages in automated as well as non automated processes. Electrical power can be readily converted to alternative energy forms: mechanical, thermal, light, acoustic, hydraulic, and pneumatic. Electrical power at low levels can be used to accomplish functions such as signal transmission, information processing, and data storage and communication. Electrical energy can be stored in long life batteries for use in locations where an external source of electrical power is not conveniently available. Alternative power sources include fossil fuels, solar energy, water, and wind. However, their exclusive use is rare in automated systems. In many cases when alternative power sources are used to drive the process itself, electrical power is used for the controls that automate the operation.

Program of Instructions: The actions performed by an automated process are defined by a program of instructions Whether the manufacturing operation involves low, medium, or high production each part or product style made in the operation requires one or more processing steps that are unique to that style, These processing steps are performed during a work cycle. The particular processing steps for the work cycle are specified in a work cycle program. Work cycle programs are called part programs in numerical control.

Control Systems: The control element of the automated system executes the program of instructions. The control system causes the process to accomplish its defined function. The control system in an automated system can be either closed loop or open loop. A closed loop control system also known as a feedback control system is one in which the output variable is compared with an input parameter and any difference between the two is found , it will be redirected back for modification. While in an open loop control system operates without the feedback loop. In this case, the process is executed without measuring the output variable. So no comparison is made between the actual value of the output and the desired input parameter. The controller completely relies on the actuator.

## Types of Automation:

Automation systems are classed into three different types of automation:

- Fixed automation
- Programmable automation
- Flexible automation

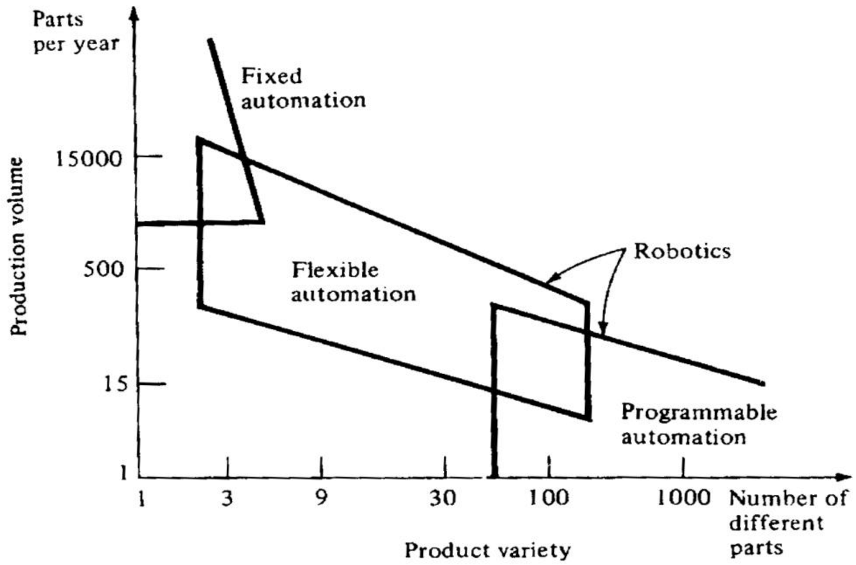
Fixed Automation: Fixed automation is a type of automation where the process of manufacturing stays fixed by the way it is configured, following a fixed sequence of automated processes. An example of this is flow production, where products are continuously being made. This is often also known as “hard automation”. Fixed automation can be expensive to set up initially due to the equipment required, but in return, it provides high production rates. This is relatively useful for many companies who use automation to create food products of one type and variant. It allows them to effectively produce that item and package it in bulk.

Programmable Automation: Programmable automation allows the production equipment and automation to be altered to changing needs. This is done by controlling the automation through a program, which can be coded in certain ways for the automation to change the sequence of automation.

It’s used more commonly in low to medium levels of production, often being most suitable for batch production. Programmable automation will often be used by factories who make different variants of foods. This allows them to make batches, from a few dozen to potentially thousands at a time, of one product. If the product needs changing, it simply needs to be reprogrammed.

Flexible automation: Flexible automation also known as “soft automation”, is an extension of programmable automation. The disadvantage with programmable automation is the time required to reprogram and change over the production equipment for each batch of new product. This is lost production time, which is expensive. In flexible automation, the variety of products is sufficiently limited so that the changeover of the equipment can be done very quickly and automatically. The reprogramming of the equipment in flexible automation is done off-line; that is, the programming is accomplished at a computer terminal without using the production equipment itself. Accordingly, there is no need to group identical products into batches; instead, a mixture of different products can be produced one right after another.

Comparison of the above three is best illustrated by the following fig.




| Automation | Consideration | Advantages | Disadvantages |
|---|---|---|---|
| Fixed / Hard | • High demand volume<br>• Long product life cycle | • Maximum efficiency<br>• Low unit cost<br>• Automated material handling – fast and efficient movement of parts | • Large initial investment<br>• Inflexibility |
| Programmable | • Batch production<br>• Products with different options | • Flexibility to deal with changes in product<br>• Low unit cost for large batches | • New product requires long set-up time<br>• High unit cost relative to fixed automation |
| Flexible/Soft | • Low production rates<br>• Varying demand<br>• Short product life cycle | • Flexibility to deal with design variations<br>• Customized products | • Large initial investment<br>• High unit cost relative to fixed or programmable automation |

**Advantages of automation:**

- Reduced human labour required
- Consistency in quality
- Fewer risks of human error
- Improved health & safety
- Improved efficiency

However, using automation can:

- Be a costly initial investment
- Require some manual labour for observation and programming.
- Failures could lead to temporary downtime in production.

## INTERNET OF THINGS (IoT):

### Definition & Characteristics.

The Internet of Things (IoT) describes the network of physical objects —"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet.
**Examples:** Connected cars, Smart appliances, Connected security systems, Smart agriculture equipment, Connected retail, Connected healthcare monitors, Connected manufacturing equipment, Connected cities, Signal lights etc.,
**Advantages:** saves time, enhanced data collection, improved security etc.
**Disadvantages:** Security issues, privacy concerns, increased unemployment, the complexity of the system, high chances of the entire system getting corrupted etc.

### Characteristics of IoT:

Some of the major characteristics of IoT which are responsible for the increasing demand for IoT devices are listed below.
**Connectivity:** Connectivity is an essential feature of IoT. IoT lets you connect mobile phones, laptops, and other internet devices. Any person can get information about anything at any time and place. IoT can connect through several wireless devices, like sensors, mobile phones, trackers, etc. This way, the person will not have to wait for an internet connection to operate a device.
**Identity of Things:** The collaboration of name and number gives an identity to an internet device. Giving an identity to the device is an essential aspect of IoT. Identity helps to differentiate between various internet devices and select the device we want to send the command. Every device needs a different controlling power based on the type of data provided. It is essential to give a unique identity to every device so that we can set up passwords or other security means. For example, fingerprints, face recognition IP addresses, and Face lock systems are several means of security given to the different identified devices to protect them.
**Intelligence:** The intelligence of IoT devices depends on the sensors' intelligence. The sensors send the data to the user for further analysis. We need to update the IoT devices regularly to get the smart work done. It adds to their features and makes them smarter.
**Dynamic:** We need to create IoT devices in a way that they can adapt to the environment. For example, an AC should have a sensor that can send a signal to the cloud and adjust it to the premises of the place. Similarly, the camera can easily click photographs by adjusting to light situations, like day and night.
**Scalability:** Scalability means the amount of data one can handle efficiently. The IoT has created a setup to handle enormous data and generate useful analysis.
**Self Upgradation:** As we saw above, updating the software regularly is important. But who has the time to remember to do that? Thus, with its artificial intelligence, IoT upgrades itself without human help. It also allows the set up of a network for the addition of any new IoT devices. Thus, the technology can quickly start working without delay if the setup has already been done.

**Architecture:** The architecture of IoT is designed in a way that it is capable of supporting various devices, technologies, and protocols. Its main work is to confirm whether each connected device does not interfere with the other. This way, the safety and security of each device's data are maintained.

**Security:** With the increasing number of IoT devices, issues regarding the security of personal data have arisen. There might be a chance of data leakage as a large amount of data is collected, exchanged, and generated. There is a chance of personal data being transferred without approval, which is a matter of concern. To overcome this challenge, IoT has created networks, systems, and devices wherein privacy is well maintained. Maintaining safety and security is a big dare for IoT. However, it still handles it without any disruption.

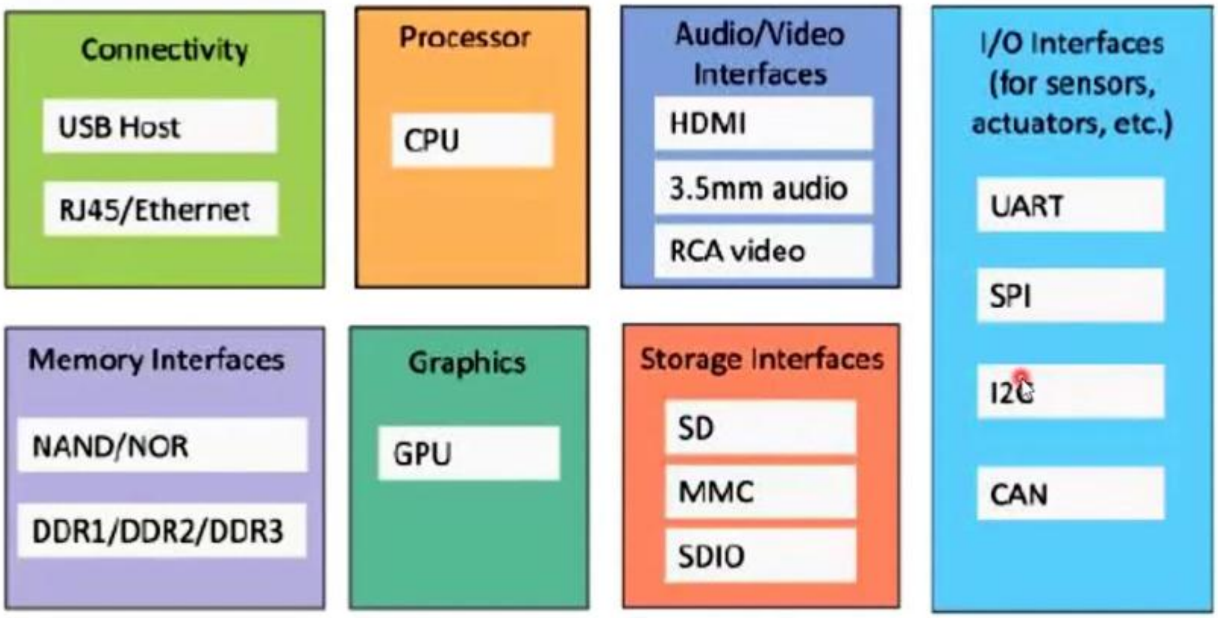
**Network:** With the increasing number of IoT devices in a network, it becomes difficult to maintain communication for proper functioning. However, cloud service and gateway are a few methods that can solve such problems. Often, one device can use the connectivity of another device to establish network connectivity even if the second device is not connected to a network. Because IoT devices can communicate with one another, it is more effective and adaptable than other current technologies.

**Data:** The data gathered from IoT devices are analyzed for future prediction. For example, a calorie meter. It helps to regulate the number of calories each day. We also have fitness data, thermostats, and various devices that monitor our health. Therefore, we can use the data collected through these devices.

## Physical Design of IoT:

The physical design of an IoT system is referred to as " The Things/Devices and protocols that are used to build an IoT system". All these things/Devices are called Node Devices and every device has a unique identity that performs remote sensing, actuating and monitoring work. While the protocols are used to establish communication between the Node devices and servers over the internet.

A generic block diagram representing physical design of IoT system is shown below.



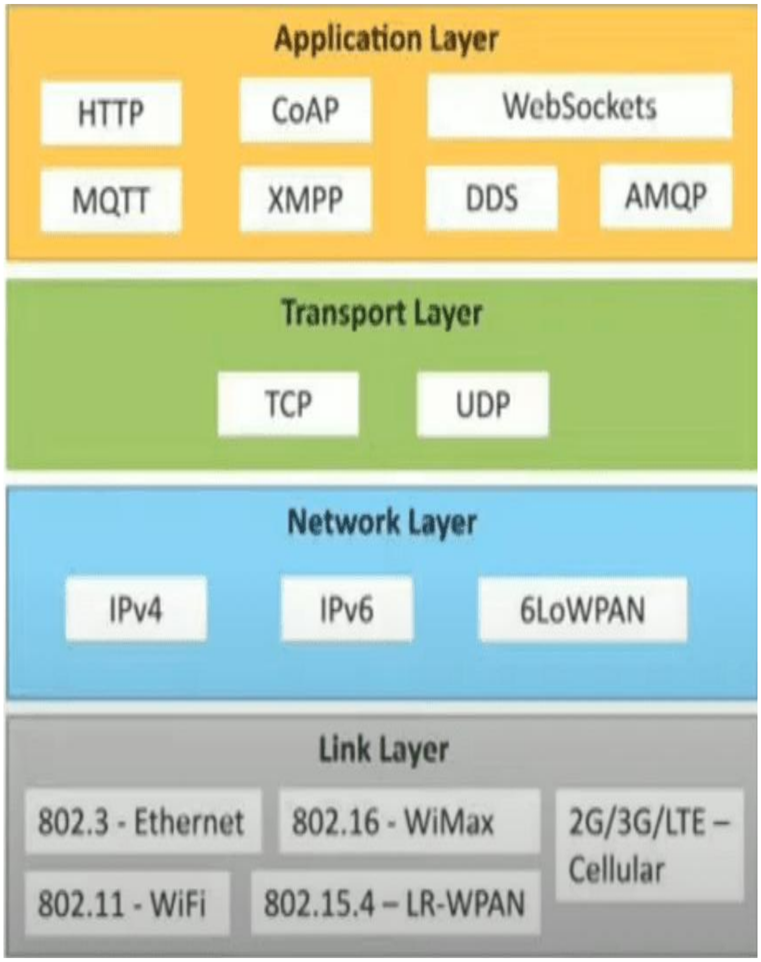

**Connectivity:** Devices like USB hosts and ETHERNET are used for connectivity between the devices and the server.
**Processor:** A processor like a CPU and other units are used to process the data. these data are further used to improve the decision quality of an IoT system.
**Audio/Video Interfaces:** An interface like HDMI and RCA devices is used to record audio and videos in a system.
**Input/Output interface:** To give input and output signals to sensors, and actuators we use things like UART, SPI, CAN, etc.
**Storage Interfaces:** Things like SD, MMC, and SDIO are used to store the data generated from an IoT device. Other things like DDR and GPU are used to control the activity of an IoT system.

**Logical Design of IoT:**

A logical design for an IoT system is the actual design of how the things/devices should be arranged to complete a particular function. It consist of the following elements.

1. **IoT Protocols**
2. **IoT Functional Blocks**
3. **IoT communication Models.**

**IoT Protocols:** To establish communication between a node device and a server over the internet IoT protocols are used. It helps to send commands to an IoT device and receive data from an IoT device over the internet. We use different types of protocols that are present on both the server and client-side and these protocols are managed by network layers like application, transport, network, and link layer explained below and shown in the fig..




**Application Layer protocol:** In this layer, protocols define how the data can be sent over the network with the lower layer protocols using the application interface. these protocols include HTTP, WebSocket, XMPP, MQTT, DDS, and AMQP protocols. Hypertext transfer protocol (HTTP) is a protocol that presents in an application layer for transmitting media documents. it is used to communicate between web browsers and servers. it makes a request to a server and then waits till it receives a response and in between the request server does not keep any data between two requests. WebSocket enables two-way communication between a client and a host that can be run on an untrusted code in a controlled environment. this protocol is commonly used by web browsers. MQTT is a machine-to-machine connectivity protocol that was designed as a publish/subscribe messaging transport. and it is used for remote locations where a small code footprint is required.

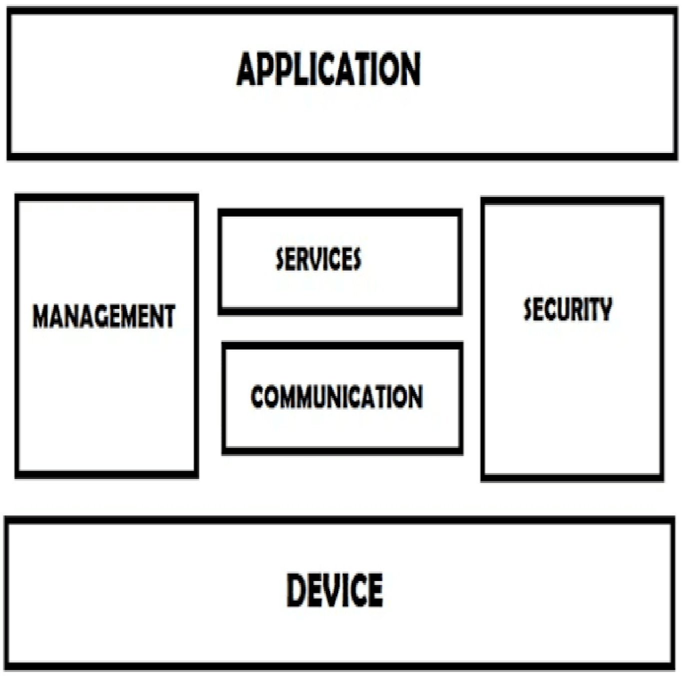
**Transport Layer:** This layer is used to control the flow of data segments and handle the error control. Also, these layer protocols provide end-to-end message transfer capability independent of the underlying network. TCP- Transmission Control Protocol defines how to establish and maintain a network that can exchange data in a proper manner using the internet protocol. UDP-User Datagram Protocol is a part of an internet protocol called the connectionless protocol.

**Network Layer:** This layer is used to send datagrams from the source network to the destination network. It use IPv4 and IPv6 protocols as host identification that transfers data in packets. IPv4- is an IP address that is 32-bit long. It is a unique and numerical label assigned to each device connected to the network. It performs two main functions host and location addressing. IPv6- It uses 128 bits for an IP address developed by the IETF task force to deal with long-anticipated problems.

**Link Layer:** Link-layer protocols are used to send data over the network's physical layer. It also determines how the packets are coded and signaled by the devices. Ethernet-is a set of technologies and protocols that are used primarily in LANs. It defines the physical layer and the medium access control for wired ethernet networks. While WiFi used for implementing wireless local area networks.

## IoT Funtional Blocks:

An IoT system consists of a number of functional blocks like Devices, services, communication, security, and application that provide the capability for sensing, actuation, identification, communication, and management. These functional blocks consist of devices that provide monitoring control functions, handle communication between host and server, manage the transfer of data, secure the system using authentication and other functions, and interface to control and monitor various terms as shown in the following block diagram.




**Application:** It is an interface that provides a control system that use by users to view the status and analyze of system.
**Management:** This functional block provides various functions that are used to manage an IoT system.
**Services:** This functional block provides some services like monitoring and controlling a device and publishing and deleting the data and restoring the system.
**Communication:** This block handles the communication between the client and the cloud-based server and sends/receives the data using protocols.
**Security:** This block is used to secure an IoT system using some functions like authorization, data security, authentication, 2-step verification, etc.
**Device:** These devices are used to provide sensing and monitoring control functions that collect data from the outer environment.

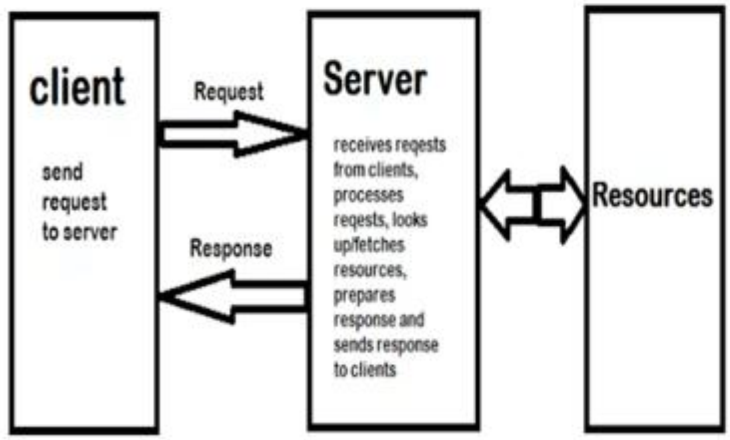
## IoT Communication Models:

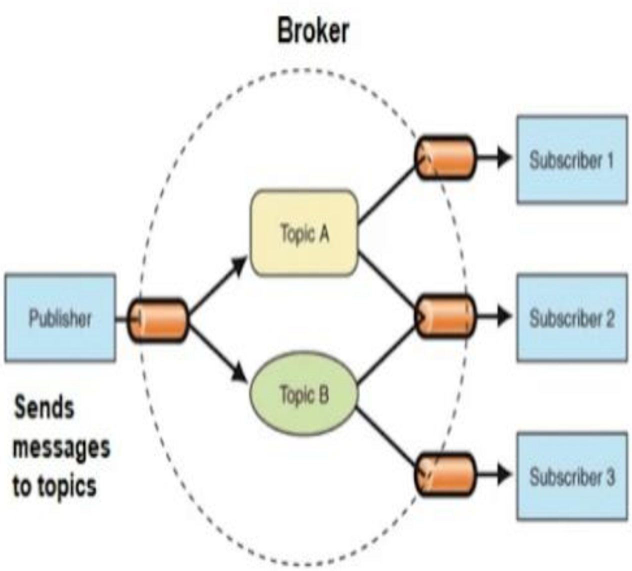
There are several different types of models available in an IoT system that is used to communicate between the system and server. Some of them are listed below.

1. Request-Response Model,
2. Publish-Subscribe Model,
3. Push-Pull Model,
4. Exclusive Pair Model etc.

**Request-Response Communication Model:** This model is a communication model in which a client sends the request for data to the server and the server responds according to the request. when a server receives a request it fetches the data, retrieves the resources and prepares the response, and then sends the data back to the client.

Example: When we search a query on a browser then the browser submits an HTTP request to the server and then the server returns a response to the browser(client).



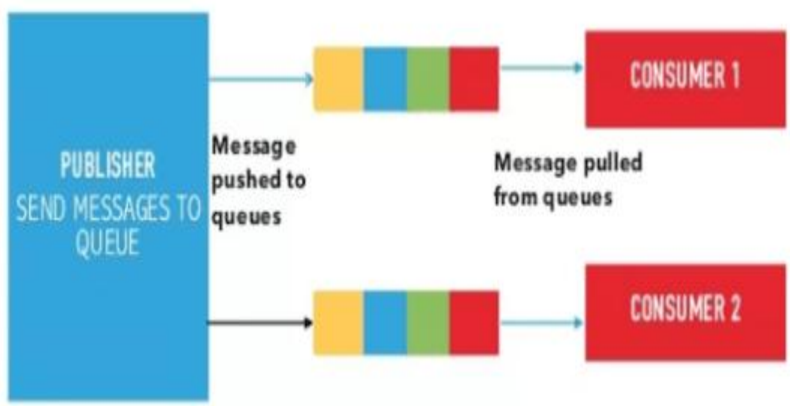




**Publish-Subscribe Communication Model:** In this communication model, we have a broker between publisher and consumer. here publishers are the source of data but they are not aware of consumers. they send the data managed by the brokers and when a consumer subscribes to a topic that is managed by the broker and when the broker receives data from the publisher it sends the data to all the subscribed consumers.

Example: On the website many times we subscribed to their newsletters using our email address. These email addresses are managed by some third-party services and when a new article is published on the website it is directly sent to the broker and then the broker sends these new data or posts to all the subscribers.

**Push-Pull Communication Model:** It is a communication model in which the data push by the producers in a queue and the consumers pull the data from the queues. here also producers are not aware of the consumers.

Example: When we visit a website we saw a number of posts that are published in a queue and according to our requirements, we click on a post and start reading it.




**Exclusive Pair Communication Model:** It is a bidirectional fully duplex communication model that uses a persistent connection between the client and server. here first set up a connection between the client and the server and remain open until the client sends a close connection request to the server.

## Difference between Physical and Logical Design of IoT

| Physical Design | Logical Design |
|---|---|
| Physical design is highly detailed. | Logical design is a high-level design and doesn’t provide any detail. |
| Physical design is more graphical than textual; however, it can comprise both. | Logical design can be textual, graphic, or both. |
| A physical design focuses on specific solutions explaining how they are assembled or configured. | A logical design focuses on satisfying the design factors, including risks, requirements, constraints, and assumptions. |

*"If we educate a man, you educate an individual, but if you educate a woman, you educate a Nation"*

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