LECTURE NOTE

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MECHANICAL ENGG DEPT.

SUBJECT: ADVANCED MANUFACTURING PROCESS

1.1 MODERN MACHINING PROCESSES / NON-TRADITIONAL MACHINING

Traditional machining is mostly based on the removal of materials using tools that are harder than the materials themselves.

New and novel materials because of their greatly improved chemical, mechanical and thermal properties are sometimes impossible to machine using traditional machining processes.

Traditional machining methods are often ineffective in machining hard materials like ceramics and composites or machining hard materials like ceramic and composites under very tight tolerances as in micromachined components.

The need to avoid surface damage that often accompanies the stresses created by conventional machining. Example: aerospace and electronics industries.

CLASSIFICATION OF NON-TRADITIONAL MACHINING

These can be classified according to the source of energy used to generate such a machining action: mechanical, thermal, chemical, and electrochemical.

Mechanical: Erosion of the work material by a high-velocity stream of abrasives or fluids (or both).

Thermal: The thermal energy is applied to a very small portion of the work surface, causing that portion to be removed by fusion and/or vaporization of the surface, causing that portion to be removed by fusion and/or vaporization of the material.

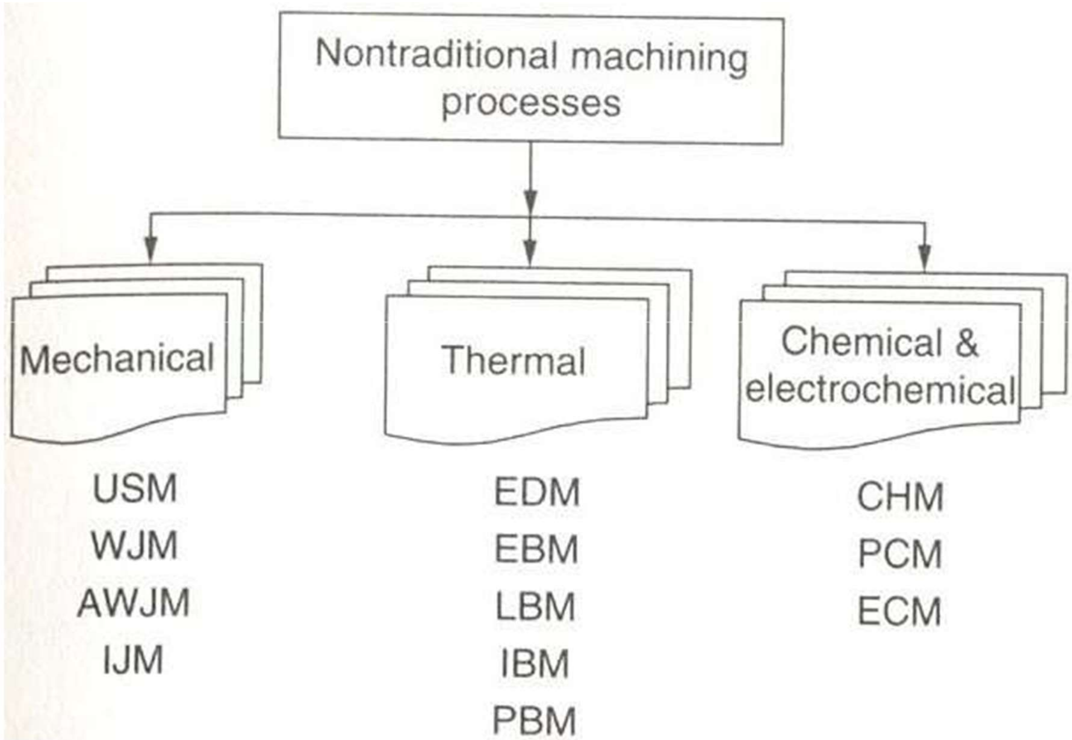
Thermal energy is generated by the conversion of electrical energy.

Electrochemical: Mechanism is the reverse of electroplating.

Chemical: Most materials (metals particularly) are susceptible to chemical attack by certain acids or other etchants.

In chemical machining, chemicals selectively remove material from portions of the work part, while other portions of the surface are protected by a mask.

CLASSIFICATION OF NON-TRADITIONAL MACHINING



1.2 ULTRASONIC MACHINING:

PRINCIPLE:

It works on the same principle as ultrasonic welding. This machining uses ultrasonic waves to produce a high-frequency force of low amplitude, which act as the driving force of the abrasive.

The ultrasonic machine generates a high-frequency vibrating wave of frequency about 20000 to 30000 Hz and an amplitude of about 25-50 microns.

This high-frequency vibration transfer to an abrasive particle contains in an abrasive slurry.

This leads indentation of the abrasive particle to a brittle workpiece and removes metal from the contact surface.

EQUIPMENT:

Power Source:

This machining process requires high-frequency ultrasonic waves. So a high-frequency high voltage power supply requires for this process. This unit converts low-frequency electric voltage (60 Hz) into high-frequency electric voltage (20k Hz).

Transducer:

Transducer is a device which converts electric single into mechanical vibration. In ultrasonic machining magneto strictive type transducer is used to generate mechanical vibration. This transducer is made by nickel or nickel alloy.

Booster:

The mechanical vibration generated by transducer is passes through booster which amplify it and supply to the horn.

Tool:

The tool used in ultrasonic machining should be such that indentation by abrasive particle, does not leads to brittle fracture of it. Thus the tool is made by tough, strong and ductile materials like steel, stainless steel etc.

Tool holder or Horn:

As the name implies this unit connects the tool to the transducer. It transfers amplified vibration from booster to the tool. It should have high endurance limit.

Abrasive Slurry:

A water-based slurry of abrasive particle used as abrasive slurry in ultrasonic machining. Silicon carbide, aluminum oxide, boron carbide are used as abrasive particles in this slurry. A slurry delivery and return mechanism is also used in USM.

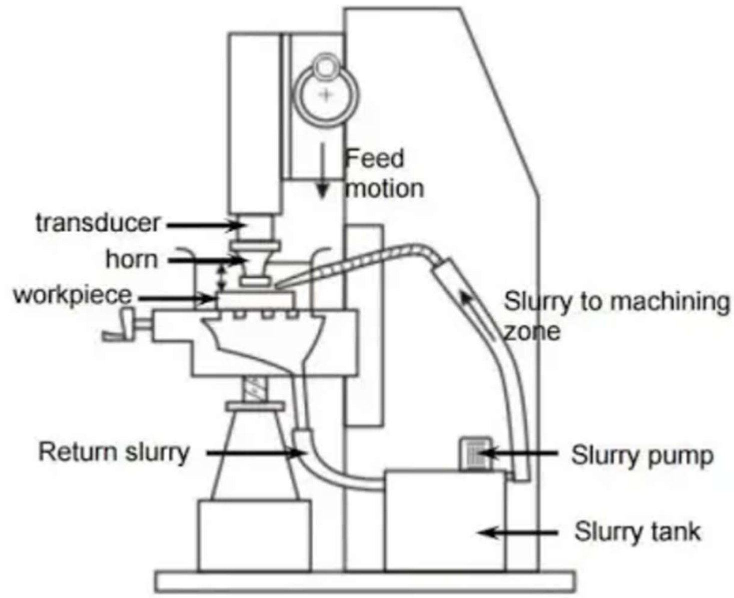
WORKING PROCESS:

In this machining, the material is removed by the indentation of an abrasive particle on the workpiece.

the low-frequency electric current passes through the electric supply. This low-frequency current converts into high-frequency current through some electrical equipment.

This high-frequency current passes through a transducer. The transducer converts this high-frequency electric single into high-frequency mechanical vibration.

This mechanical vibration passes through the booster. The booster amplifies this high-frequency vibration and sends it to the horn.



Horn which is also known as a tool holder transfers this amplified vibration to a tool that makes the tool vibrate at an ultrasonic frequency.

As the tool vibrates, it makes an abrasive particle vibrate at this high frequency. This abrasive particle strikes the workpiece and removes metal from it.

Application:

- This machining is used to machine hard and brittle materials like carbide, ceramic, glass etc.
- This is used in machining of die and tool of the drill, wire drawing machine etc.
- Used in fabrication of silicon nitrite turbine blade.
- It is used to cut diamond in desire shape.
- It is used machining of machining non-conductive hard material which cannot be machined by ECM or EDM due to poor conductivity.

Advantages:

- Hard material can be easily machined by this method.
- No heat generated in work so there is no problem of work hardening or change in structure of work piece.
- Non-conductive metals or non-metals, which cannot be machined by ECM of EDM can be machined by it.
- It does not form chips of significant size.

Disadvantages:

- It is quite slower than other mechanical process.
- Tool wear is high because abrasive particle affect both work-piece and tool.
- It can machine only hard material. Ductile metal cannot be machine by this method.
- It cannot used to drill deep hole.

1.3 ELECTRIC DISCHARGE MACHINING

Electrical Discharge machining is the process of metal removal from the work surface due to an erosion of metal caused by electric spark discharge between the two electrodes tool (cathode) and the work (Anode).

PARTS OF ELECTRO-DISCHARGE MACHINING

DC Pulse Generator: This is a power source for the machining operation. DC power is supplied.

Voltmeter: The voltmeter measures the voltage.

Ammeter: It measures the flow of the current. If Ammeter is not connected, we might not see or check current is flowing or not.

Tool: A tool is connected to the negative terminal of power whereas the workpiece is connected to the positive terminal. from the filter, the fluid comes to the tool for the operation. When the Power supply will increase, between tools and workpieces the spark generates, and then machining starts.

Die Electric Fluid: It possesses the property of insulation which means no current flows from one point to another. The Die electric fluid will be ionized in the form of an ion which will help between the tool and workpiece again when the power supply stops the fluid comes to its initial position.

Pump: The pump is connected there for sending the fluid to the filter. This works like flowing the fluid from one source to another one.

Filter: As the name indicates the filter, is used to filtrate the different particles In this device, if there are dust particles present the filter will remove that particle and then it will send it to the tool for operation.

Servo-Controlled Feed: The constant feed will be supplied by the servo for the operation.

Fixture: To hold the table.

Table: To hold the workpiece.

WORKING PRINCIPLE

It consists of an electric power supply, the dielectric medium, the tool, the workpiece, and the servo control.

The workpiece is connected to the positive terminal and the tool is connected to the negative terminal of the DC power supply.

An air gap of 0.005 to 0.05 mm is maintained between the tool and the work.

The die electric fluid which is a non-conductor of electricity is forced under pressure through the gap.

When DC power is supplied, the fluid in the gap gets ionized and produces a spark between the tool and workpiece, causing a local rise in temperature at about 1000 degrees Celsius, when melts the metal in a small area of the workpiece and vaporizes.

The DC supply generates a pulse between 40 to 3000 V and the frequency of spark at the rate of 10000 sparks per second can be achieved.

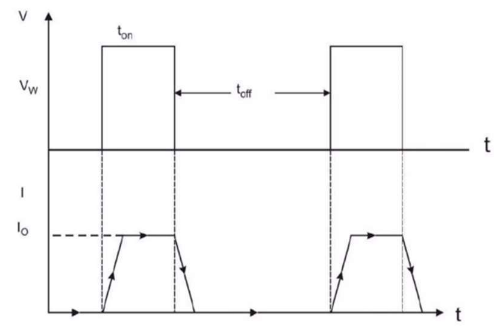
The electric and magnetic fields on heated metal cause a compressive force that removes the metal from the work surface.

The die electric fluid acts as a coolant to carry the cooled metal from the work surface.

The die electric fluid acts as a coolant and carries the eroded metal particles which are filtered regularly and supplied back to the tank.

A servo mechanism is used to feed the tool and continues to maintain a constant gap between two electrodes. An accuracy of about 0.005 mm can be achieved in this process

The process parameters - mainly related to the waveform characteristics.

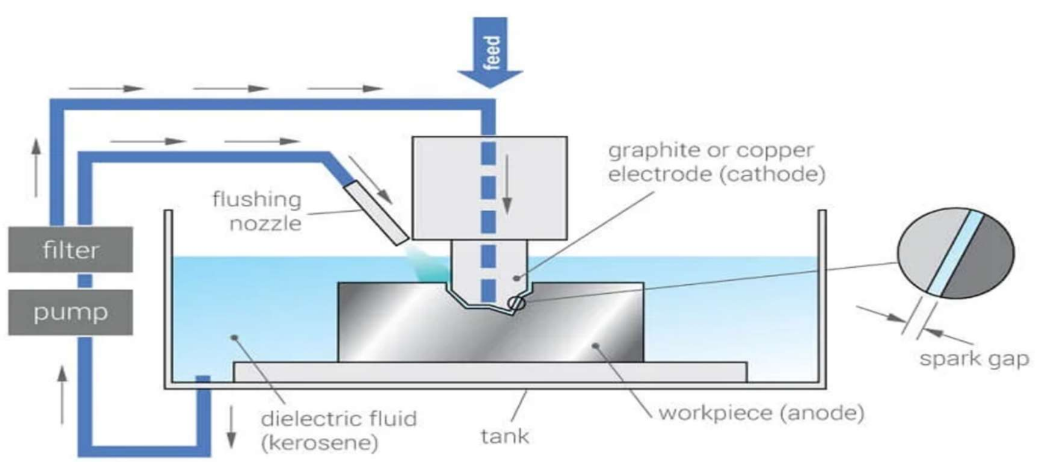


EDM – Process Parameters

- The waveform is characterized by the:
- The open circuit voltage – Vo
- The working voltage – Vw
- The maximum current – Io
- The pulse on time – the duration for which the voltage pulse is applied - ton
- The pulse off time – toff
- The gap between the workpiece and the tool – spark gap – δ
- The polarity – straight polarity – tool (-ve)
- The dielectric medium
- External flushing through the spark gap.

Applications

- Drilling for micro holes in the nozzle.
- Used in thread cutting.



- Used in wire cutting.
- Rotary form cutting.

- Helical profile milling.
- Curved hole drilling.
- Engraving operation on harder materials.
- Cutting off operation.
- The shaping of alloy steel and tungsten carbide dies.

Advantages

- It can be used for any hard material and even in heat-treated condition.
- Any complicated shapes made on the tool can be reproduced.
- High accuracy of about 0.005 mm can be achieved.
- Good surface finish can be achieved economically up to 0.2 microns.
- Machining time is less than the conventional machining process.

Disadvantages

- Excessive tool wear.
- High power consumption.
- The sharp corner cannot be reproduced.
- The workpiece must be an electrical conductor.
- Surface cracking may take place in some materials.

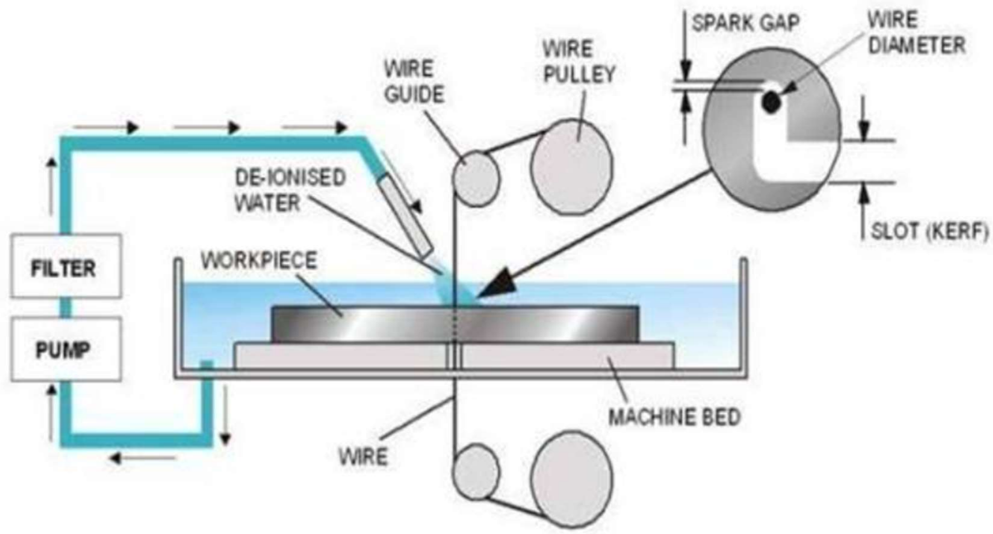
1.4 WIRE CUT EDM

Wire electrical discharge machining is a non-contact subtractive manufacturing process that uses an electrically charged thin wire with a dielectric fluid to cut a metal part into different shapes.

Components of WEDM

CNC Tools:

The CNC tools control the entire operation of the Wire EDM machining process. Controlling the entire operations include being in control of the sequencing of the wire path and being able to manage the cutting process automatically.



Power Supply:

The power supply unit is the component that delivers pulses (from 100V to 300V) to the wire electrode and the workpiece. Furthermore, it controls the frequency and strength of the electrical charges that pass through the wire electrode to interact with the workpiece.

Wire:

The wire serves as the electrode to create the electrical discharge. The shape and thickness of the workpiece directly influence the wire's diameter. Typically, one can use wires with diameters ranging from 0.05 to 0.25mm.

Dielectric Medium

The wire cut EDM process must be carried out in a tank filled with dielectric fluid. This liquid prevents the tiny particles from the workpiece from getting attached to the wire electrode. The most common medium is deionized water which cools the process and gives the workpiece a good surface finish.

Electrodes:

The electrodes in the machine are the wire (cathode) and the workpiece (anode). The servo motor controls the wire electrode, ensuring it does not encounter the workpiece at any point during the wire EDM cutting process.

PRINCIPLE:

Machining a part using the process involves submerging the workpiece into a dielectric fluid, securing it with a machinist vise, and running the wire through it to produce sparks as it passes an electric current.

The wire carries one side of the charge, and the workpiece, which must be a conductive material, carries the other side of the charge.

When the two get close, a hot electric charge jumps the gap and melts tiny pieces of the metal away.

The electric spark is the cutting tool to cut the material in the desired shape.

Additionally, the wire EDM process involves deionized water to control the process and flush away tiny particles removed.

Controlling Parameters of WEDM

- Discharge Current: The discharge current in between 20 to 30 amperes.
- Duration of pulse: The high duration of pulse goes produce more removal rate and low duration of pulse produce low removal rate.
- Frequency of pulse: The frequency of pulse in between 50KHz to 1MHz.
- Wire Diameter: The diameter of thin wire is 0.05mm to 0.25mm.
- Wire Speed: The speed of wire is about 5 to 200 mm/sec.

Advantages of WEDM

- It gives high accuracy.
- There is no need of storage of tool is required.
- There is low operating skill is required.
- Smooth complex surfaces can be possible to machining.
- A good surface finish can be obtained.

Disadvantages of WEDM

- It is only compatible with materials that conduct electricity.
- An oxide layer may develop on the cut surface of some materials, such as aluminum. Therefore, this could necessitate additional finishing, which raises the cost.
- It has a high initial investment and maintenance cost

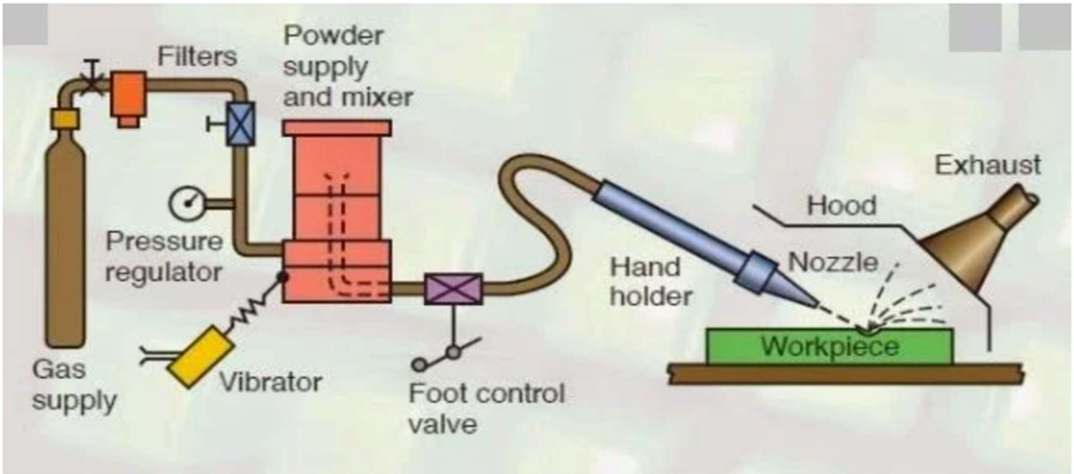
Applications

- It works for the production of prototypes.
- It is used for making stamping dies, drawings, extrusion tools, etc.
- IT is used for making blanking dies, plastic molding dies, stamping dies, etc.
- It is used for gauges and cam discs.
- It is used to machining larger parts that need to hold accurate tolerances.
- It is also used for making of small series of spare parts.

1.5 ABRASIVE JET MACHINING:

Abrasive Jet Machining is a material removal process with the help of concentrated abrasive grains enclosed in a nozzle that removes by the action of impact erosion. In abrasive-jet machining, a high-velocity jet containing abrasive particles is aimed at the workpiece surface under controlled conditions.

Parts or Construction



Gas Supply: A high-velocity jet of airlike nitrogen carbon dioxide etc and enclosed abrasive particles are aimed at the workpiece under controlled conditions. The gas is supplied under a pressure of 2 to 8 kilopascal.

Filter: The filter is used to clean the fuel supply so that dirt or other impurities do not hamper the progress of the process.

Pressure Gauge: The pressure gauge is used to control the pressure of the compressed used in the abrasive jet machining. As the pressure decides the depth of cutting and the amount of force required for cutting.

Mixing chamber: In the mixing chamber abrasive powder is being fed and with the help of a vibrator amount of abrasives can be controlled. So that the abrasives and the gases will be mixed thoroughly in the mixing chamber.

Nozzle: The nozzle is used to increase the velocity of the fine abrasive jet slurry at the expense of the pressure as we know if we decrease the pressure the velocity will increase. The velocity of the jet will be around 100-300m/s.

The nozzle can be adjusted accordingly so that the desired angular cutting can be achieved and the material will be removed by impact erosion.

The nozzle is usually made up of tungsten carbide because it is subjected to a high degree of wear. The diameter of the nozzle is around 0.2-0.8mm.

Abrasives: Silicon carbide, and aluminum oxide glass beads are used as abrasives in abrasive jet machining. The shape of the abrasives can be regular or irregular. The size of the abrasives is around 10 to 50 microns. The mass flow rate of the abrasives is around 2-20 grams/min.

Working Principle:

The working principle of abrasive jet machining involves the use of a high-velocity stream of Compressed abrasives particles carried by a high-pressure gas through a nozzle on the workpiece.

Metal will remove due to erosion by the abrasive particles that hit at a very high speed on the workpiece. the pressure energy of the stream is converted into kinetic energy and

Hence the high-velocity jet is produced. The high-velocity abrasive particles remove the material of the workpiece by micro-cutting action as well as a brittle fracture.

The nozzle is made of either circular or rectangular cross-sections and the head can be straight or at a right angle. It is designed that loss of pressure due to the bends, friction, is minimum possible.

The divergence of jet stream increases resulting in more irregular cutting and high inaccuracy.

Material removal rate:

$$\therefore MRR_{brittle} = 1.04 \frac{M_g . U^{3/2}}{{\rho_g}^{1/4} . H^{3/4}}$$

$$\therefore MRR_{ductile} = 0.5 \frac{M_g U^2}{H}$$

U = Velocity of abrasive jet at the point of impact.

H = Flow strength or hardness of the work material.

M_g = Mass flow rate of abrasive particles.

ρ_g = Density of each abrasive particle.

Advantages

- Suitable for removal of deposits on surface
- Wide range of surface finish can be obtained
- Process is independent of electrical or thermal properties
- No thermal damage of workpiece
- Suitable for nonconductive brittle materials
- Low capital investment

Disadvantages

- Not suitable for soft and ductile materials
- Abrasives are not reusable
- Abrasive collection and disposal are problematic
- Inaccurate cutting and drilling (stray cutting)
- Limited nozzle life.

Application

- It is used for abrading and frosting glass, ceramics, and refractories and it is more economical as compared to etching or grinding.
- Cleaning of layering of metals like resistive coating.
- Deflashing small castings and trimming of parting lines of injection molded parts and forgings.
- It is used for engraving registration numbers on toughened glass for car windows.
- AJM is used for cutting thin fragile components like germanium, silicon, quartz, mica, etc.

1.6 LASER BEAM MACHINING

Laser Beam Machining is a non-conventional machining process in which the laser machining process is holing the workpiece. To remove the material from the workpiece the process used thermal energy.

Laser Beam Machining Parts or Construction

Power Supply:

The electric current or power is supplied to the system. A high voltage power system is used in laser beam machining. It will give initial power to the system after that reaction starts in a laser that will machine the material. There is a high voltage supply so that pulses can be initiated easily.

Capacitor:

During the major portion of the cycle, a capacitor bank charges and releases the energy during the flashing process. The capacitor is used for the pulsed mode for charging and discharging.

Flash Lamps:

It is the electric arc lamp that is used to produce extremely intense production of white light which is a coherent high-intensity beam. It is filled with gases that ionize to form great energy that will melt and vaporizes the material of the workpiece.

Reflecting Mirror:

Reflecting Mirror are two main types of internal and external. Internal mirrors also called a resonator that is used to generate maintain and amplify the laser beam. It is used to direct the laser beam towards the workpiece.

Laser Light Beam:

It is the beam of radiation produced by the laser through the process of optical amplification based on the coherence of light created by the bombarding of active material.

Ruby Crystal:

Ruby laser produces a series of coherent pulses which is deep red in color. It achieves by the concept of population inversion. It is a three-level solid-state laser.

Lens:

Lenses are used to focus the laser beam onto the workpiece. First laser light will enter into the expanding lens and then into the collimating lens which makes the light rays parallel and the expanding lens expands the laser beams to the desired size.

Workpiece:

The workpiece can be metallic or non-metallic. In this machining process, any material can be machined.

Laser Beam Machining Working Principle:

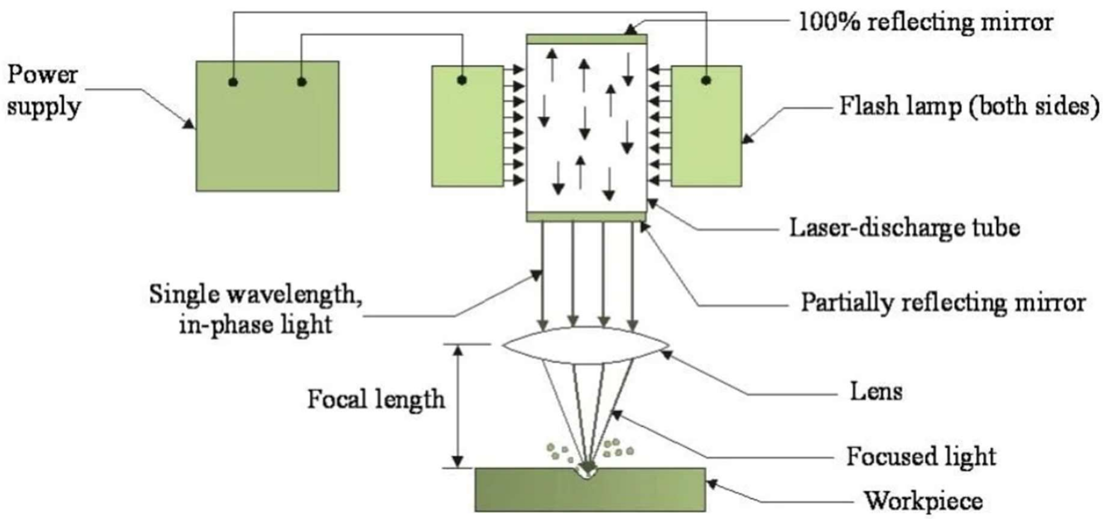
Laser Machining is based on the LASER and conversion or process of Electric Energy into Light Energy and into Thermal Energy.

Negatively charged electrons in the atomic model rotate around the positively charged nucleus in orbital paths. It depends on the number of electrons, electron structure, neighboring atoms, and the electromagnetic field.

Every orbital of electrons is associated with different energy levels. An atom is considered to be at ground level at absolute zero temperature at this, all electrons occupy their lowest potential energy.

The electrons at the ground state move to a higher state of energy by absorbing energy like an increase in electronic vibration at elevated temperatures.

High voltage is applied at the ends that leads to discharge and gas plasma will be formed. Population inversion and lasing action will take takes place due to energy transformation.



Laser beam machining schematic

The laser has one 100% reflector and the other one is a partial reflector. 100% the reflector directs the photons inside the gas tube and the partial reflector allows only some part of the laser beam that will be used for the processing of materials.

The laser beam produced is focused on the workpiece that has to be machined. When the laser strikes the workpiece, the thermal energy impinges on the workpiece.

This will heat then melt, vaporize, and finally, the material will be removed from the workpiece. So laser machining is a thermal material removal process that uses a coherent beam of light to machine the workpiece very precisely.

In the laser machining process, MRR (Material Removal Rate) depends on the wavelength used because it will decide the amount of energy impinged on it.

Material Removal Rate

- The basic assumptions to analyze the material removal process are:
- The intensity of LASER beam does not vary with time.
- LASER beam is uniform over the entire area of hotspot.
- The material being removed is both melting and evaporating.
- The steady state ablation is characterized by constant rate of material removal and by the establishment of a steady state distribution.

According to the above assumptions, the steady temperature distribution is given by,

$$(T - T_0)/(T_m - T_0) = e^{-Vx/\alpha}$$

Where, T = temperature at distance x below the ablating surface,

To = initial uniform temperature of the workpiece,
Tm = melting point of the workpiece
V = steady ablation velocity,
a = thermal diffusivity of workpiece, i.e., (K/ρ) * Cp
K, Cp= thermal conductivity, density, and specific heat, respectively, of the workpiece.

$$x_c = \frac{\alpha}{V}$$

After steady ablation is realized, the relationship between the intensity, exposure time, the thickness of material that has been removed, and thermal properties of the material is:

$$ft = K(T_m - T_o)\rho H/f + \rho H d$$

Where t is the exposure time.

Application

- Laser Machining is used for making very small holes, Welding non-conductive and refractory material.
- It is best suited for brittle material with low conductivity and Ceramic, Cloth, and Wood.
- Laser Machining is also used in surgery, micro-drilling operations.
- Spectroscopic Science and Photography in medical science.
- It is also used in mass macro machining production.
- Cutting complex profiles for both thin and hard materials.
- It is used to make tiny holes. Example: Nipples of the baby feeder.

Advantages

- In Laser Beam Machining any material including non-metal also can be machined.
- Extremely small holes with good accuracy can be machined.
- The tool wear rate is very low.
- There is no mechanical force on the work.
- Soft materials like plastic, rubber can be machined easily.
- It is a very flexible and easily automated machine.
- The heat-affected zone is very small.

Disadvantages

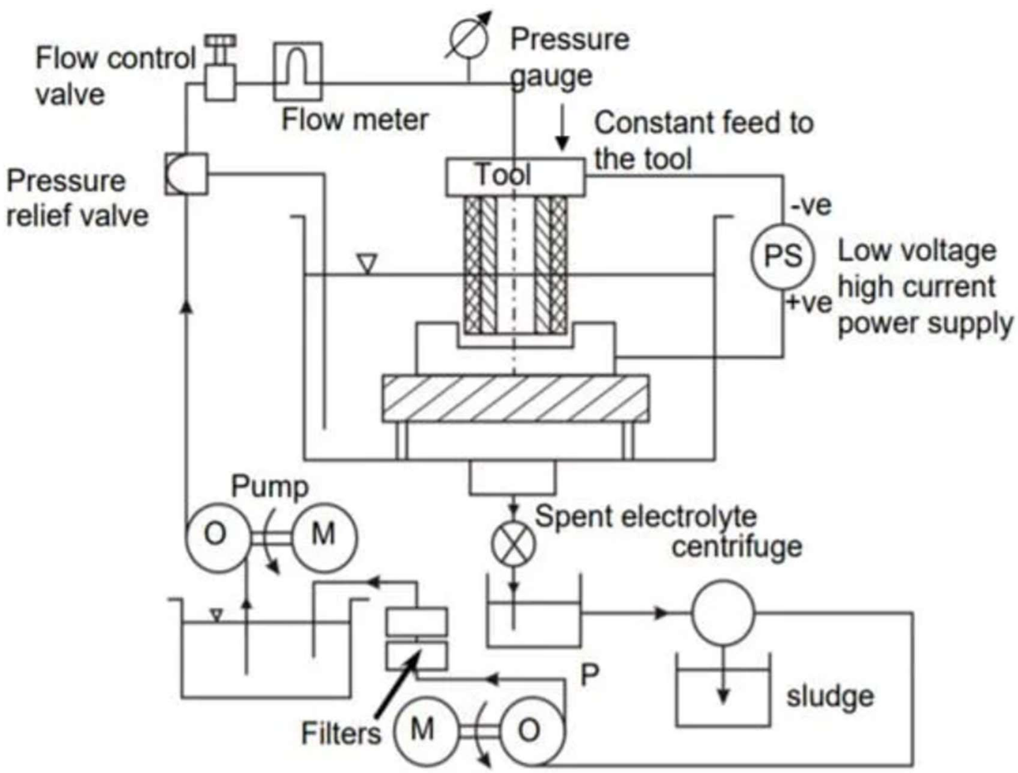
- Laser Machining cannot be used to produce a blind hole and also not able to drill too deep holes.
- The machined holes are not round and straight.
- The capital and maintenance cost is high.
- There is a problem with safety hazards.
- The overall efficiency of the Laser beam machining is low.
- It is limited to thin sheets.

1.7 ELECTROCHEMICAL MACHINING

Electrochemical Machining (ECM), characterized as non-traditional machining, is an advanced machining, non-contact, reverse electroplating process (ECM removes material instead of depositing it).

In ECM, a high electric current is passed between the tool and workpiece through a conductive fluid.

The high current and the conductive fluid are used to ionize and remove the metal atoms of the workpiece yielding a burr-free surface.



Electrochemical Machining Parts or Construction

Power supply:

Voltage must be kept low to avoid short-circuit because the gap between the tool and workpiece is low for high-pitched correctness.

Material removal rate ∝ Current density. Therefore, high current values are used for the ECM process.

Electrolyte:

Electrolytes are conductive fluid and are selected in parity with electrodes. Some electrolyte-electrodes combination is given below:

- Sodium chloride (NaCl) at a concentration of 20% is used for ferrous alloys.
- Sodium nitrate ($NaNO_3$) is used for ferrous alloys.
- Hydrochloric acid (HCl) is used for Nickel alloys.

Work piece:

A workpiece is an object that needs to be machined from which material goes into the solution. The workpiece is made the anode in ECM. The material removal rate or machining is only dependent upon the atomic weight and valency of the work material.

The workpiece can be any electrically conducting material and is insulated from the system so that there is no leakage or short-circuiting of current.

Tool:

The tool is used to remove material from the workpiece. It is made the cathode and connected to the negative terminal of the power supply.

The cavity obtained in the workpiece is the replica of the tool shape. Therefore, the accuracy of the workpiece after machining is directly affected by the accuracy of the tool shape.

Feed Unit:

The servo motor is used to provide the controlled feed to the tool for material removal from the workpiece. Feed rate is 0.5 mm/min to 15 mm/min.

Pump:

The pump helps in circulating the electrolyte. The rate of pumping and pressure at which electrolytes will be pumped should be decided beforehand depending on the application or requirement of the process.

Filters:

The filter helps in filtering the impurities present in the electrolyte which may choke the supply lines.

Filters are used to realize precise ECM with high-cost effectiveness by maintaining the electrolyte quality constant and removing residual toxic ions from the electrolyte for health and environmental conservation purposes.

Electrochemical Machining Working Principle:

Let us take an example of the machining of an iron workpiece. The iron workpiece is assembled in the workpiece holding table.

The tool is brought close to the workpiece. The two electrodes immersed in the electrolytic solution of NaCl (common salt solution).

The cathode (tool) and anode (iron workpiece) are connected to the negative and positive terminal of the power supply (usually around 10 V) respectively.

The electrolyte from the reservoir tank is continuously pumped, streaming through the hole in the tool, into the gap between the tool and the workpiece with the help of a circulating pump.

The tool feed system advances the tool towards the workpiece.

Reactions at the anode are called anodic reactions. Reactions at the cathode are called catholic reactions.

Basic reactions for sodium chloride electrolyte:

- Disassociation of sodium chloride: $NaCl \longrightarrow Na^+ + Cl^-$
- Disassociation of water: $H_2O \longrightarrow H^+ + OH^-$

Cathodic Reactions: Hydrogen ions take away electrons from the cathode (tool) to form H_2 gas.

- $2H^+ + 2e^- \longrightarrow H_2\uparrow$

Only H_2 gas is evolved at the cathode. The electrode shape remains unaltered during the electrolysis process, which is the most significant feature of the ECM process.

Anodic Reactions:

- Iron comes out of the workpiece (anode) as iron ions
- $Fe \longrightarrow Fe^{++} + 2e^-$
- Reaction within sodium chloride electrolyte
- $Na^+ + OH^- \longrightarrow NaOH$
- $Fe^{++} + 2OH^- \longrightarrow Fe(OH)_2 \downarrow$
- $Fe^{++} + 2Cl^- \longrightarrow Fe(Cl)_2 \downarrow$

$Fe(OH)_2$, $Fe(Cl)_2$ are precipitated as sludge. The workpiece gets gradually machined to give an excellent surface finish and stress-free surface because of this controlled anodic dissolution process at the atomic level.

There are no constraints over the geometry of the tool shape. Initially, the gap between the tool and workpiece is uneven. After the machining, the gap is uniform (0.1 mm to 2 mm) throughout the length of the workpiece and maintained as such through the appropriate tool or workpiece advancement rate.

The width of the gap gradually tends towards a steady-state value and under such conditions, the cavity obtained is the replica of the tool shape.

The sludge from the tank is taken out and separated out from the electrolyte using the centrifuge.

The electrolyte, after going through the filtration process in filters, again transported to the reservoir tank to be pumped for the machining process.

MRR in ECM

The material removal rate in ECM is,

$$MRR = \frac{IA}{FV} \times \eta$$

where I = current, A = atomic weight, V = valency, F = faraday's constant = 96500, η = efficiency

Advantages

- Complex and concave curvature parts can be produced easily using concave and convex tools.
- More complex geometries can be produced using a single connected CNC machine.
- Since there is negligible tool wear, the same tool can be used for producing an infinite number of components.
- Since there is no direct contact between the tool and work material, there are no forces and residual stresses.
- Less heat is generated.

Disadvantages

- The saline(acidic) electrolyte can cause corrosion of the tool, workpiece, and equipment.
- High specific energy consumption.
- ECM can machine only electrically conductive work material.
- It cannot be used for soft material.
- A large production floor is required.

Application

- Electrochemical Machining is used for Die sinking and hole-contouring operations.
- Grinding, by combining with grinding processes (using the negatively charged abrasive grinding wheel) to remove material. The process is also referred to as electrochemical grinding.
- Cutting cavities, drilling deeper and even irregular-shaped holes in complex structures like jet engine turbine blades.
- Profiling and machining complex profiles like steam turbine blades within closed limits.

1.8 PLASMA ARC MACHINING

Plasma-arc machining (PAM) employs a high-velocity jet of high-temperature gas to melt and displace material in its path. Called PAM, this is a method of cutting metal with a plasma-arc, or tungsten inert-gas-arc, torch. The torch produces a high-velocity jet of high-temperature ionized gas called plasma that cuts by melting and removing material from the workpiece. Temperatures in the plasma zone range from 20,000° to 50,000° F (11,000° to 28,000° C).

Plasma

Solids, liquids, and gases are the three familiar states of matter. In general when a solid is heated, it turns to liquids and the liquids eventually become gases. When a gas is heated to sufficiently high temperature, the atoms (molecules) are split into free electrons and ions. The dynamical properties of this gas of free electrons and ions are sufficiently different from the normal unionized gas. So, it can be considered
a fourth state of matter, and is given a new name, PLASMA'.

This plasma is used for the metal removal process. The plasma arc machining process is used for cutting alloy steels, stainless steel, cast iron, copper, nickel, titanium, aluminum, etc.

Components of Plasma Arc Machining:

PlasmaGun:

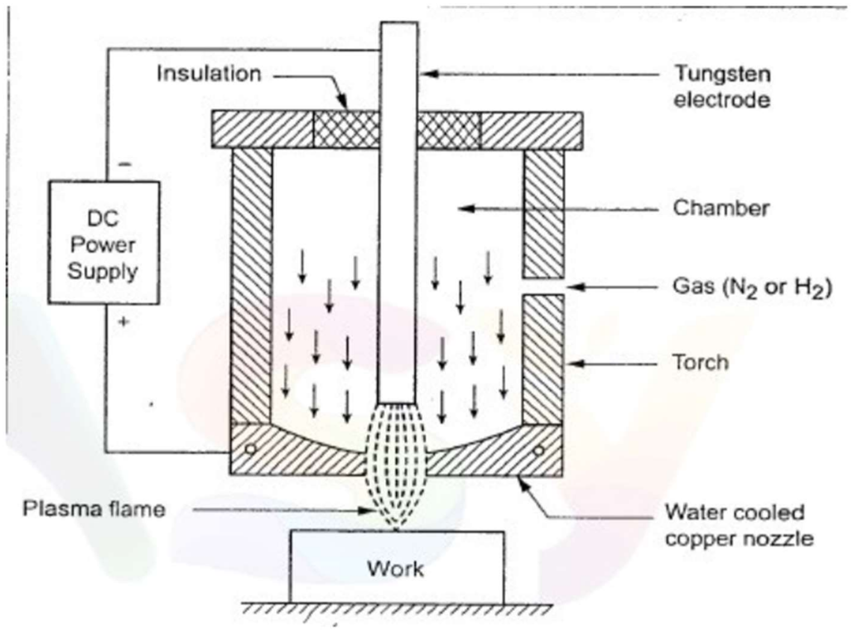
Different gases like nitrogen, hydrogen, argon or a mixture of these gases are used to create plasma. This plasma gun has a chamber that has a tungsten electrode. This tungsten electrode is connected to the negative terminal and the nozzle of the plasma gun is connected to the positive terminal of the DC power supply. The required mixture of gas is supplied to the gun. A strong arc is produced between the anode and the cathode.

After that, there is a collision between the electron of the arc and the molecules of the gas and due to this collision, gas molecules get ionized and heat is generated.

Power Supply:
DC Power Supply is used to develop two terminals in the plasma gun. Heavy potential difference is applied across the cathode and anode so that arc produced is strong and can ionize the gas mixture and convert it into plasma.

Cooling Mechanism:
A cooling mechanism is added to the plasma gun as heat is produced in it as hot gases continuously pass out from the nozzle.
A water jacket is used to cool the nozzle. The nozzle is surrounded by a water jet.

Workpiece:
Different materials can be worked using this plasma arc machining. Different



Construction of PAM

metals like aluminum, magnesium, carbon, stainless steel and alloy steels can be worked using this process.

Working of PAM:

When a DC power is given to the circuit, a strong arc is produced between the electrode (cathode) and the nozzle (anode).

A gas usually hydrogen (H2) or Nitrogen (N2) is passed into the chamber.

This gas is heated to a sufficiently high temperature of the order of 11,000°C to 28,000°C by using an electric arc produced between the electrode and the nozzle.

In this high temperature, the gases are ionized and a large amount of thermal energy is liberated.

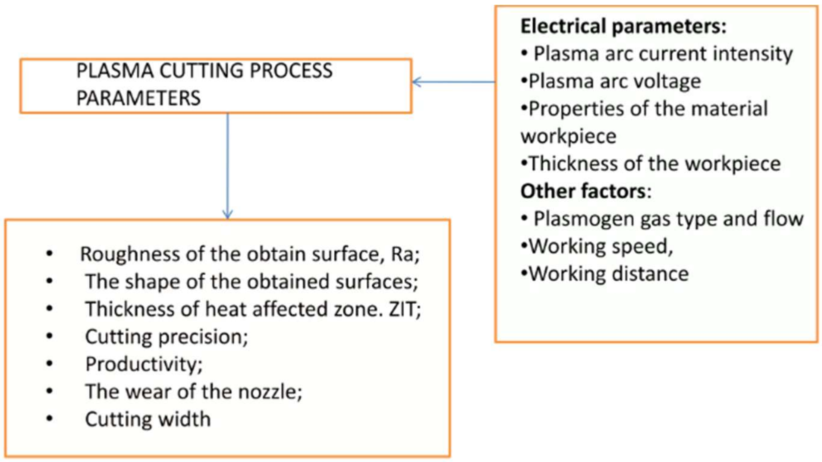
This high velocity and high-temperature ionized gas (plasma) is directed on the workpiece surface through the nozzle.

This plasma jet melts the metal of the workpiece and the high-velocity gas stream effectively blows the molten metal away.

The heating of the workpiece material is not due to any chemical reaction, but due. to the continuous attack of plasma on the workpiece material. So, it can be safely.

used for machining any metal including those which can be subjected to the chemical reaction.

Process Parameter



Characteristics

- Metal removal technique: Heating, melting, and vaporizing by using plasma.
- Work material: All materials that conduct electricity.
- Tool: Plasma jet
- Velocity of plasma jet: 500 m /s
- Power range: 2 to 220 kW
- Current: As high as 600 amp.
- Voltage: 40 – 250 V
- Cutting speed: 0. 1 to 7 m / min
- Metal removal rate: 145 cm3 /min

Advantages

- It can be used to cut any metal.
- The cutting rate is high.
- As compared to the ordinary flame-cutting process, it can cut plain carbon steel four times faster.
- It is used for the rough turning of very difficult materials.

- Due to the high speed of cutting, the deformation of sheet metal is reduced while the width of the cut is minimum, and the surface quality is high.

Disadvantages

- It produces a tapered surface.
- The protection of noise is necessary.
- The equipment cost is high.
- Protection of eyes is necessary for the operator and persons working in nearby areas.
- Oxidation and scale formation takes place. So, it requires shielding.
- The work surface may undergo metallurgical changes.

Applications

- It is used for cutting alloy steels, stainless steel, cast iron, copper, nickel, titanium, aluminum, and alloy of copper and nickel, etc.
- It is used for profile cutting.
- It is successfully used for turning and milling of hard to-machine materials.
- It can be used for stack cutting, shape cutting, piercing, and underwater cutting

1.9 ELECTRON BEAM MACHINING

Electron beam machining is a thermal process used for metal removal during the machining process.

In electrical beam machining, electrical energy is used to generate the electrons with high energy. In the Electron Beam Machining process, a high velocity focused beam of electrons are used to remove the metal from the workpiece. These electrons are traveling at half the velocity of light i.e., 1.6 x 10∧8 m / s. This process is best suited for the micro-cutting of materials.

When the high-velocity beam of electrons strikes the workpiece, its kinetic energy is converted into heat. This concentrated heat raises the temperature of workpiece material and vaporizes a small amount of it, resulting in the removal of material from the workpiece.

Types of EBM Process:

The following two methods are used in the EBM process.

1. Machining inside the vacuum chamber.
2. Machining outside the vacuum chamber.

Construction

Tungsten Filament: which is connected to the negative terminal of the DC power supply and acts as the cathode.
Grid cup: which is negatively based concerning the filament
Anode: which is connected to the positive terminal of the DC power supply.

- The focusing lens is used to focus the electrons at a point and reduces the electron beam up to the cross-sectional area of 0.01 to 0.02 mm diameter.
- The electromagnetic deflector coil is used to deflect the electron beam to different spots on the workpiece. It can also be used to control the path of the cut.

Annular Bias Grid:

It is present next to the cathode. An annular bias grid is a spherical-shaped bias grid and prevents the bend of electrons produced by the cathode. It acts as a switch and operates the electron gun in pulse mode.

Magnetic Lenses:

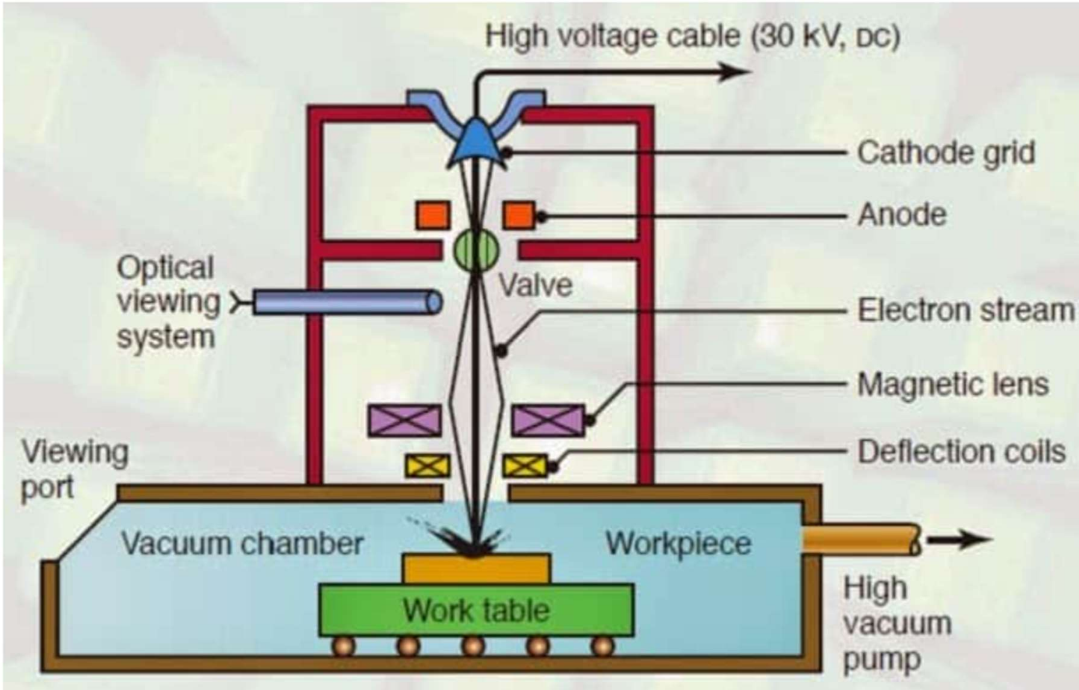
Magnetic lenses reduce the deviation of electron beams and give them shape. It only allows convergent electrons to pass and occupy electrons with low energy deviations. This improves the quality of the beam.

Deflector Coils:

The deflector coil carefully guides the high-velocity electron beam to the desired location on the workpiece and improves the pore size.

Electromagnetic Lens:

This helps to focus the electron beam to the desired location.



Electron beam machining Diagram

Working of EBM:

When the high voltage DC source is given to the_electron gun, tungsten filament wire gets heated and the temperature raises up to 2500°C.

Due to this high temperature, electrons are emitted from tungsten filament. These electrons are directed by a grid cup to travel towards downwards and they are attracted by the anode.

The electrons passing through the anode are accelerated to achieve high velocity as half the velocity of light (i.e., 1.6 x 10 ^8 m /s) by applying 50 to 200 kV at the anode.

The high velocity of these electrons are maintained until they strike the workpiece. It becomes possible because the electrons travel through the vacuum.

This high-velocity electron beam, after leaving the anode, passes through the tungsten diaphragm and then through the electromagnetic focusing lens.

Focusing lenses are used to focus the electron beam on the desired spot of the workpiece.

When the electron beam impacts on the workpiece surface, the kinetic energy of high-velocity electrons is immediately converted into the heat energy. This high-intensity heat melts and vaporizes the work material at the spot of beam impact.

Since the power density is very high (about 6500 billionW/mm ^2), it takes few microseconds to melt and vaporize the material on impact.

This process is carried out in repeated pulses of short duration. The pulse frequency may range from 1 to 16,000 Hz and duration may range from 4 to 65,000 microseconds.

By alternately focusing and turning off the electron beam, the cutting process can be continued as long as it is needed.

A suitable viewing device is always incorporated with the machine. So, it becomes easy for the operator to observe the progress of the machining operation.

Process Parameters:

The parameters which have a significant influence on the beam intensity and metal removal rate are given below:

- Control of current.
- Control of spot diameter.
- Control of focal distance of the magnetic lens.

Characteristics

- The electron beam machine operates in pulse mode, and this biasing is achieved by an annular biased grid.
- Beam currents can be as low as 200 μamp to 1 amp.
- The pulse duration obtained in the EBM machine is 50 μs to 15 ms.
- The energy near the pulse is 100 j / pulse.
- It uses voltages in the range of 150 kV to 200 kV. And this voltage is used to speed up electrons to about 200,000 km/s.

Advantages

- It is an excellent process for micro finishing (milligram/ s).
- Very small holes can be machined in any type of material to high accuracy.
- Holes of different sizes and shapes can be machined.
- There is no mechanical contact between the tool and the workpiece.

Disadvantages

- The metal removal rate is very slow.
- The cost of equipment is very high.
- It is not suitable for large workpieces.
- High skilled operators are required to operate this machine.
- High specific energy consumption.

Application

- Electron Beam Machining is mainly used for micro-machining operations on thin materials. These operations include drilling, punching, slotting, scribing, etc.
- Drilling of holes in pressure differential devices used in nuclear reactors, aircraft engines, etc.
- It is used to remove small broken taps from holes.
- The micro-drilling operation for thin drilling (up to 0.002 mm), wire drawing dies, parts of the electron microscope, injector nozzle for diesel engine, etc.
- A microcracking technique is known as "electron beam lithography" is being used in the manufacture of field emission cathodes, integrated circuits, and computer memories.

2.2 Moulding processes:

1. Injection Moulding Process-Machine

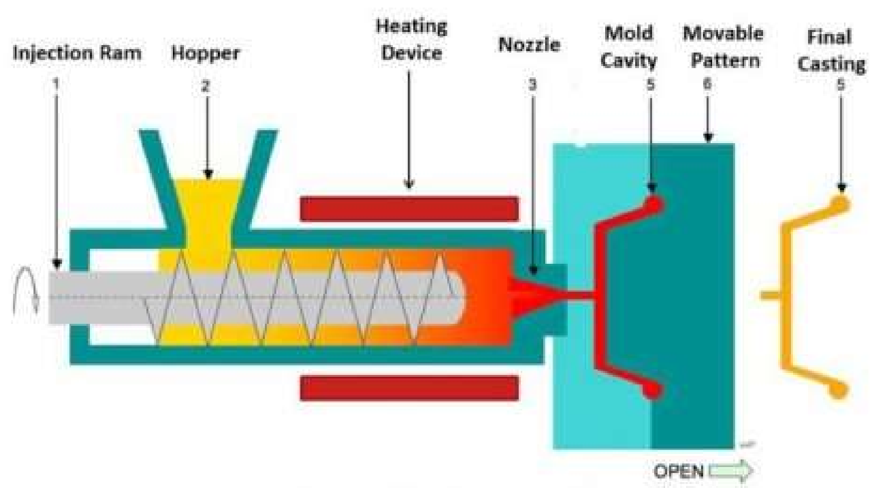
It is a manufacturing process used for producing parts or components by injecting molten material into the mold cavity.

Injection molding can be performed with only one of these materials like glasses and most common thermoplastic polymers.

Injection molding is mainly done on glasses, elastomers, and most commonly thermoplastic and thermosetting polymers but this technique is widely used for the fabrication of thermoplastic materials.

This process is done by heating of raw material and injecting them into the mold cavity by applying pressure at a specific temperature without any change in their chemical composition.

Working



Injection Moulding Machine

The Injection Molding Machine consists of

- Hopper
- Hydraulic System
- Motor
- Screw
- Heater
- Mold

Molding material/ raw material pour into the hopper by feeding device.

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LECTURE NOTE

After that molding material goes down under the action of gravity into the cylinder (barrel) as shown in diagram.

A circumferential heater which is located on the barrel is used to melt the material. When powder form of molding material goes dawn into the barrel from hopper it starts melting and a hydraulic ram or rotating screw pushes the material forward into the mold by applying some pressure.

Molten plastic material is injected into a closed mold attached on the other side of barrel; in this split mold is used. Molding material goes forward continuously by the rotating screw.

The pressure applies by the hydraulic system, the Injection pressure is generally 100-150 MPa. After injection; pressure is applied for some time or locked at the same position with some force.

After the whole process is done the parts manufactured is cooled sufficiently. Then mold is open and some ejectors are used for proper removal of the part without damage. After removing the part mold is closed again

PROCESS PARAMETERS:

- Process parameter varies according to condition and requirements.
- Weight of the parts produced by this process is generally 100 to 500 g.
- Cycle time for produce a single part is generally 5 to 60 seconds depends upon the parts manufacture.
- Heating temperature of molding material is 150-350 degree centigrade.
- Injection capacity of molding machine is 12,000 to $2.2 \times 10^6 \ mm^3$.
- Injection pressure is 100-150 MPa.
- Locking force is 0.1 to 8.0 MN.

ADVANTAGES:

- The main advantage of this process is that complex shapes components having small wall thickness (5-15 mm) can be easily molded and removed from the die without damage.
- Parts which are made by injection molding have good dimensional tolerance.
- The major advantage of this technique is that the scrap produced by this is very less as compare to some other processes.

- Parts made by injection molding process are competing with parts made by investment casting and complex machining parts.
- This process is having high production rate as compare to other techniques.

DISADVANTAGE:

- Initial cost/ setup cost of this process is very high due to design, testing and tooling of the whole equipment.
- Investment molding is generally limited to some special kind of materials like thermoplastic materials or some polymers only.
- High tooling cost i.e. the mould used is made by several processes and testing the overall cost of making a single mold is very high. For different parts different kind of molds are required.

APPLICATIONS:

- Injection molding is used for making complex shape parts of various sizes having less wall thickness.
- Typical parts like cups, containers, toys, plumbing fittings, electrical components, telephones receivers, bottle caps, automotive parts and components.

2. <u>COMPRESSION MOLDING PROCESS:</u>

- Compression Molding is a molding method in which the molding material(especially Thermoplastics or Thermoset Plastics) are generally preheated and are placed in a mold cavity.
- The heating or cooling given to the cavity is dependent upon the type of plastic you are using.

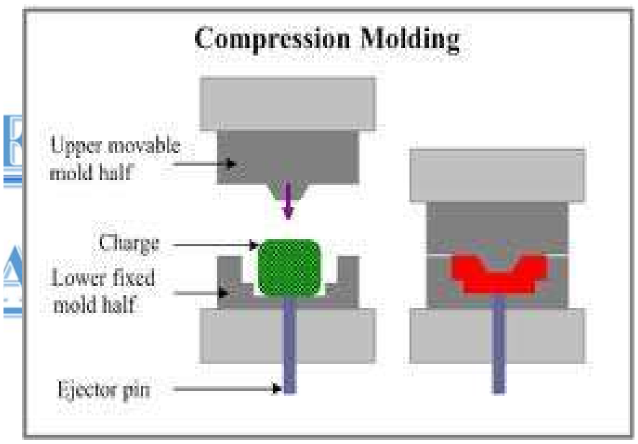
Compression Molding for Thermoset Plastics:

- In this Process, the Thermoset liquid will be kept in the mold of a required shape of the component and is subjected to the heating process.
- During heating, the liquid will undergo the following changes i.e. liquid will undergo in the form of **gel** and by the application of pressure, it turns to **solid.**
- After that, the Compression load is applied at the gel condition of the liquid so that shaping of the component takes place.
- **Heating** converts the liquid into solid whereas, compression load will give the shape to the component.

Compression Molding for Thermoplastics:

- The Thermoplastic molten liquid will be kept in the mold of the required shape of the component and subjected to compression followed by **a cooling process** of the mold.
- Compression gives the shape of the component whereas cooling converts the molten liquid into a solid.
- Density and the Strength of the plastic can be controlled by varying the compression load “P”.
- Small and simple shapes of the component can be produced with uniform density.
- Larger and more complex shapes of the components are difficult to produce with uniform density.
- Difficult to insert metal pieces in the plastic part during the production of the component.

Working



The material is placed into the mould.
The product is heated until somewhat soft and pliable.
A hydraulic tool presses the material against the mould.
Once the material is hardened and has taken shape of the mould it is ejected
The final products will require additional work, such as cutting away the flashing
Other products will be ready immediately upon leaving the mould.

Advantages

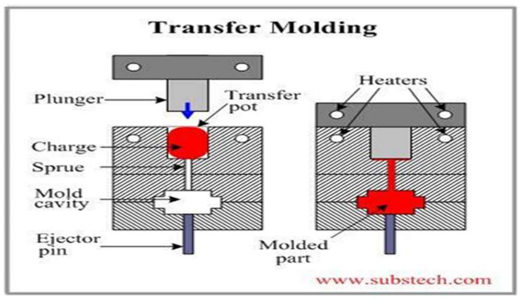
- It is a simpler process.
- It involves lower tooling costs.
- It is great for producing large items and thicker parts.
- It can be a good choice for insert molding and multi-color molding.
- It is cost-effective for short production runs.

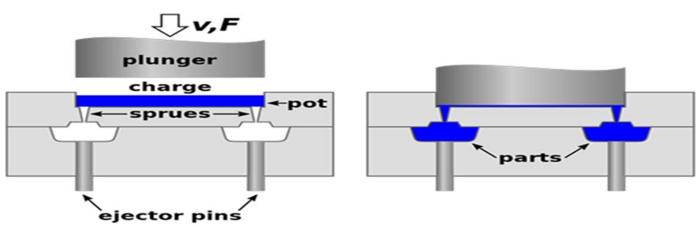
Disadvantages

- It has a higher chance of post-molding costs
- It has slower processing times.
- It is not suitable for all complex designs

3. TRANSFER MOULDING.

Transfer moulding process combines the principle of compression and transfer of the polymer charge. Transfer moulding is similar to compression moulding except that instead of the moulding material being pressurized in the cavity, it is pressurized in a separate chamber and then forced through an opening and into a closed mould. The advantages of transfer moulding are that the preheating of the material and injection through a narrow orifice improves the temperature distribution in the material and accelerates the crosslinking reaction. As a result the cycle times are reduced and there is less distortion of the moulding. The improved flow of the material also means that more intricate or complicated shapes can be produced.





MOULDING SEQUENCE:

- The required amount of polymer charge is weighted and inserted into the transfer pot before the moulding process.
- The transfer pot is heated by the heating element above the melting temperature of the polymer charge.
- The liquid charge is gravity filled through the sprue to the mold cavity.
- A "piston/plunger/ram and cylinder" arrangement is built in the transfer pot so that the resin is transferred into the mould cavity through a sprue.
- The plunger is also preheated in the transfer pot.
- The plunger is used to push the liquid polymer charge from the transfer pot into the mould cavity under pressure.

- The mould cavity remains closed as the polymer charge is inserted.
- The mould cavity is held closed until the resin gets cured which means the material sets hard to the cavity shape after a certain time (cure time) has elapsed.
- The mold cavity is opened and the molded part can be removed once it has hardened with the help of an ejector pin.
- The sprue and gate attached to the moulded part have to be trimmed after the process has been completed.

ADVANTAGES:

- Fast setup time and lower setup costs.
- Low maintenance cost.
- More intricate or complicated shapes can be produced.
- Plastic parts with metal inserts can be made.
- Design flexibility.
- Dimensionally stable.

DISADVANTAGE:

- Warpage is more of a problem because the flow of transfer materials is softer and shrinks more than compression grade materials.
- The scrap rate for transfer molded parts will usually be higher than that for compression moulded parts because of the added scrap from the cull and runner.
- To prevent the mould from opening slightly resulting in heavy flashing of the parts, the clamping tonnage for transfer mould parts is greater than for compression molded parts. Thus, a higher tonnage press is required.
- Air can be trapped in the mould.

2.3 EXTRUDING; CASTING; CALENDERING.

Extrusion

In extrusion, mixed plastic compound is conveyed through a heated barrel using a spiral-shaped screw, converting it into molten plastic. A lip die flattens the mass into a sheet of the desired width and thickness, which then passes through heated embossing rolls that impart a surface finish. The sheet is then trimmed to its final dimension.

Calendaring

In calendaring, raw materials enter a mixing chamber where they are melted. This molten plastic then moves through a series of heated rollers that compress the material to the desired thickness. Finally, it passes through a series of surface conditioning and cooling rolls, then is wound into custom rolls or cut into sheets.

The calendaring machine is represented in the following figure.

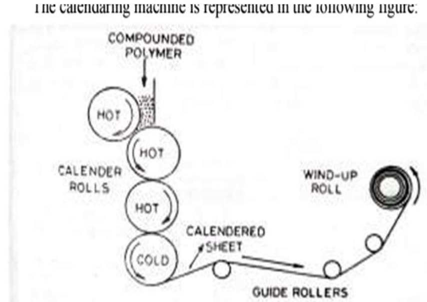


Fig. 15.1 Schematic diagram of a calendering machine.

Casting

Casting is the process in which liquid polymeric material is poured into the mold. The mold contains a hollow cavity of the desired shape and size.

The molded material is allowed to cool to make the solid.

This solidified part is known as casting which is ejected out of the mould to complete the process.

Mainly three types of casting techniques are known: 1. Die casting 2. Rotational casting 3. Film casting.

2.4 FABRICATION METHODS-SHEET FORMING, BLOW MOULDING, LAMINATING PLASTICS (SHEETS, RODS & TUBES), REINFORCING.

1. SHEET FORMING

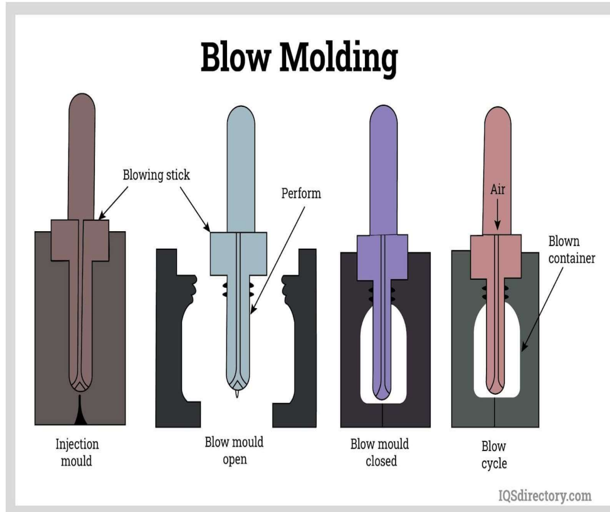
Thermoforming is plastic fabrication process in which the thermoplastics are heated and reshaped under pressure.

It is a unique process that involves the use of very thin plastic and is carried out by various techniques including bending plastic sheets and vacuum forming.

In this process, the tooling cost is considerably low in comparison to other fabrication processes because the thermoformed part does not need high temperature and pressure conditions to be fabricated.

Due to this, the mold used in thermoforming is often made up of wood, plaster of Paris, plastic, or aluminum.

It is a versatile and efficient process. It is usually used in the packaging of food, fabrication of disposable cups, toys, aircraft windscreen, and cafeteria trays.



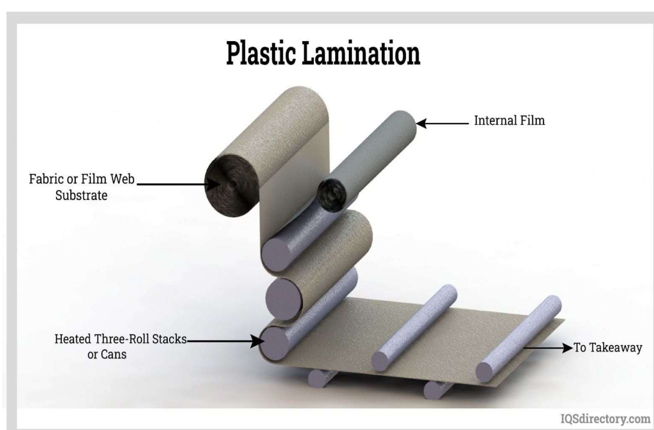
2. BLOW MOULDING

Blow molding is another plastic fabrication process that involves the heating of plastic and transferring it into a mold. In this method, the tubes of plastic called parison are heated and transferred to the mold, then at the opening of the tube, the air is blown in to inflate the tube into the desired shape.

The material used in this method is thermoplastic pellets which can be either high-density polyethylene, polypropylene, polystyrene, or polyvinyl chloride. In blow molding, there are three main types, extrusion blow molding, injection blow molding, and injection stretch blow molding. Although in each sub-type a few steps differ from each other yet the main principles stay the same , the air is blown into the heated tubes of plastic to acquire a desired shape. This method is popular to manufacture bottles, fuel tanks, etc.

The most important advantage of blow molding is the low tool and die cost and fast production rates. However, the products made out of blow molding have limited strength.

3. LAMINATING PLASTICS



In the plastic lamination method, various layers of plastic are held together creating a barrier along the surface of another material. This technique not only improves the durability and aesthetics of the product but reduces the potential need for maintenance by shielding the sensitive and deterioration-prone material.

There are two common types of plastic lamination, film, and resin. In both types, heat and pressure are applied to create the barrier. Film lamination on the other hand is considered to be more effective than resin lamination. Although the resin application is frequently used to create adhesive layers between common materials such as papers, fabrics, etc.

A major drawback of this process is that this is a time-consuming process hence the production rate is very low as compared to other plastic fabrication methods. However, this method produces plastic with properties like strength, stiffness, and temperature resistance much superior to others.

2.5 Applications of Plastics

- Aerospace
- Construction
- Electrical and Electronic Applications
- Packaging: Plastics are the perfect material for use in packaging goods. Plastics is versatile, hygienic, lightweight, flexible, and highly durable.
- Automotive: Bumpers, dashboards, engine parts, seating, and doors
- Energy Generation: Wind turbines, solar panels, and wave booms
- Furniture: Bedding, upholstery, and household furniture
- MedicalandHealthcare: Syringes, blood bags, tubing, dialysis machines, heart valves, artificial limbs, and wound dressing.

3.1 ADDITIVE MANUFACTURING PROCESS

Additive manufacturing technology uses 3-Dimensional printing technology to create parts and assemblies without tooling. Additive manufacturing reduces design risk, provides efficiencies for the manufacturing process, and is used for low-production part runs. There are five industries where the amazing capabilities of additive manufacturing have transformed production:

- Aerospace. Aerospace companies were some of the first to adopt additive manufacturing.
- Medical.
- Transportation.
- Energy.
- Consumer Products.

The term rapid prototyping (RP) is used in various industries to describe the process of rapidly creating a system or part representation before final release commercialization.

In other words, the emphasis is on creating something quickly and the output is a prototype or basis model from which further models and eventually the final product will be derived.

Management consultants and software engineers both also use the term rapid prototyping to describe a process of developing business and software solutions in a piecewise fashion that allows clients and other stakeholders to test ideas and provide feedback during the development process.

In a product development context, rapid prototyping was used widely to describe technologies that created physical prototypes directly from digital model data. This text is about these latter technologies, first developed for prototyping, but now used for many more purposes.

Users of RP technology have come to realize that this term is inadequate and does not effectively describe more recent applications of the technology.

The term rapid prototyping also overlooks the basic principle of these technologies in that they all fabricate parts using an additive approach.

NEED FOR ADDITIVE MANUFACTURING

Initially, AM was used specifically to create visualization models for products as they were being developed.

It is widely known that models can be much more helpful than drawings or renderings in fully understanding the intent of the designer when presenting the conceptual design.

While drawings are quicker and easier to create, models are nearly always required in the end to fully validate the design.

Following this initial purpose of simple model making, AM technology has developed over time as materials, accuracy, and the overall quality of the output improved.

Models were quickly employed to supply information about what is known as the"3 Fs" of Form, Fit, and Function.

The initial models were used to help fully appreciate a design's shape and general purpose (Form).

Improved accuracy in the process meant that components were capable of being built to the tolerances required for assembly purposes (Fit).

AM technology is only useful for making models, though, which would be inaccurate and undervaluing the technology.

AM, when used in conjunction with other technologies to form process chains, can be used to significantly shorten product development times and costs.

Improved material properties meant that parts could be properly handled so that they could be assessed according to how they would eventually work (Function).

3.2 FUNDAMENTALS OF ADDITIVE MANUFACTURING, AM PROCESS CHAIN

Step 1: Conceptualization and CAD

The generic AM process starts with 3D CAD information.

There may be many ways as to how the 3D source data can be created.

The model description could be generated by a computer.

Most 3D CAD systems are solid modeling systems with some surface modeling components.

Step 2: Conversion to STL

The term STL was derived from STereoLithograhy. STL is a simple way of describing a CAD model in terms of its geometry alone.

It works by removing any construction data, modeling history, etc., and approximating the surfaces of the model with a series of triangular facets.

The minimum size of these triangles can be set within most CAD software and the objective is to ensure the models created do not show any obvious triangles on the surface.

The process of converting to STL is automatic within most CAD systems.

STL file repair software is used when there are problems with the file generated by the CAD system that may prevent the part from being built correctly.

With complex geometries, it may be difficult to detect such problems while inspecting the CAD or the subsequently generated STL data.

If the errors are small, then they may even go unnoticed until after the part has been built.

STL is essentially a surface description, the corresponding triangles in the files must be pointing in the correct direction; (in other words, the surface normal vector associated with the triangle must indicate which side of the triangle is outside vs. inside the part). While most errors can be detected and rectified automatically, there may also be a requirement for manual intervention.

Step 3: Transfer to AM Machine and STL File Manipulation

Once the STL file has been created, it can be sent directly to the target AM machine. Ideally, it should be possible to press a "print" button and the machine should build the part straight away.

However, there may be a few actions required prior to building the part. The first task would be to verify that the part is correct.

AM system software normally has a visualization tool that allows the user to view and manipulate the part.

The user may wish to reposition the part or even change the orientation to allow it to be built at a specific location within the machine.

It is quite common to build more than one part in an AM machine at a time. This may be multiples of the same part (thus requiring a copy function) or completely different STL files.

Step 4: Machine Setup

All AM machines will have at least some setup parameters that are specific to that machine or process.

Some machines are only designed to run perhaps one or two different materials and with no variation in layer thickness or other build parameters. In the more complex cases to have default settings or save files from previously defined setups to help speed up the machine setup process and to prevent mistakes.

Step 5: Build Setup

The first few stages of the AM process are semi-automated tasks that may require considerable manual control, interaction, and decision-making.

Once these steps are completed, the process switches to the computer- controlled building phase.

All AM machines will have a similar sequence of layer control, using a height-adjustable platform, material deposition, and layer cross-section formation.

All machines will repeat the process until either the build is complete or there is no source material remaining.

The output from the AM machine should be ready for use.

More often the parts still require a significant amount of manual finishing before they are ready for use. The part must be either separated from the build platform on which the part was produced or removed from excess build material surrounding the part. Some AM processes use additional material other than that used to make the part itself (secondary support materials).

Step 7: Post Process

Post-processing refers to the (usually manual) stages of finishing the parts for application purposes.

This may involve abrasive finishing, like polishing and sandpapering, or application of coatings.

3.3 ADVANTAGES

- AM can print complex 3D geometries with internal features without any tooling.
- Reduced waste compared to machining.

- Part can be printed directly from the 3D model without the need for a drawing.
- Prototypes can be made quicker, allowing designers to check different iterations resulting in a quicker design cycle phase.
- No or less tooling for smaller batches compared to traditional machining.
- Production tooling can be printed.
- Different materials can be mixed during the printing process to create a unique alloy.
- Different sections of the part can be different variants of the same alloy.

DISADVANTAGES

- High production costs because of the equipment cost
- Various post-processing required depending on the type of additive manufacturing used.
- Small build volume compared to other manufacturing part sizes such as sand casting.
- Poor mechanical properties hence need post-processing.
- Poor surface finish and texture compared to manufacturing processes like CNC and investment casting.
- The strength of the parts is comparably weaker compared to manufacturing processes such as Die casting, Investment casting and CNC machining.

3.4 CLASSIFICATION OF AM PROCESS

VAT PHOTOPOLYMERIZATION:

This process uses a technique called Photopolymerization, in which radiation-curable resins or photopolymers are used to create three-dimensional objects by selectively exposing them to ultraviolet light. When exposed, these materials undergo a chemical reaction and become solid. Only plastics can be printed using these technologies.

BINDER JETTING PROCESS:

Binder Jetting selectively deposits the bonding agent, a binding liquid, to join the powder material to form a 3D part. This process is different to any other AM technology as it does not employ heat during the process like others to fuse the material.

The print head and a powder spreader deposit alternating layers of bonding agent and build material to form a 3d object.

DIRECTED ENERGY DEPOSITION:

Directed energy deposition technology uses focused thermal energy such as a laser, electron beam, or plasma arc to melt and fuse the material as they are deposited to create a 3d object. These are very similar to the welding process but very finely detailed.
The geometric information included in a Computer-Aided Design (CAD) solid model is used by LENS 3D printers to autonomously direct the DED process as it builds up a part layer by layer.
The two main types of Directed energy deposition technologies are LENS and EBAM. EBAM uses an electron beam, and LENS uses a focused laser to melt the material.

MATERIAL EXTRUSION:
Material Extrusion is an additive manufacturing technique that uses a continuous filament of thermoplastic or composite material to construct 3D parts
In this additive manufacturing technique, the continuous filament of thermoplastic is fed through a heated nozzle before being deposited layer by layer onto the build platform to create the object.

MATERIAL JETTING:
In material jetting, build material droplets are selectively deposited layer by layer into the build platform to form a 3D part.
This additive manufacturing technique is very similar to standard inkjet printers, where the material droplets are deposited layer by layer selectively to create a three-dimensional object. Once a layer is complete, its cured by ultraviolet light.
Powder material jetting includes the following commonly used printing technologies: UV cured Material Jetting, Drop on Demand (DOD), and NanoParticle Jetting (NPJ).

POWDER BED FUSION:
Powder bed fusion is an Additive Manufacturing technique that uses either a laser or electron beam to melt and fuse the material to form a 3D geometry part. The Powder Bed Fusion includes the following commonly used printing technologies: Multi Jet Fusion (MJF), Direct metal laser sintering (DMLS), Electron beam melting (EBM), Selective heat sintering (SHS), Selective laser melting (SLM) and Selective laser sintering (SLS).
Powder bed fusion processes, especially selective laser sintering, are early industrial additive manufacturing techniques. This method uses a laser or electron beam to melt the powdered material and fuse them to create a solid object.

SHEET LAMINATION:

Sheet lamination technologies use sheets of material to create 3D objects by stacking them and laminating them using either adhesive or ultrasonic welding. Once the object is built, the unwanted areas of the sections are removed layer by layer.

Sheet lamination technology is an umbrella term for Ultrasonic Additive Manufacturing (UAM, Selective Deposition Lamination (SDL, and Laminated Object Manufacturing (LOM).

Distinguish between additive manufacturing (AM) and CNC machining

Parameter	AM machining	CNC machining
Material	AM includes development of polymeric material, waxes and paper laminates.	CNC used for machining soft materials or medium density fiber board, machinable foams and machinable waxes etc.
Speed	Higher, takes few hours to make part.	Lower, takes weeks to develop same part.
Complexity	Complex operation	Easy operation
Efficiency	Higher	Lower
Accuracy	More accurate	Comparatively less
Programming	In AM machine the part won't be built properly if in correct programming is done	In correct programming can badly damage the machine and may even be safety risk.
Process	It is an additive process.	It is subtractive process.

3.5 APPLICATION OF AM

Medical

The rapidly innovating medical industry is using additive manufacturing solutions to deliver breakthroughs to specialists, patients, and research institutions. Medical manufacturers are using a wide range of high-strength and biocompatible 3D printing materials, from unbending to flexible and hazy to transparent, to modify designs like never before.

From practical prototypes and true-to-life anatomical models to surgical grade components, additive manufacturing is making way for unforeseen advancements and life-saving devices. Some applications revolutionizing the medical industry are orthopedic implant devices, pre-surgery models from CT scans, dental devices, custom saw and drill guides, enclosures, and specialized instrumentation.

Benefits of Additive manufacturing for medical:

- Personalized healthcare
- Enhanced medical devices.

Energy

Success in the energy industry depends on rapidly developing tailored, mission-critical elements that can withstand extreme conditions. Additive manufacturing's advancements in producing efficient, lightweight, on-demand components and environmentally friendly materials give answers for diverse needs and field functions. Some crucial applications that have emerged from the gas, oil, and energy sectors include rotors, turbine nozzles, stators, down-hole tool components and models, flow meter parts, mud motor models, fluid/water flow analysis, pressure gauge pieces, pump manifolds, and control-valve components.

With the advancement in corrosion-resistant metal materials for customized parts that might require going underwater or in other harsh environments, there is no telling what major energy companies may accomplish with additive manufacturing.

Aerospace

Aerospace organizations were the first to adopt additive manufacturing. Some of the most demanding sector performance standards exist in this realm, needing parts to hold up in tough conditions. Engineers designing and manufacturing commercial and military aerospace platforms should consider flight-worthy components made from high-performance materials.

Benefits of Additive Manufacturing for Aerospace:

- Low-volume production
- Material efficiency
- Part consolidation

- Weight reduction

Consumer Products

For graphic artists, designers, and marketing teams, the time it takes to form an idea and launch it to the market is about everything. Part of that time is spent on simulating the final product's look and feel during design feedback to prove ideas to stakeholders. Consumer product manufacturers have adopted 3D printing to assist in developing iterations and fast adjust the design.

Benefits of Additive manufacturing for consumer products:

- Faster time-to-market
- Enhanced product development
- Mass customization

Transportation

Life in the fast lane simply means endurance to challenging environments such as extreme speeds and heat. The transportation sector requires parts that stand up to rigid testing and is lightweight to avoid any unnecessary drag. With a variety of rugged, high-temperature materials and additive manufacturing innovation, and the ability to build very complex geometries, transportation organizations are just scratching the surface of what can be made using additive manufacturing for their vehicles.

3.6 Web Based Rapid Prototyping Systems