ADVANCE MANUFACTURING MANUAL

5 SEM

20ME53I

DIPLOMA MECHANICAL ENGINEERING

INDEX

QUALITY AND INSPECTION METHODS		
1	Perform measurement with desired accuracy to check the components for Functionality and conformance to defined standards using different instruments like Vernier calliper, Vernier height gauge, Micrometre, Depth Gauge, Bevel Protractor, Sine bar, Dial Indicator	
2	Demonstrate the construction and working Principle of Profile Projector Check the Dimensional Accuracies of the Models using Profile Projector	
3	Check the Dimensional Accuracies of the Models using CMM for different Components	
4	Discuss and Demonstrate different Non-destructive testing Methods • Radiography Testing • Ultrasonic Testing • Magnetic Particle Testing	
5	Discuss and Demonstrate different Non-destructive testing Methods • Penetrant Testing • Visual Testing • Electromagnetic testing	
IOT AND IIOT		
1	Material handling in Advanced Manufacturing: a) Automated Guided Vehicle (AGV)- • Overview on AGV • Working Principle • Applications of AGV's • Types of AGV • AGV Navigation	
2	Automated storage and Retrieval System (AS/RS) • Overview on AS/RS • Working Principle • Types of AS/RS • Application of AS/RS	
3	Robots in Advanced Manufacturing • Concepts of Industrial Robots • Impacts of Robots in Manufacturing • Application of Robots Types of Robots • Articulated Robots • SCARA Robots • Cartesian Robots • Delta Robots	
4	Demonstration - Future of Robots in Manufacturing • Lights-Out Manufacturing • Internet of Things Capability • Transformations in Cybersecurity • Collaborative Industrial Robots- Cobots	
5	Convergence of IT (Information Technology) and OT (Operation Technology) • Technologies which bring Convergence of OT and IT ➢ No code Application ➢ Digital Twins ➢ Augmented Reality ➢ Edge computing	
6	Concepts of IIOT (Industry Internet of Things)- How it Works • IIOT – Analytics and Data Management	
7	Demonstrate Adoption of IIOT Technology • Predictive maintenance. • Remote Production Control. • Asset tracking. • Logistics management	
8	Demonstrate IIOT for • Sustainability Assessment of Manufacturing Industry • Lean Production System • Smart Factories	

Experiment: -1 USM: ULTROSONIC MACHINING

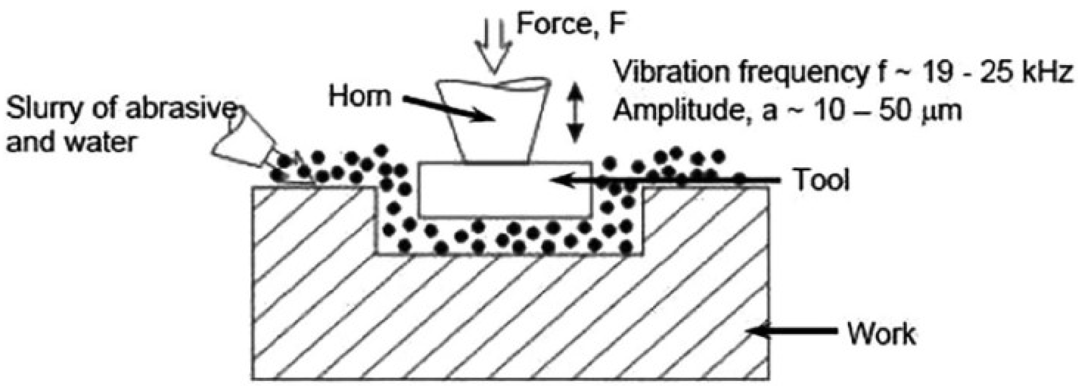
OBJECTIVE: To determine the material removal rate MRR dimensional tolerance (DT) and circularity of holes (CHO) using ultrasonic machining system (USM).

EQUIPMENT REQUIRED:

1. High power ultrasonic wave generator.
2. Transducer/converter.
3. Sonotrode/horn
4. Tool tip.
5. Abrasive feed system.

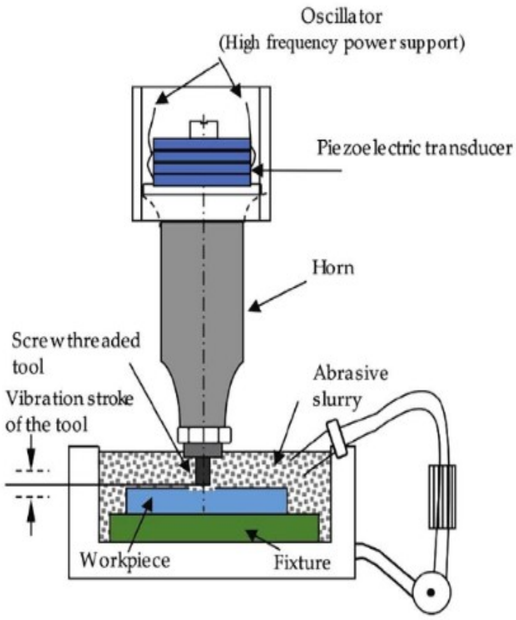
THEORY

Ultrasonic machining USM is a nontraditional process in the which abrasives contained in the slurry of driven against the work by a tool security oscillating of 25-200 μm and high frequency of 15 to 30kHz. In ultrasonic machining tool is deserved shape vibration at ultrasonic frequency 19 to 25 Khz with amplitude of 15 to 50 microns over workpiece is generally tool is pressed down with a feed force f between the tool and work. Machining zone is flooded with the hard-abrasive particles generally in the form of water-based slurry. As the tool vibrate over the work piece. Abrasive particles act as indenture and indent both work and tool material. Abrasive particles as they indent the work material would remove the material from both tool and workplace. In ultrasonic machine in material removal is due to crack initiation. Propagation and brittle fracture of material. Usama is used for machining hard and brittle material. Which are poor conductors of electricity and does cannot be processed by electrochemical machining ECM or electro discharge machining EDM. The tool is USM is made to vibrate with high frequency.



WORKING PRINCIPLE

Ultrasonic machining is a mechanical type nontraditional machining process. It is employed to machine and brittle material both electrically conductive and nonconductive material having hardness usually greater than 40 HRC. The process was first developed in 1950s and was originally used for finishing EDM surfaces. On to the work surface in the midst of the flowing slurry. Main reason for using ultrasonic frequency is to produce better performance.



Schematic Diagram of Basic

HIGH-POWER ULTRASONIC WAVE GENERATOR

This solid-State variable Output Power supply with internal or external power or external power control. That converts 50/60Hz electrical power into 20KHz Electrical power by the help of an electro strictive transducer the power supply is designed for continuous duty industrial operation for optimum efficiency it is equipped with automatic frequency control and automatic load compensation providing constant output amplitude at desired setting to meet the different energy requirements encountered during the operation the cycle. The power supply incorporates and overload monitor to protect the system from conditions that could normally result in failure if an overload condition occurs.

TRANSDUCER/CONVERTER

Then 20 Khz electrical energy from the power supply is applied to the transducer elements Which transform the High frequency electrical oscillation into high frequency mechanical Vibration the heart of the converter is a lead zirconate Titanate electro strictive element Which when subjected to an alternating voltage expand and contract at the frequency of the Voltage. This electro strictive converter is highly efficient and the degree of energy conversion is 96. %

SONOTRODE/HORN

The purpose of the horn is to transfer the ultrasonic vibration from the converter to the tool material for horn should have good acoustical properties. Titanium and aluminum horns are considered the best material for the fabrication of horns. Horns are also made of brass. Steel and model. These horns are generally used for tools that over 1st (25.4mm) in diameter and model.

TOOL TIP

Tip attach to titanium horns and are available in a range or head thickness in order to maintain weight relationship with the horn for varying weights and lengths of tools. This allows the horn/tip/tool to operate at optimum frequency. Generally, tools are made of the materials like brass. Stainless steel mild steel or titanium so that tool wear rate (TWR) can be minimized. The value of ratio of TWR and MRR depends on kind of abrasive. Work material and tool material.

ABRASIVE FEED SYSTEM

Recirculating system with container and pump assembly with agitation jets helps to keep the pump grit in suspension. The slurry used in ultrasonic machining process is a mixture of abrasive grains and a liquid media mainly water. Kerosene benzene glycerol or thin oil. The ratio of abrasive to liquid can vary from 1:4 to 1:1 (by weight) slurry can be fed externally or internally. In the case of externally feeding. the slurry is pump fed by several jets covering the circumference of the tool or by a single jet. The abrasive used for an application should be harder than the material being machined otherwise the usable time of the abrasive will be reduced

OPERATIONS OF ULTRASONIC MACHINING

As the tool vibrates with a specific frequency, an abrasive slurry (usually a mixture of abrasive grains and water of definite proportion) is made to flow through the tool work interface. The impact force arising out of vibration of the tool end and the flow of slurry through the work tool interface actually causes thousands of microscopic abrasive grains to remove the work material by abrasion. Material removal from the hard and brittle materials will be the form of sinking, engraving or any other precision shape.

PROCESS PARAMETERS

The important parameters which affect the process are

a) frequency
b) amplitude
c) static loading (feed force)
d) hardness ratio of the tool and the workpiece
e) grain size
f) concentration of abrasive in the slurry
g) tool shape

PROCEDURE

1. After switching on the system, go to manual code (operator can perform following operation from main screen of MMI).
2. Manually open two safety locks and rotate the lever wheel to clockwise direction to check the gap between sonotrode tip and job.
3. Then put on the safety locks.
4. Then press down key from main screen and maintain the distance between sonotrode tip and job(required clearance up to 0.5 mm).
5. By pressing parameter key from main screen, operator can control system parameter by entering appropriate value.(speed (RPM)), distance (mm), dunking' distance(mico-meter), Dunking delay (sec).
6. For activation of auto and manual mode of operation, emergency switch must be released.
7. Go to auto mode and the system is ready for use to press start switch

OBSERVATIONS:

SL NO	Vibration amplitude (µm)	static load (gm)	Concentration (gm/m^3)	Weight of sample before machined (gm)	Weight of sample after machined(gm)	Machine time (sec)	First diameter (mm)	Second diameter (mm)	Third diameter (mm)	MRR (gm/sec)	DTE (mm)	COH (mm)
1												
2												
3												
4												
5												
6												
7												
8												
9												

CALCULATION:

1. Material removal Rate (MRR)

$$MRR = \frac{W1 - W2}{t}$$

Where W1= Weight of the sample before experiment
W2= Weight of the sample after experiment
T= Time of machining

2. Dimensional Tolerance (DT):

DT= (Average hole diameter)-(Cutting tool diameter(2 mm)

3. Circularity of hole (COH):

COH= (Highest hole diameter)- (Lowest hole diameter)

Conclusion:

From the above set of the experiment the following performance measures are obtained

MRR:...................gm/sec

DT:.......................mm

COH:....................mm

Experiment 2: - ECM : ELECTROCHEMCIAL MACHINING

AIM:

1. To understand the operating principle of electro chemical machining process
2. To understand the process parameters affecting the machining process
3. To understand the significance of governing equation for estimation of Material Removal Rate

EQUIPMENT REQUIRED:

The electrochemical machining system has the following modules:

1. Power supply
2. Electrolyte supply and cleaning system
3. Tool and tool feed system
4. Work piece and Work holding system.

THEORY

This is a process of anodic dissolution of work material by high current flowing through an electrolyte between shaped tool and work piece. The principle is exactly same as electroplating where the anode goes into solution expecting the cathode deposition. In ECM, the electrolyte is so chosen that there is no plating (decomposition of metals) on the cathode (tool) so the tool shape remains unchanged and if a close gap (0.1-0.2 mm) is maintained between the tool and work, the machined surface takes the replica of the tool shape.

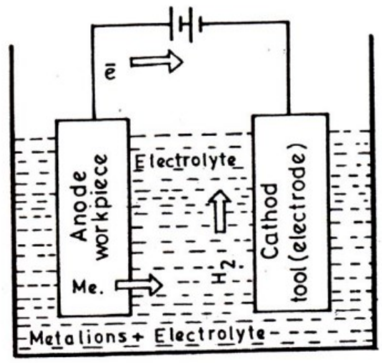
WORKING PRINCIPAL:

In the electrolyte cell (ECM) the reactions take place at different levels electrolyte, cathode and anode. It is evident from the above schemes that when current is flown through a solution of NaCL in water, the ions formed and will proceed to produce the desired effects as:

$NaCL = Na^+ + CL^-$

$H_2O = H^+ + (OH)^-$

The positive ions move towards the cathode (tool) while negative ions move towards anode (work piece) to react. Let - us analyse the two possible reactions at the cathode and anode.



1. Cathode Reaction

$\mathbf{Na^+ + e^- = Na}$

$\mathbf{Na + H_2O = Na(OH) + H^+}$

$\mathbf{2H^+ + 2e^- = H_2 \uparrow}$

It shows that there is no deposition on tool but only gas is formed, whereas, in cathode in machining an iron specimen for example:

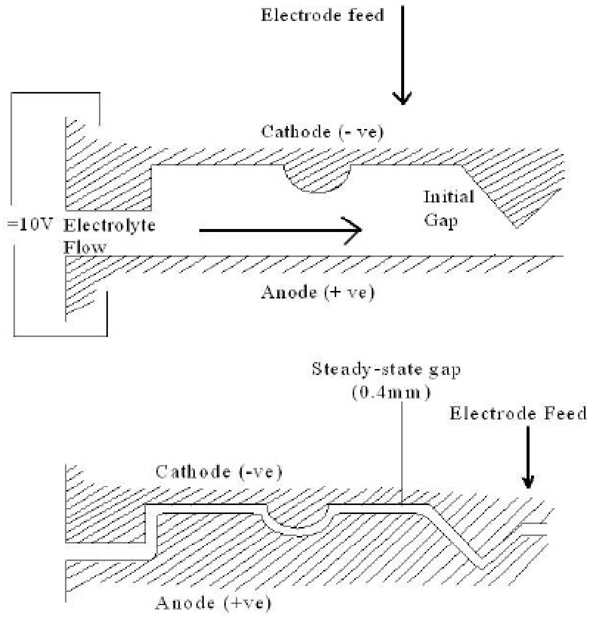
2. Anode Reaction

(iron) $Fe = Fe^{++} + 2e^-$

$Fe^{++} + 2CL^- = FeCL_2$

$Fe^{++} + 2(OH)^- = Fe(OH)_2$

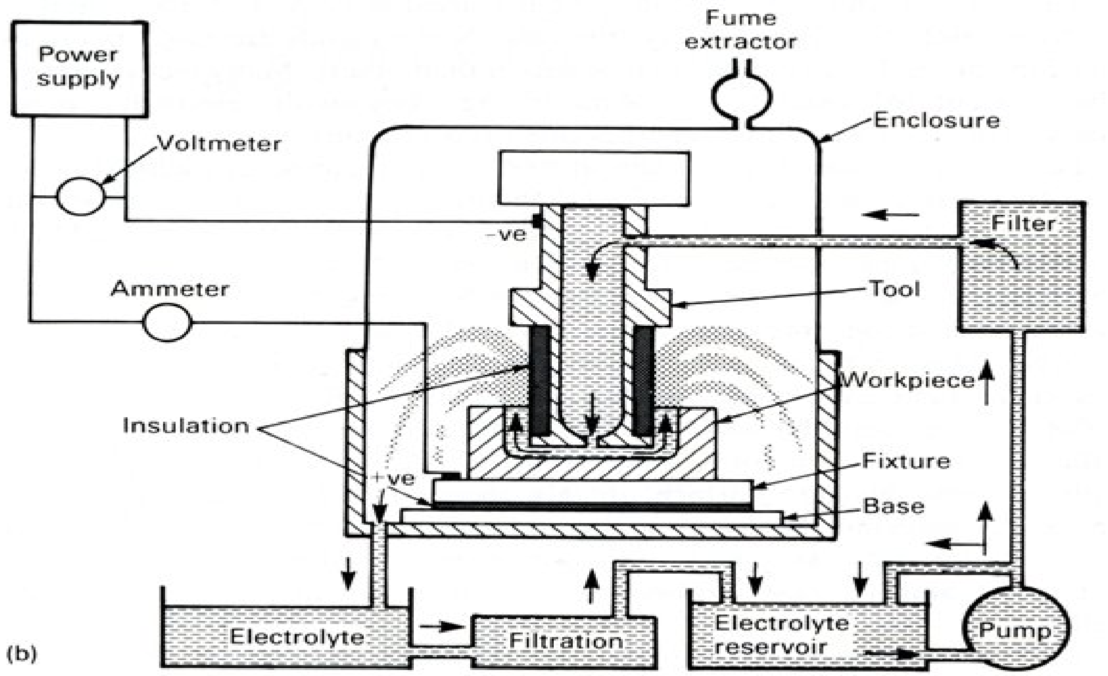
$FeCL + 2(OH)^- = Fe(OH)_2 + 2CL^-$



It shows metal (work piece), i.e. Fe goes into solution and hence machined to produce reaction products as iron-chloride and iron-hydroxide as a precipitate. Interesting part is that the removal is an atom by an atom, resulting in higher finish with stress and crack free surface, and independent of the hardness of the work material.

As current flows, several phenomena occur at the electrode surfaces to oppose the very cause of it (make the above reactions to proceed). These emf opposing the flow are termed as anode and cathode overvoltage (Fig. 3.4) and include activation polarization, concentration polarization and ohmic overvoltage. When no current flows, electrochemical reactions occurring at an electrode are in equilibrium. However, to make the dissolution proceed, one has to apply a voltage in excess of electrode and activation polarization potentials, i.e. about 2 volts maximum.

Equipment Details



POWER SUPPLY:

During ECM, a high value of direct current (may be as high as 40000 A) and a low value of electric potential (in range of 5-25 V) across IEG (Interelectrode gap) is desirable. The highest current density achieved so far is around 20,000 A/cm2. Hence, with the help of a rectifier and a transformer, three phase AC is converted to a low voltage, high current DC. Silicon controlled rectifier (SCRs) are used both for rectification as well as for voltage regulation because of their rapid response to the changes in the process load and their compactness. Voltage regulation of ± 1% is adequate for most of the precision ECM works. However, lack of process control, equipment failure, operator's error, and similar other reasons may result in sparking between tool and work. The electrical circuitry detects these events and power is cut off (using the device like SCRs) within 10 microseconds to prevent the severe damage to the tool and work. In case of precision works even a small damage to an electrode is not acceptable. It may be minimized by using a bank of SCRs placed across the DC input to ECM machine.

ELECTROLYTE SUPPLY AND CLEANING SYSTEM:

The electrolyte supply and cleaning system consisting of a pump, filter, piping's, control valves, heating or cooling coils, pressure gauges, and a storage tank (or reservoir). Electrolyte supply ports may be made in the tool, work or fixture, depending upon the requirement of the mode of electrolyte flow. Small inter electrode gap, usually smaller than 1mm, should be maintained for achieving High MRR and high accuracy. For this purpose, smooth flow of electrolyte should be maintained and any blockade of such a small gap by particles carried by electrolyte, should be avoided. Hence, electrolyte cleanliness is imperative. It is normally done with the help of filters made of SS steel, Monel or any other anticorrosive material. It should be ensured that the piping system does not introduce any foreign material like corroded particles, scale or pieces of broken seal material. Piping system is therefore made of SS steel, Glass fibre reinforced plastic (GFRP), plastic lined MS or similar other anti-corrosive material. The required minimum capacity of electrolyte tank is 500 gallons for each 10000 A of current. ECM is supposed to machine different metals and alloys at optimum machining conditions and with varying requirements of accuracy, surface texture, etc. Under such situations, a single tank system is not recommended because of loss of time and wastage of electrolyte during drilling cleaning, mixing or filling of new electrolyte in the tank. It results in higher cost and poor accuracy of electro chemically machined surface and also poor control of operating conditions. More than one tank therefore, can be used and their number would depend upon the range of electrolytes needed to meet the work load.

TOOL AND TOOL FEED SYSTEM: -

Use of anti-corrosive material for tools and fixtures is important because they are required for a long period of time to operate in the corrosive environment of electrolyte. High thermal conductivity and high thermal conductivity are main requirements. Easy machining of tool material is equally important because dimensional accuracy and surface finish of the tool directly affect the work piece accuracy and surface finish. Aluminum, Brass, Bronze, copper, carbon, stainless steel and Monel are a few of the material used for this purpose. Further, those areas on the tool where ECM action is not required, should be insulated. For example, lack of insulation on the sides of die sinking tool causes unwanted machining of work and results in a loss of accuracy of the machined work piece. Use of non – corrosive and electrically non conducting material for making fixtures is recommended. Also, the fixtures and tools should be rigid enough to avoid vibration or deflection under the high hydraulic forces to which they are subjected.

WORK PIECE AND WORK HOLDING SYSTEM: -

Only electrically conductive material can be machined by this process, the chemical properties of anode (work) material largely govern the material removal rate (MRR). Work holding devices are made of electrically nonconductive materials having good thermal stability, and low moisture absorption properties, For Example, graphite fibers reinforced plastics, plastics, Perspex, etc., are the materials used for fabricating the work holding device.

PROCESS PARAMETERS

1. Power supply Type – DC Voltage – 30V
2. Current - 40000A
3. Current Density – 500 A/Cm2
4. Electrolyte Type – Nacl, NaNo3, Proprietary mixtures.
5. Temperature – 26 to 50 deg.
6. Flow rate – 16 LPM to 20 LPM
7. Velocity – 1500 m/min to 3000 m/min
8. Inlet pressure – 2200 kPa.
9. Outlet Pressure- 300 kpa
10. Working Gap 0.075 to 0.75mm
11. Side over cut 0.125 to 1mm
12. Feed rate 0.500 to 13 mm/min
13. Electrode material Copper, Brass, Bronze
14. Tolerance 0.025mm (2D) and 0.050mm(3D)
15. Roughness 1.5 microns

DEVELOPMENT OF CHARACTERISTICS OF ECM:

The means by which high current densities are obtained can be understood from an examination of other characteristics of an ECM cell in particular, the electrolyte conductivity and inter-electrode gap width. These parameters are related to the current through Ohm's law, which states that the current I flowing in a conductor is directly proportional to the applied voltage V.

$$V= IR \text{----------(2)}$$ R is the resistance of the conductor.

In electrolysis process, electrolytes are conductors of electricity. Ohm's law also applies to this type of conductor, although the resistance of electrolytes may amount to hundreds of ohms. Now, the resistance R of a uniform conductor is directly proportional to its length h, and inversely proportional to its cross-sectional area A. Thus

$$R= h\rho/A \text{---------- (3)}$$

Where ρ is the constant of proportionality. If the conductor is a cube of side 10 mm, then R = ρ; ρ is termed as specific resistivity of the conductor. The reciprocal of specific resistivity is known as specific conductivity. Combining equations 2 and 3 the relationship are derived between the average current density, current, surface area to be machined, applied potential difference, gap width, and electrolyte conductivity being denoted by the respective symbols J, I, A, V, h, and ke

$$J= I/A = ke\ V/ h$$

In actual practice the voltage values ranges from 10 to 20 V. and for this the gap width is about 0.4 mm and feed rate about 0.02 mm/sec is needed.

MRR = C .I. h (cm^3/min)

C= specific (material) removal rate (e.g., 0.2052 cm^3/amp-min for nickel)

I = current (amp)

h = current efficiency (90–100%).

PROCEDURE:

1. After switching on the system, go to manual code (operator can perform following operation from main screen of MMI).
2. Then put on the safety locks
3. Check the current and voltage to the system
4. Check the flow control of electrolyte and set the required pressure of the electrolyte
5. Check the gap between the tool and workpiece.
6. For activation of auto and manual mode of operation, emergency switch must be released.
7. Go to auto mode and the system is ready for use to press start switch

Experiment 3: - CM : CHEMCIAL MACHINING

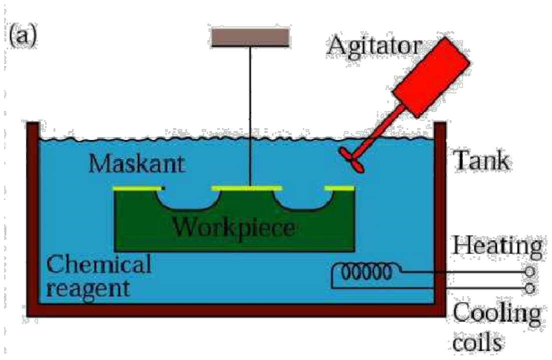
OBJECTIVE: To determine the material removal rate MRR using Chemical machining (CHM).

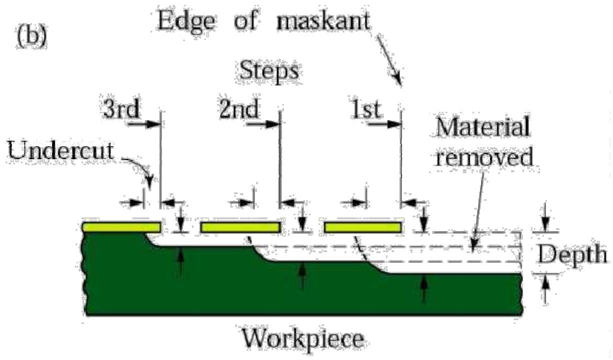
EQUIPMENT REQUIRED:

1. Stirrer / Agitator
2. Chemical solution like HCL, water (acid and Alkaline solution)
3. Etching reagent
4. Maskants
5. Workpiece

THEORY

Chemical machining (CM) is the controlled dissolution of workpiece material (etching) by means of a strong chemical reagent (etchant). In CM material is removed from selected areas of workpiece by immersing it in a chemical reagents or etchants; such as acids and alkaline solutions. Material is removed by microscopic electrochemical cell action, as occurs in corrosion or chemical dissolution of a metal. This controlled chemical dissolution will simultaneously etch all exposed surfaces even though the penetration rates of the material removal may be only 0.0025–0.1 mm/min. The basic process takes many forms: chemical milling of pockets, contours, overall metal removal, chemical blanking for etching through thin sheets; photochemical machining (pcm) for etching by using of photosensitive resists in microelectronics; chemical or electrochemical polishing where weak chemical reagents are used (sometimes with remote electric assist) for polishing or deburring and chemical jet machining where a single chemically active jet is used. A schematic of chemical machining process is shown in Figure.





a) Schematic of chemical machining process	(b) Stages in producing a profiled cavity by chemical machining

1. **Tank:**

This process has a tank with its face open. The tank is built of strong metal coated with materials that are non-reactive to etchant depending on the applications and concentration of chemical reagent.

2. **Heating coil:**

   A heating coil is mounted at the lowest section of the tank to maintain the temperature of the tank at a constant level. It is practical that in any metal removal process the heat generation is natural. Also, the coil does cooling in necessary conditions.

3. **Stirrer:**

   A stirrer is placed in the etchant whose main purpose is to mix the etchant consistently to maintain a uniform concentration and heat along the volume of the etchant. It is well known to us that the hot particles always accumulate at the top, leaving the cold below. So, to spread the heat uniformly along the etchant, the stirrer is used. The stirrer also helps in the flushing of dissolved metal from the workpiece simultaneously breaking the bubbles formed during machining due to oxidation.

4. **Workpiece:**

   The workpiece is held in the etchant by the use of a hanger in the case of small applications. The length of the hanger is fastened over a masked area so that the fixing of the workpiece does not disturb the machining zone. In the case of a larger workpiece, fixtures coated with rubbers and polymers are used to hold the workpiece.

STEPS INVOLVED IN CHEMCIAL MACHINING PROCESS(CHM)

PROCEDURE:

1. Workpiece pre cleaning process: The surface of workpiece metal is cleaned thoroughly, degreased and pickled by acid or alkalis. Pre cleaning is the most important method to remove oil, grease, dirt, rust, or any foreign substance from the work surface to produce a good adhesion of masking material
2. Masking and scribing mask: Masking involves covering the portion of the workpiece metal where material is not to be removed by the chemical action. masking with adhesive types or paints is a common practice although rubber (elastomers) and plastics are also used. Since it is difficult to apply maskant on small surface, the maskant is initially applied on a large surface

3. Etching: The unmasked surface of the workpiece is machined chemically with selected etchant. Etching is carried out by immersing the work material in a tank of agitated etchant. The process is carried out at high temperature depending on the etched material. Temperature control and agitation during chemical machining. Erosion of the work material takes place from the exposed surface. The work piece is converted into metallic salt, which is then dissolved and carried away in the etchant solution.

    There is a formula for Etching:

    E=s/t

    E = Rate of Etching.

    s = depth of cut.

    t = Immersion time

4. Damasking: When etching is completed the mask is removed either through mechanical or chemical means. any etchant on the work material is also removed by cold water to clean. A deoxidizing bath may also be required in order to remove the oxide coating or films left on the surface of the work material.

Experiment 4:-EDM: ELECTRODISCHARGE MACHINING

AIM: Determine the material removal rate (MRR) and tool wear rate (TWR) in electro discharge machining of mild steel using copper electrode.

APPARATUS:

1. Electro Discharge Machine (EDM)
2. EDM oil (Dielectric)
3. Mild steel workpiece (80 mm * 40 mm * 6 mm)
4. Copper electrode (16 mm diameter)
5. Weighing machine

Theory:

Introduction to EDM machining:

Electro Discharge Machine is a process of repetitive sparking cycle. A series of electrical pulses generated by the pulse generator unit is applied between the work piece and the tool electrode. In the event of spark discharge, there is a flow of current across the tool electrode-work piece gap. Energy content in a tiny spark discharge removes a fraction of work piece material, leaving behind a small crater on the work piece surface. Material removal is assisted with the spark discharge plasma temperature ranging is excess of few thousands of degrees of centigrade. Better work piece material removal and low tool electrode wear can be achieved by using appropriate machining conditions, e.g. by increasing the spark energy one can achieve an increase in material removal rate but not so good surface finishing. By lowering spark energy (lower IP and lower Ton values) one can obtain better surface finish. Best surface finish, however can be achieved at cost of machining time. This because of lower material removal rate achieved with lower spark energy setting. To achieve optimum result of material removal rate, over cut or surface finish, the machining parameter should be properly set.

Construction and machining parameters:

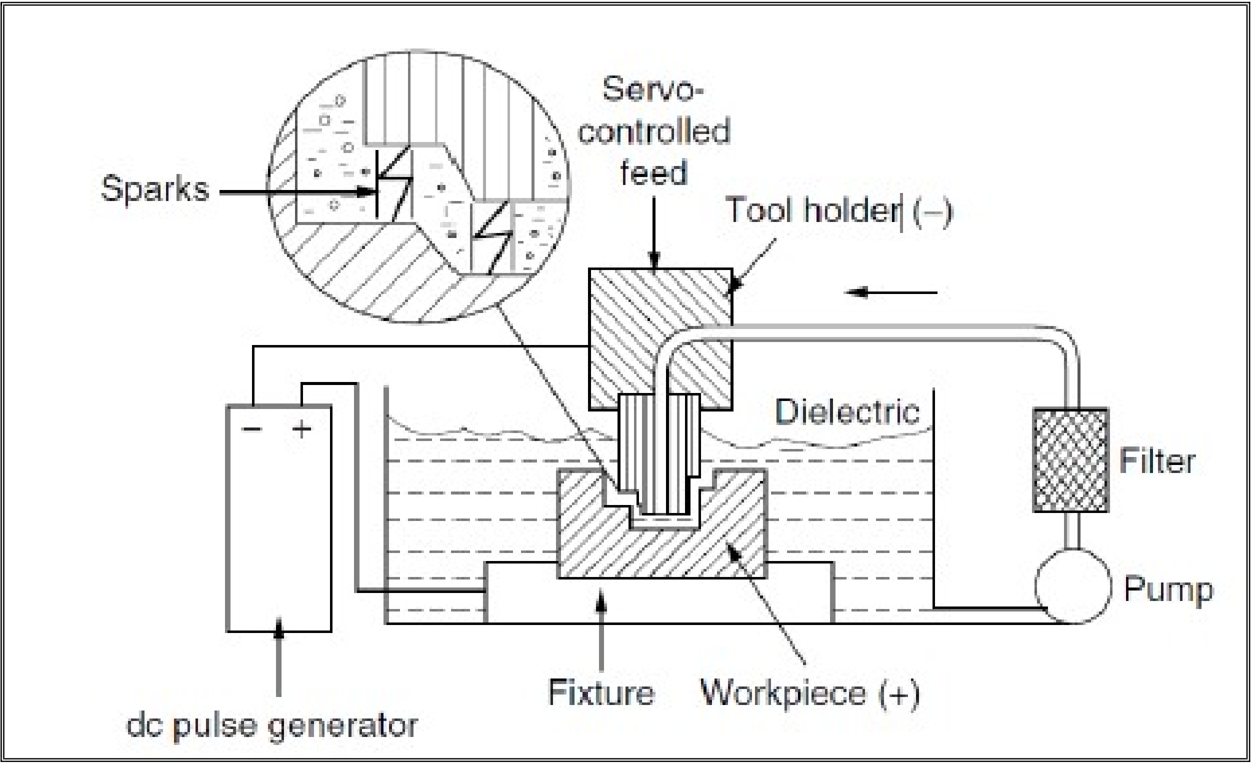
Construction:

EDM is comprised a machine tool, a power supply unit and a dielectric supply unit. It comprises of a base, column, work table and work head. Work table is mounted inside a work table. Work piece is mounted and clamped on the work table (with or without a flushing pot). An electrode is mounted on the platen using an axis controller. Work tank is filled with dielectric. As the machining proceeds the Z quill comes down till the preset distance is reached.

Machine parameters:

IP: Machining peak current.
IB: By pulse current.
Ton: Pulse on time or period.
Toff: Pulse off period.
t (τ): Pulse duty factor (work time).

Vg: Upper gap voltage.
SEN: Sensitivity of z-axis speed.
ASEN: Anti arc sensitivity.
Rd: Retract distance



Measurements:

Material removal rate (g/s):

$$\text{MRR (g/s)} = \frac{(\text{Weight of workpiece before machining} - \text{Weight of workpiece after machining})}{\text{Machining time}}$$

Tool (electrode) wear rate (g/s):

$$\text{TWR (g/s)} = \frac{(\text{Weight of electrode before machining} - \text{Weight of electode after machining})}{\text{Machining time}}$$

Experimentation procedure:

1. Stabilizer MCB ON with stabilizer green button ON.
2. Release emergency button (rotate clock wise) and hold power switch once again.
3. After main display visible, press auto position on remote.
4. After the auto position go to job set (press F9). F2-X, F3-Y, F4-Z
5. Before spark all axis be in zero set. After that (ESC Red color) press ←←←
6. Go to Z position, give the depth in minus (-) and set the different parameter.
7. Start pump for dielectric supply (press pump symbol on remote).
8. Adjust the flushing pressure according to requirement.
9. After fill of dielectric press spark symbol on remote.

Observation Table

Sl. No	Peak current, IP (A)	Pulse on time, Ton (µs)	Voltage gap, VG (V)	Duty Factor, τ	Weight of workpiece		Weight of electrode		machining Time (s)	MRR (g/s)	TWR (g/s)
					Before Machining (g)	After Machining (g)	Before Machining (g)	After Machining (g)			
1	12	150	65	8	460	395	350	345	175		
2											
3											

Calculation:

Material removal rate (g/s):

$$\text{MRR (g/s)} = \frac{(Weight\ of\ workpiece\ before\ machining - Weight\ of\ workpiece\ after\ machining)}{Machining\ time}$$

Tool (electrode) wear rate (g/s):

$$\text{TWR (g/s)} = \frac{(Weight\ of\ electrode\ before\ machining - Weight\ of\ electode\ after\ machining)}{Machining\ time}$$

Conclusion: The experiment was completed successfully and the MRR and TWR are calculated as ………g/s and ………..g/s respectively.

Experiment 5: -WEEDM: WIRE CUT ELECTRICAL DISCHARGE MACHINING

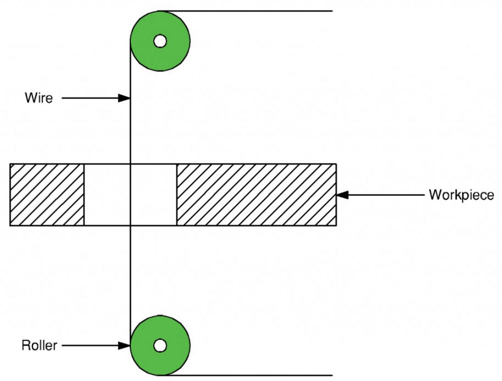
AIM: Determine the material removal rate (MRR) in wire electric discharge machining of mild steel using copper electrode

APPARATUS:

1. Tool electrode and work piece,
2. pulsed power supply system,
3. dielectric supply system
4. electrode feeding system

THOERY:

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. In other words, 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.



In Electrical Discharge Machining (EDM) process, the tool electrode having particular shaped, but in wire cur electrical discharge machining (WEDM) the tool electrode having a thin wire. As the material removal is obtained continuously in the feed of the workpiece is called as wire-cut electrical discharge machining.

COMPONENTS OF A WIRE EDM **MACHINE**

The machine comprises several parts that work together to give a material the desired shape. Below are the components of the machine.

1. **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. (Note: The CNC tool's sophistication determines the error level and the machining time.)
2. **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. It is necessary to use a highly developed power supply unit to deliver the necessary quality and type of charges during Wire EDM machining.

3. **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. The main types of wires used include

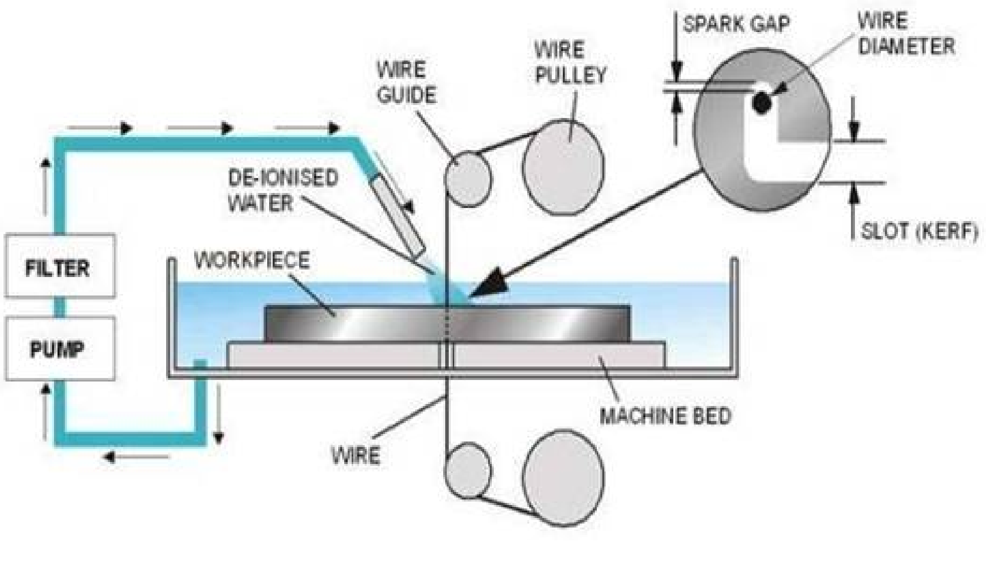
   -Brass Wires: Brass is the most common EDM wire material because of its excellent conductive properties. It is an alloy of copper and zinc, and the higher the zinc content, the faster the wire cuts. However, there should be a balance because when the zinc content is over 40%, this decreases the corrosion rate of the brass wire.

   -Zinc coated Wires: As the name implies, you obtain it by applying a coating of pure zinc or zinc oxide on the wire surface. Manufacturers use zinc-coated wires because it improves the machining speed.

   -Diffusion-annealed Wires: The diffusion annealing process helps to create wires with higher zinc content (more than 40% zinc). It involves coating wires with layers of pure zinc. These wires are ideal for mass production and can machine many materials.

4. **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.
5. **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 come in contact with the workpiece at any point during the wire EDM cutting process.

EDM Wire cutting



MATERIAL REMOVAL RATE (MRR)

After machining the samples were taken to analyze MRR and Surface roughness.
The material removal rate (MRR) for Wire cut EDM is calculated by using the equation

$$MRR = F \times Dw \times H$$

Where, F is the machine feed rate (mm/min),
Dw is wire diameter (mm),
H is the thickness of the workpiece (mm)

CONTROLLING PARAMETERS OF WEDM:

The controlling parameters of wire-cut electrical discharge machining are as follows:

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

Experiment 6:-EBM: ELECTRON BEAM MACHINING

AIM: Determine the material removal rate (MRR) in Electron Beam Machining

APPARATUS:

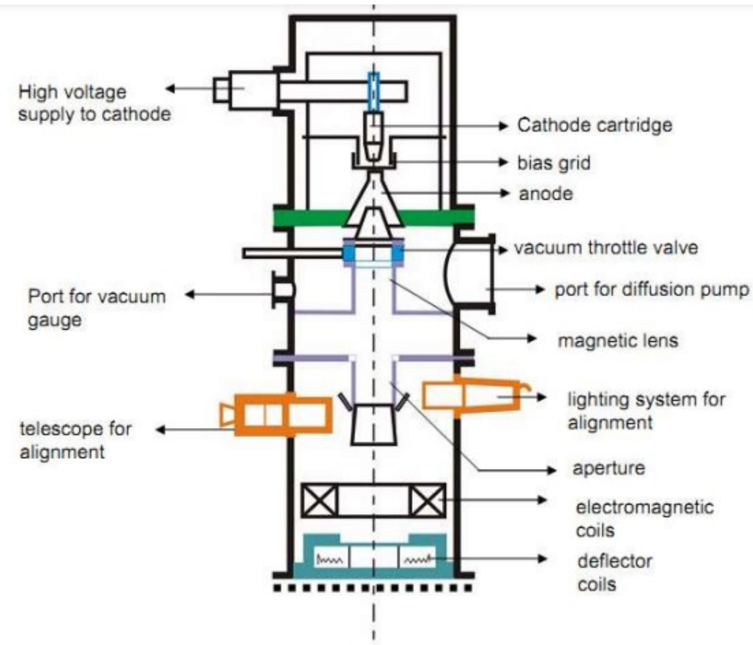
1. Cathode.
2. Annular Bias Grid.
3. Anode.
4. Magnetic Lenses.
5. Electromagnetic Lens.
6. Deflector Coils.

THOERY:

Electron beam machining is a thermal process that is used to remove metals during the machining process. In electric beam machining, electrical energy is used to generate electrons with high energy. In the electron beam machining process, a high velocity focused beam of electrons is used to remove the metal from the workpiece. These electrons are travelling at half the velocity of light, i.e., 1.6 x 10^8 m / s. This process is best suited for the micro-cuttings of materials. Electron beam machining are a process in which high-velocity electrons are focused into a narrow beam and then directed toward the workpiece for machining. When this high-velocity electron strikes the workpiece, it melts and vaporizes the material from the workpiece.

PRINCIPLE OF ELECTRON BEAM MACHINING:

When the high-velocity beams of electrons strike the workpieces, their kinetic energy is converted into heat. This concentric heat increases the temperature of the workpiece material and evaporates a small amount of it, resulting in the removal of materials from the workpiece.



Electron Beam Gun

When the electron voltage is given a high voltage dc source, the tungsten filament wire heats up, and the temperature rises to 2500°c. Due to these high temperatures, electrons are emitted from the tungsten filament. These electrons are guided by a grid cup to travel downward and are attracted by the anode.

Electrons passings through the anode are accelerated to achieve a velocity as high as half the velocity of lights (i.e., 1.6 x 10^8 m / s) by applying 50 to 200 kV at the anode. The high velocities of these electrons are maintained until they strike the workpiece. This becomes possible because electrons travel through a vacuum.

This high-velocity electron beam, after leaving the anode, passes through the tungsten diaphragms and then through the electromagnetics focusing lens. Focusing lenses are used to focus the electrons beam to the desired location of the workpiece.

When the electron beam affects the surface of the workpiece, the kinetic energy of high-velocity electrons is immediately converted to heat energy. It melts high-intensity heat and vaporizes the work material in place of the beam effect. Since power density is very high (about 6500 billion w / mm^2), it takes a few microseconds to melt and evaporate the material for impact.

ELECTRON BEAM PROCESS – PARAMETERS

1. The accelerating voltage (100 KV)
2. The beam current (250 µA – 1A
3. Pulse duration (50 µS– 50 mS)
4. Energy per pulse (100 J/pulse)
5. Power per pulse
6. Lens current
7. Spot size (10 µm – 500 µm)
8. Power density

PROCEDURE:

1. The electron beam is generated in an electron beam gun.
2. Electron beam gun provides high-velocity electrons over a very small spot size.
3. Electron Beam Machining is required to be carried out in a vacuum.
4. Otherwise, the electrons would interact with the air molecules, thus they would lose their energy and cutting ability.
5. Thus, the workpiece to be machined is located under the electron beam and held in vacuum chamber.
6. The high-energy focused electron beam is made to impinge on the workpiece with a spot size of 10 – 100 µm.
7. The kinetic energy of the high-velocity electrons is converted to heat energy as the electrons strike the work material.
8. Due to high power density instant melting and vaporization starts and "melt – vaporization" front gradually progresses
9. Finally, the molten material, if any at the top of the front, is expelled from the cutting zone by the high vapour pressure at the lower part.
10. Unlike in Electron Beam Welding, the gun in EBM is used in pulsed mode.
11. Holes can be drilled in thin sheets using a single pulse.
12. For thicker plates, multiple pulses would be required.
13. Electron beam can also be maneuverer using the electromagnetic deflection coils for drilling holes of any shape.

Experiment 7:-LBM: LASER BEAM MACHINING

AIM: Determine the material removal rate (MRR) in Laser Beam Machining

APPARATUS:

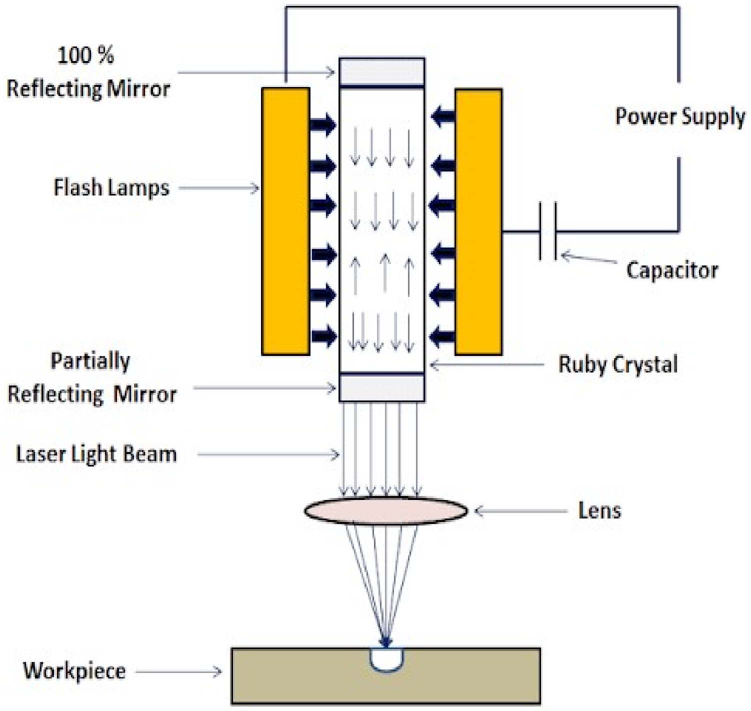
1. Power Supply:
2. Flash Lamps
3. Capacitor
4. Reflecting Mirror.
5. Lense
6. Workpiece

THOERY:

In this process, the Laser Beam is called monochromatic light, which is made to focus on the workpiece to be machined by a lens to give extremely high energy density to melt and vaporize any material. The Laser Crystal (Ruby) is in the form of a cylinder as shown in the above figure or Diagram with flat reflecting ends which are placed in a flash lamp coil of about 1000W. The Flash is simulated with the high-intensity white light from Xenon. The Crystal gets excited and emits the laser beam which is focused on the workpiece by using the lens. The beam produced is extremely narrow and can be focused to a pinpoint area with a power density of 1000 kW/cm2. Which produces high heat and the portion of the metal is melted and vaporized.

PARTS OF LASER BEAM MACHINING

1. Power Supply: A high voltage is required for Laser. The power is supplied to the system for exiting the electron. When the power is supplied the electron gets in an excited state that means ready to work.
2. Flash Lamps: Flash lamps are used for providing white and coherent light for a very short duration.
3. Capacitor: In general, we know the work of capacitor, it is used for storing and releasing the charge. Here it is used during the flashing process.
4. Reflecting Mirror: A reflecting Mirror is used here to reflect the light directly to the workpiece. It is of two types



Internal and external.

5. Lenses: Lenses are provided here for vision purposes. It shows the image in a bigger size so that it will be easy to perform an operation on the given workpiece mark.
6. Workpiece: The workpiece is like the object in which the operation is to be carried out. For example, if the body needed any laser operation, then we are the workpiece for this machine, same like manufacturing the objects need to be drill or hole the Laser machine carried out the operation.

PROCESS DESCRIPTION

1. LASER rod is excited by xenon filled flash lamp surrounding it.
2. Both are enclosed in cylinder with highly reflective inner walls.
3. The dopes present in LASER tube get excited.
4. These atoms release photons while returning to normal state.
5. Thus high energy beam is emitted in short pulses.
6. The apparatus has reflective mirrors on the back side & side walls
7. The partially reflective mirror on the bottom face allows emission of LASER beams.
8. A converging lens is used to focus the LASER beam on the workpiece.
9. Extremely high temperatures are generated which melt or evaporate the metal.
10. This is removed by melt ejection, vaporization, or ablation mechanisms.

$$MRRm = \frac{MRRv \times \rho}{1000}$$

$$MRRv = \frac{V}{T}$$

$$V = d \times c \times l$$

$$d = zi - zf$$

$$E = P \times T$$

Where MRRm is the mass material removal rate in [g/s], ρ is density in [g/cm^3], MRRv is the volumetric material removal rate in [mm^3/s], V is the volume in [mm^3], d is depth in [mm], c and l are the sides of the cavities, zi and zf are the beginning and final z average in [mm]. E is total machining energy in [kJ], P is power in [kW] and T is total machining time in [s].

PROCESS VARIATIONS PROCESS PARAMETERS

- Nature of Beam light: Unidirectional, Coherent, Monochromatic, Short Pulse
- Total radiation of sun is 7 kW/cm2
- Area: Can be focused on 1/100 mm2
- Concentrated power intensity of 10 5 kW/cm2
- Laser rod of 3 joule unit is 6 cm in dia & 70 mm long

Experiment 8:-PAM: PLASMA ARC MACHINING

AIM: Determine the material removal rate (MRR) in Plasma arc Machining

APPARATUS:

1. Plasma Gun.
2. Power Supply and Terminals.
3. Cooling Mechanism.
4. Tooling.
5. Workpiece.

THOERY:

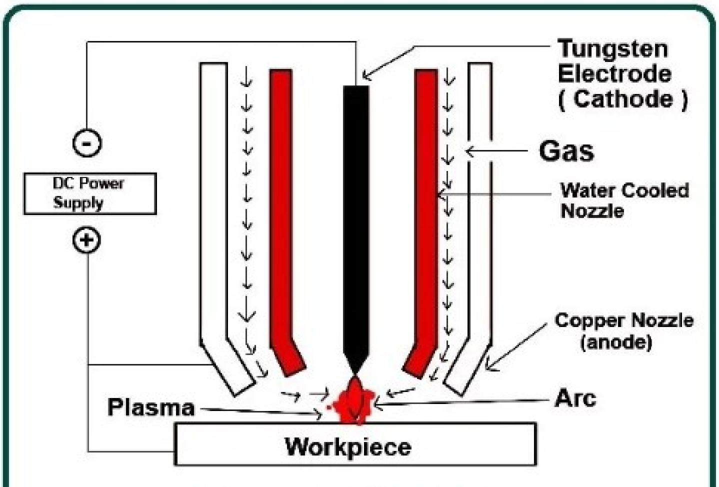
A plasma is a high temperature ionized gas. The plasma arc machining is done with a high-speed jet of a high temperature plasma. The plasma jet heats up the work piece (where the jet impinges on it), causing a quick melting. PAM can be used on all materials which conduct electricity, including those which are resistant to oxy-fuel gas cutting. This process is extensively used for profile cutting of stainless steel, Monel, and super alloy plates.

A plasma is generated by subjecting a flowing gas to the electron bombardment of an arc. For this, the arc is set up between the electrode and the anodic nozzle; the gas is forced to flow through this arc.

The high velocity electrons of the arc collide with the gas molecules, causing a dissociation of the diatomic molecules or atoms into ions and electrons resulting in a substantial increase in the conductivity of the gas which is now in plasma state. The free electrons, subsequently, accelerate and cause more ionization and heating. Afterwards, a further increase in temperature takes place when the ions and free electrons recombine into atoms or when the atoms recombine into molecules as these are exothermic processes.

So, a high temperature plasma is generated which is forced through the nozzle in the form of a jet. The mechanics of material removal is based on – (i) heating and melting, and (ii) removal of the molten metal by the blasting action of the plasma jet.

1. **PLASMA GUN-**
   - Gases, like plasma, are used to make nitrogen, argon, hydrogen, or a mixture of these gases.
   - The plasma gun consists of a tungsten electrode that is fitted into the chamber.
   - The electrodes are given negative polarity, and the gun nozzle is given positive polarity.
   - The supply of gases remains in the gun. A strong arc is established between two



Plasma Arc Machining

terminals, anodes, and cathode. There is a collision between the molecules of the gas and electrons of the established arc.

- As a result of this collision, the gas molecules ionize, and heat develops.
- This hot and ionized gas called plasmas is directed to the workpieces with high velocity.
- The installed arc is controlled by the supply rate of gases.

2. POWER SUPPLY AND TERMINALS-

- A power supply (DC) is used to develop two terminals in a plasma gun.
- A tungsten electrode is inserted into the gun, and a cathode is made, and the gun nozzle is the anode.
- A massive potential difference is applied to the electrodes to develop a plasma state of gases.

3. COOLING MECHANISM-

- As we know that hot gases continuously exit the nozzle; hence there is a possibility of heating it.
- Water jackets are used to surround the nozzle to avoid overheating.

4. TOOLING-

- There is no directly visible device in pam. A concentrated spray of hoit, plasma state gases serves as cutting tools.

5. WORKPIECE-

- The workpiece of various materials can be processed by the pam process.
- These materials are aluminum, stainless steel, magnesium, and carbon and alloy steel.
- All materials that can be processed by LBM can also be processed by the pam process.

Process Description Steps in formation of Plasma

- Temperature is raised to 2000̊ C increasing collisions.
- Stripping of electrons leads to Ionization.
- Further heating takes place by
    - Collisions between free electrons & atoms.
    - Increase of Thermal Kinetic energy.
    - Heating by relaxation.
    - Production of light by De-excitation of atom.
- The final resultant temperature may go up to 30000̊ C. which is enough to melt & even vaporize most of the metals.
- An electrical channel of ionized gas i.e. plasma from the plasma cutter itself, through the workpiece to be cut, thus forming a completed electric circuit back to the plasma cutter via a grounding clamp.
- A suitable compressed gas is blown through a focused nozzle at high speed.
- An electrical arc is formed within the gas,
    - between an electrode near or integrated into the gas nozzle & the workpiece.
- The electrical arc ionizes some of the gas
    - An electrically conductive channel of plasma is created.
- It delivers sufficient heat to melt through the work piece.

- At the same time, much of the high velocity plasma & compressed gas blow the hot molten metal away, thereby separating i.e. cutting through the work piece

Process Parameters

- Stand off distance:
    - It refers to the distance between the nozzle & the workpiece.
    - It is inversely proportional to depth of penetration.
    - Long distance gives narrow widths at the bottom.
    - Short distance damages the workpiece.
    - Preferred range: 5 to 10mm
    - Varied depending on thickness to be cut & material of the workpiece.
- Speed of cutting
    - It refers to the relative speed between the nozzle & the workpiece.
    - High cutting speed gives narrower bottom width.
    - Slower cutting speed widens the bottom of the kerf.
    - At optimum speed, nearly perpendicular & parallel kerf surfaces can be obtained.
- Jet velocity: 500 m/s
- Specific energy: 100 W/(cm3 .min)
- Power Range: 2-200 Kw
- Voltage: 30-250 V (DC)
- Current: Upto 600 A
- Plasma gases
    - It flows through the spark & gets ionized.
    - Hydrogen has high heat capacity
        - Achieves best conditions for transfer of plasma arc heat.
        - Has smooth cutting action.
    - Nitrogen is cheap but not smooth.
        - Cutting speed is considerably less.
    - Nitrogen + Hydrogen most generally used.
    - Sometimes argon is added.
- Selection depending on materials:
    - Stainless steel(t<50mm) Nitrogen – Hydrogen mixture
    - Aluminium & Magnesium Nitrogen,
    - Nitrogen – Hydrogen mixture
    - Plain carbon steel Mixture containing Oxygen

ADDITIVE MANUFACTURING TECHNOLOGIES

INTRODUCTION

A 3D printer uses a virtual, mathematical model to construct a physical artefact. For example, a designer in the process of creating a new laptop can use a software package to create a three-dimensional model of his creation that can be manipulated and viewed on the computer screen. The 3D printer can take the symbolic representation of this new object and use it to build a full-size, physical model that can be held and manipulated, helping the designer to better understand the strengths and limitations of his design.

An architect can turn the plans for a building into a three-dimensional model and then "print" a scale model to help him understand and communicate his design. An archaeologist can print duplicates of an important, but fragile, tool so that her students can hold it in their hands and better understand how it might have been used by an ancient civilization. A biochemist can print accurate models of DNA molecules, enlarged by many orders of magnitude, to help students and researchers better understand nature by engaging their hands as well as their eyes in comprehending the geometry of nature. And a student of the arts can create a unique object that would be difficult or impossible to build by hand.

We will not here consider other types of computer-controlled manufacturing, such subtractive machines, which work by cutting away from a larger piece of material in order to build a part. Additive rapid prototyping machines were first introduced twenty years ago, when 3D Systems introduced the Stereo lithography, or SLA machine. While these machines were remarkable for their ability to create complex parts, they were large, expense, and difficult to operate.

Early AM equipment and materials were developed in the 1980s. In 1984, Chuck Hull of 3D Systems Corporation invented a process known as stereo lithography, in which layers are added by curing photopolymers with UV lasers. Hull defined the process as a "system for generating three-dimensional objects by creating a cross-sectional pattern of the object to be formed. He also developed the STL (Stereo Lithography) file format widely accepted by 3D printing software as well as the digital slicing and infill strategies common to many processes today.

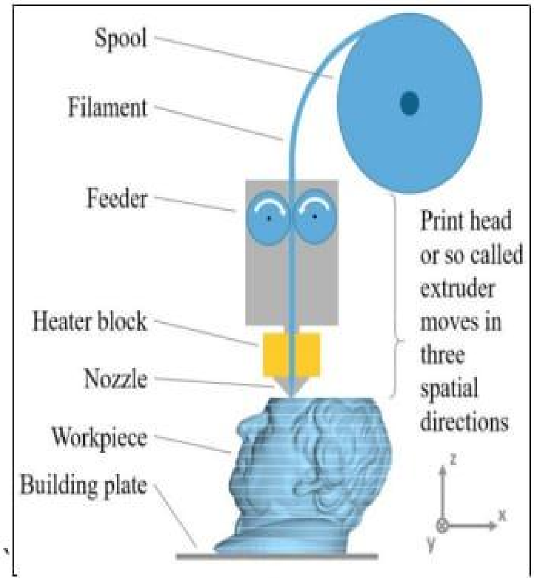
1. Liquid Based Additive Manufacturing: It is an additive manufacturing technique which deposits a liquid or high viscosity material (ex: Liquid, Silicone Rubber) onto a build surface to create an object which then vulcanized using heat to harden the object.
   Example: Fusion Deposit Modelling (FDM), Stereo lithography (SLA), Poly jet etc.
2. Solid Based Additive Manufacturing: This system utilizes solids as the primary medium to create the part or prototype. The building material is in solid state (excluding powder). The solid type may include the shape of the wire, Rolls & Lamination.
   Example: Laminated object manufacturing (LOM) etc.
3. Powder Based Additive Manufacturing: This system utilizes powder a s the primary medium to create the part or prototype.
   Example: Selective Laser Sintering (SLS), Electron beam Sintering (EBS),, Laser Engineered Net Shaping (LENS) and Binder Jetting etc

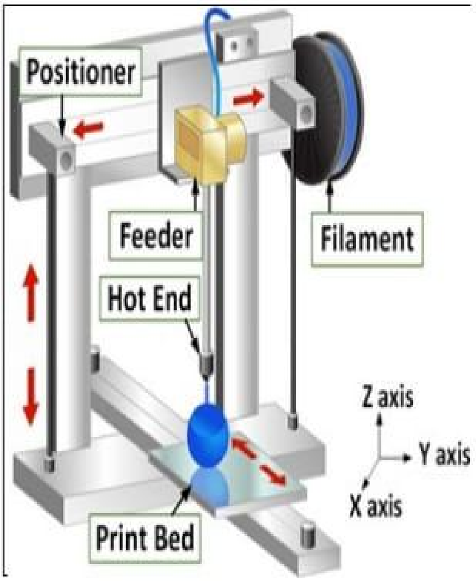
3D PRINTING MACHINE

FUSION DEPOSIT MODELLING (FDM):

It is an AM technology that creates 3D printing component using thermoplastic or composite material in filament form.

CONSTRUCTION:





The FDM 3D printer has the following main components:

1. FILAMENT COIL: The filament coil is a wire spool made up of thermoplastics or composite material that serves material to the printer. The filament comes in a variety of colours.

2. FEEDER: The Feeding mechanism is used to continuously feed the filament to the extruder.

3. NOZZLE (Extruder with a heating element): The filament is melted by the extruder of the printer, Nozzle used to release the material layer by layer onto the print bed.
4. STEPPER MOTOR MECHANISM: A set of stepper motors are used to advance the thermoplastic material in to the nozzle and control the movements of the extruder and the build platform in X, Y, and Z directions.

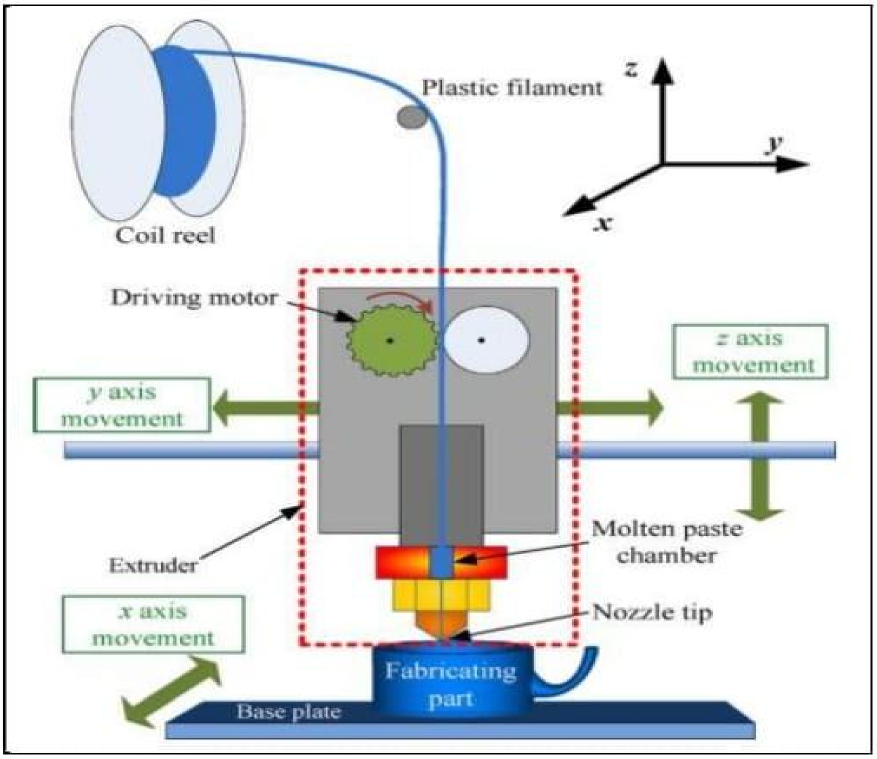
5. **PRINT BED OR BUILD PLATFORM:** It is a printing plate on which the 3D part is printed. A print bed is the part that the 3D printed object rests on during the printing process. As each layer is extruded, the print bed moves down to allow for the next layering step.

6. PRINTER BASE: disposable base which is printed first onto the build surface, with the object being built on top. Provides more adhesion to the build surface and reduces warping. A technique used to prevent warping.

7. DISPLAY KIT: 3d printer display is a 3D printer part. This Smart LCD controller contains an SD-Card reader, a rotary encoder, and an LCD display.

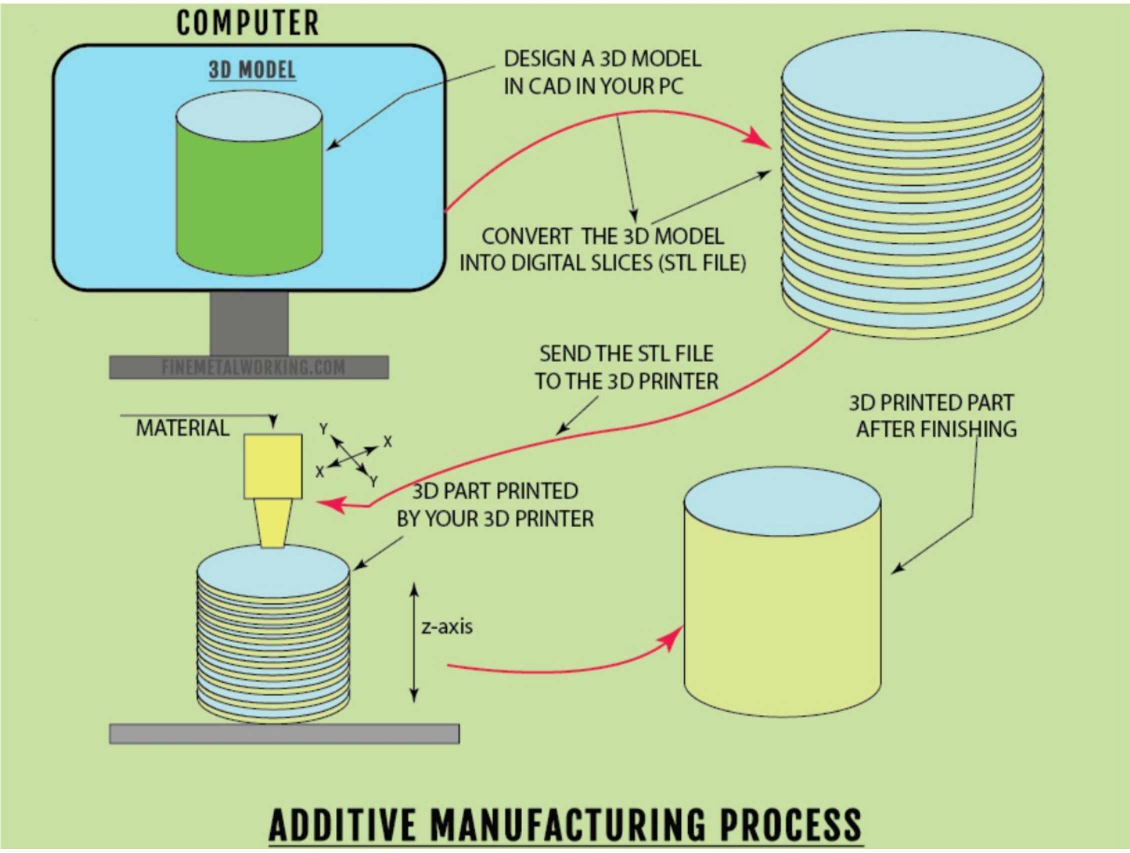
8. NOZZLE KIT: The nozzle is the component of a 3D printer that deposits the molten filament into the build area. There are many different types of 3D printer nozzles available and leveraging their different strengths is important.

WORKING PRINCIPLE:



The part which is to be 3D printed is first designed in Computer Aided Design software. After that, its CAD file must be converted to a format that a 3D printer can understand usually .stl format. This .stil file is then sent to slicing software for eg: Cura. In the slicer software, you can control the print parameters like the layer height, temperature of the filament, etc. After setting the parameters, the file is then saved to an SD card and then inserted into the 3D printer Or else some 3D printer scan be directly connected through a USB. Select the file in the 3D printer and set it accordingly.

The feeding mechanism of the 3D printer intakes the filament and sends it to the extruder where it is heated to the set temperature. The filaments are melted and fed on to the print bed through nozzle. Both print bed and nozzle are controlled by a computer that translates the dimensions of an object into X, Y and Z coordinates for the nozzle and base to follow during printing. As the nozzle moves across the print bed the plastic cools and become solid, forming a hard layer bond with previous layer. At this point the print nozzle goes up or base is lowered for the formation of next layer of plastic. This continues until all the slices are printed and the model is complete. The stepper motors control the movement of the nozzle as well as the build platform accordingly. Once an object comes off the FDM printer, its support materials are removed either by soaking the object in a water and detergent solution or, in the case of thermoplastic supports, snapping the support material off by hand. Objects may also be sanded, milled, painted or plated to improve their function and appearance.



ADVANTAGES:

- 3D printing allows for the design and print of more complex designs than traditional manufacturing processes.
- Rapid Prototyping. Print on Demand.

- Strong and Lightweight Parts Fast Design and Production. Minimizing Waste.
- Cost Effective. Ease of Access. It reduces waste.
- It produces quality print.

DISADVANTAGES:

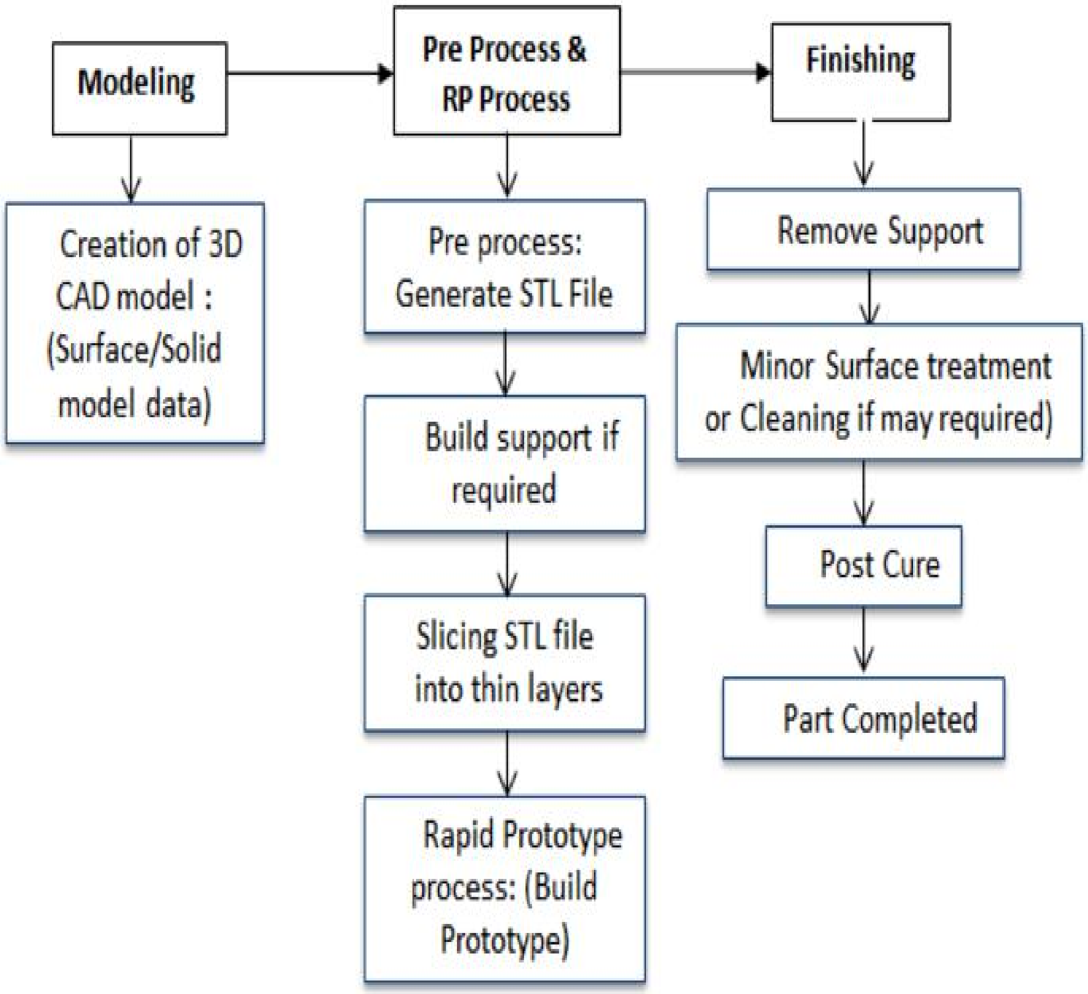
- Limited Material. While 3D Printing can create items in a selection of plastics and metals the available selection of raw materials is not exhaustive.
- Restricted Build Size. Post Processing.
- Large Volumes. Part Structure.
- Reduction in Manufacturing Jobs. Design Inaccuracies.
- Copyright Issues.

MATERIALS USED IN ADDITIVE MANUFACTURING:

Five types of materials can be used in AM process.

1. Ceramics.
2. Non-Metals (Plastics): Acrylonitrile butadiene styrene (ABS), Polylactide (PLA), Polyethylene Terephthalate (PET), Polycarbonate (PC) etc.
3. Polymers.
4. Metals & Alloys: Cobalt based alloys, Aluminum based alloys, Nickel based alloys, Stainless steel, Titanium Alloys etc.
5. Composite Materials & Smart Materials: Shape memory Alloys & Shape Memory Polymers etc.

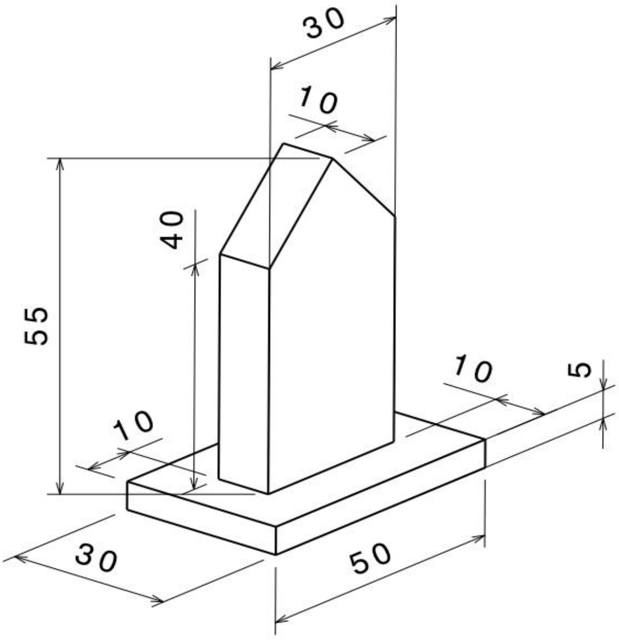
STEPS INVOLVED IN ADDITIVE MANUFACTURING PROCESS:



AM: PART MODELLING BY 3-D PRINTING MACHINING

EXPERIMENT :1

AIM: Develop an AM Process required to produce the given Component on a 3-D Printing machine.



APPARATUS:

1. **CAD SOFTWARE**: CATIA-V5, Autodesk, Unigraphics, Solid works, Solid edge, 3DS Max etc.,
2. **RAW MATERIALS:** ABS (Acrylonitrile Butadiene Styrene), Polylactide (PLA), Polyethylene Terephthalate (PET), Polycarbonate (PC), Nylon etc.
3. **SLICING SOFTWARE:** Cura, Slice3r, Craft Ware etc.,

PROCEDURES:

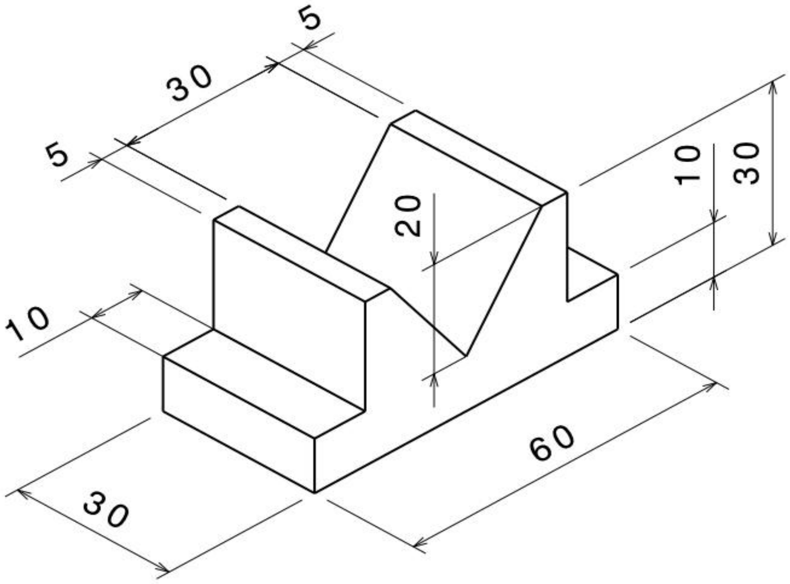
1. The solid model in CAD Software (CATIA, Autodesk, Unigraphics, Solid works etc.,) as for the given dimensions.
2. The digital design (Cad part) is to be converted to STL file using slicer software (Cura, Idea maker etc.,)
3. Select suitable material for creating the object.
4. Perform machine setting: Levelling of the built Plate (Bed), Lubrications, Set the desired print speed, Set the required temperature of the built plate & printer nozzle.
5. Feed the filament in to the extruder of the printer.
6. Select the G-code file in the printer to start the print.
7. Final Part is building layer by layer on the print bed.

8. **PART REMOVING:** Final created object can be removed by use of liquid solutions to weaken the bond between print bed & plastic object and also using a good quality scraper to remove the object from print bed. Create
9. **POST PROCESSING:** It is the final stage of the 3D printing. It has the following
    - **STEPS CLEANING:** Remove the support material from the object
    - **FIXING:** Sometimes small repairs are needed to fill small holes or cracks or even to attach together parts that have been printed separately.
    - **CURING OR HARDENING:** It is heating the object to bring the parts to its optimal mechanical properties.
    - **SURFACE FINISHING:** You can use specific chemicals or coating or polishing process to make the model surface smoother & brighter.
    - **COLORING:** Painting can be done manually a brush or spray. It will improve the aesthetic characteristics of the model.
10. Develop the Model & check the dimensional accuracies of the object using different instruments like Vernier caliper, Scale, Vernier height gauge, Micrometer, Depth Gauge, Bevel Protractor, Sine bar and Dial Indicator, Profile Projector etc.

AM: PART MODELLING BY 3-D PRINTING MACHINING

EXPERIMENT :2

AIM: Develop an AM Process required to produce the given Component on a 3-D Printing machine.



APPARATUS:

1. **CAD SOFTWARE**: CATIA-V5, Autodesk, Unigraphics, Solid works, Solid edge, 3DS Max etc.,
2. **RAW MATERIALS:** ABS (Acrylonitrile Butadiene Styrene), Polylactide (PLA), Polyethylene Terephthalate (PET), Polycarbonate (PC), Nylon etc.
3. **SLICING SOFTWARE:** Cura, Slice3r, Craft Ware etc.,

PROCEDURES:

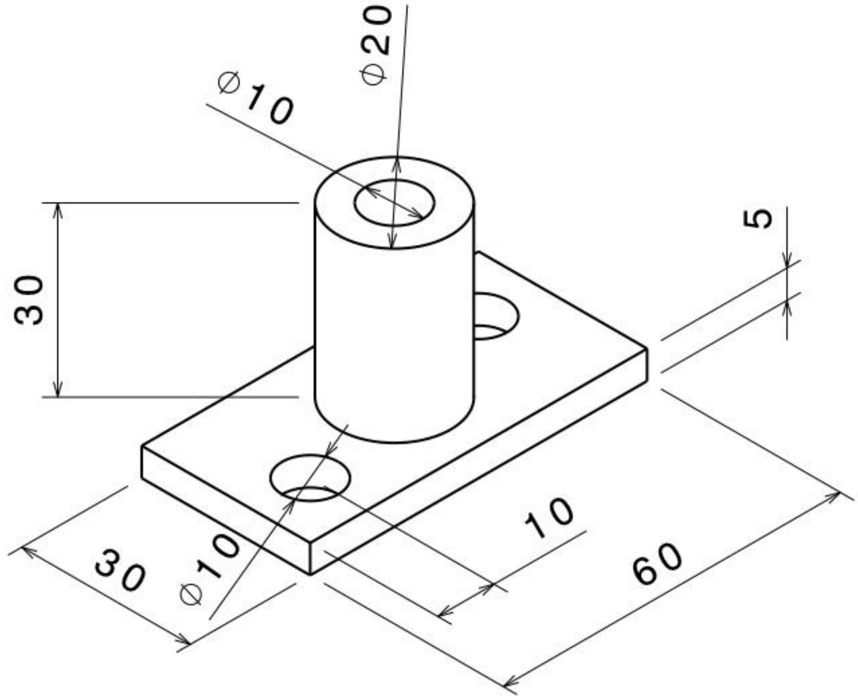
1. The solid model in CAD Software (CATIA, Autodesk, Unigraphics, Solid works etc.,) as for the given dimensions.
2. The digital design (Cad part) is to be converted to STL file using slicer software (Cura, Idea maker etc.,)
3. Select suitable material for creating the object.
4. Perform machine setting: Levelling of the built Plate (Bed), Lubrications, Set the desired print speed, Set the required temperature of the built plate & printer nozzle.
5. Feed the filament in to the extruder of the printer.
6. Select the G-code file in the printer to start the print.

7. Final Part is building layer by layer on the print bed.
8. **PART REMOVING:** Final created object can be removed by use of liquid solutions to weaken the bond between print bed & plastic object and also using a good quality scraper to remove the object from print bed. Create
9. **POST PROCESSING:** It is the final stage of the 3D printing. It has the following
   - **STEPS CLEANING:** Remove the support material from the object
   - **FIXING:** Sometimes small repairs are needed to fill small holes or cracks or even to attach together parts that have been printed separately.
   - **CURING OR HARDENING:** It is heating the object to bring the parts to its optimal mechanical properties.
   - **SURFACE FINISHING:** You can use specific chemicals or coating or polishing process to make the model surface smoother & brighter.
   - **COLORING:** Painting can be done manually a brush or spray. It will improve the aesthetic characteristics of the model.
10. Develop the Model & check the dimensional accuracies of the object using different instruments like Vernier caliper, Scale, Vernier height gauge, Micrometer, Depth Gauge, Bevel Protractor, Sine bar and Dial Indicator, Profile Projector etc.

AM: PART MODELLING BY 3-D PRINTING MACHINING

EXPERIMENT :3

AIM: Develop an AM Process required to produce the given Component on a 3-D Printing machine.



APPARATUS:

1. **CAD SOFTWARE**: CATIA-V5, Autodesk, Unigraphics, Solid works, Solid edge, 3DS Max etc.,
2. **RAW MATERIALS:** ABS (Acrylonitrile Butadiene Styrene), Polylactide (PLA), Polyethylene Terephthalate (PET), Polycarbonate (PC), Nylon etc.
3. **SLICING SOFTWARE:** Cura, Slice3r, Craft Ware etc.,

PROCEDURES:

1. The solid model in CAD Software (CATIA, Autodesk, Unigraphics, Solid works etc.,) as for the given dimensions.
2. The digital design (Cad part) is to be converted to STL file using slicer software (Cura, Idea maker etc.,)
3. Select suitable material for creating the object.
4. Perform machine setting: Levelling of the built Plate (Bed), Lubrications, Set the desired print speed, Set the required temperature of the built plate & printer nozzle.

5. Feed the filament in to the extruder of the printer.
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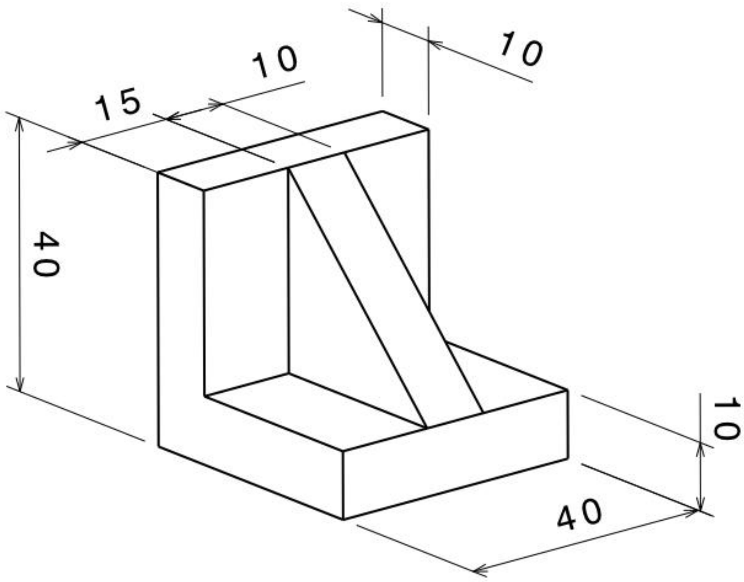
10. Develop the Model & check the dimensional accuracies of the object using different instruments like Vernier caliper, Scale, Vernier height gauge, Micrometer, Depth Gauge, Bevel Protractor, Sine bar and Dial Indicator, Profile Projector etc.

AM: PART MODELLING BY 3-D PRINTING MACHINING

EXPERIMENT :4

AIM: Develop an AM Process required to produce the given Component on a 3-D Printing machine.



APPARATUS:

1. **CAD SOFTWARE**: CATIA-V5, Autodesk, Unigraphics, Solid works, Solid edge, 3DS Max etc.,
2. **RAW MATERIALS:** ABS (Acrylonitrile Butadiene Styrene), Polylactide (PLA), Polyethylene Terephthalate (PET), Polycarbonate (PC), Nylon etc.
3. **SLICING SOFTWARE:** Cura, Slice3r, Craft Ware etc.,

PROCEDURES:

1. The solid model in CAD Software (CATIA, Autodesk, Unigraphics, Solid works etc.,) as for the given dimensions.
2. The digital design (Cad part) is to be converted to STL file using slicer software (Cura, Idea maker etc.,)
3. Select suitable material for creating the object.
4. Perform machine setting: Levelling of the built Plate (Bed), Lubrications, Set the desired print speed, Set the required temperature of the built plate & printer nozzle.
5. Feed the filament in to the extruder of the printer.

6. Select the G-code file in the printer to start the print.
7. Final Part is building layer by layer on the print bed.
8. **PART REMOVING:** Final created object can be removed by use of liquid solutions to weaken the bond between print bed & plastic object and also using a good quality scraper to remove the object from print bed. Create
9. **POST PROCESSING:** It is the final stage of the 3D printing. It has the following
   - **STEPS** CLEANING**:** Remove the support material from the object
   - **FIXING:** Sometimes small repairs are needed to fill small holes or cracks or even to attach together parts that have been printed separately.
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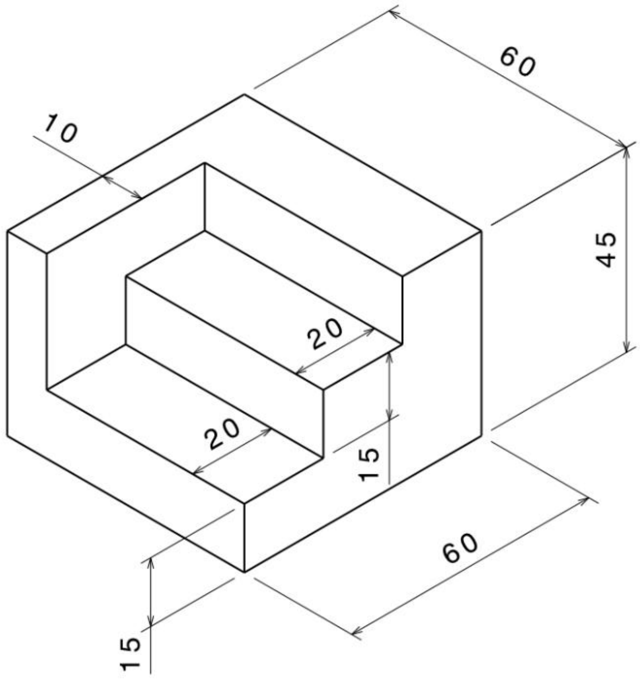
   - **COLORING:** Painting can be done manually a brush or spray. It will improve the aesthetic characteristics of the model.
10. Develop the Model & check the dimensional accuracies of the object using different instruments like Vernier caliper, Scale, Vernier height gauge, Micrometer, Depth Gauge, Bevel Protractor, Sine bar and Dial Indicator, Profile Projector etc.

AM: PART MODELLING BY 3-D PRINTING MACHINING

EXPERIMENT :5

AIM: Develop an AM Process required to produce the given Component on a 3-D Printing machine.



APPARATUS:

1. **CAD SOFTWARE**: CATIA-V5, Autodesk, Unigraphics, Solid works, Solid edge, 3DS Max etc.,
2. **RAW MATERIALS:** ABS (Acrylonitrile Butadiene Styrene), Polylactide (PLA), Polyethylene Terephthalate (PET), Polycarbonate (PC), Nylon etc.
3. **SLICING SOFTWARE:** Cura, Slice3r, Craft Ware etc.,

PROCEDURES:

1. The solid model in CAD Software (CATIA, Autodesk, Unigraphics, Solid works etc.,) as for the given dimensions.
2. The digital design (Cad part) is to be converted to STL file using slicer software (Cura, Idea maker etc.,)
3. Select suitable material for creating the object.

4. Perform machine setting: Levelling of the built Plate (Bed), Lubrications, Set the desired print speed, Set the required temperature of the built plate & printer nozzle.
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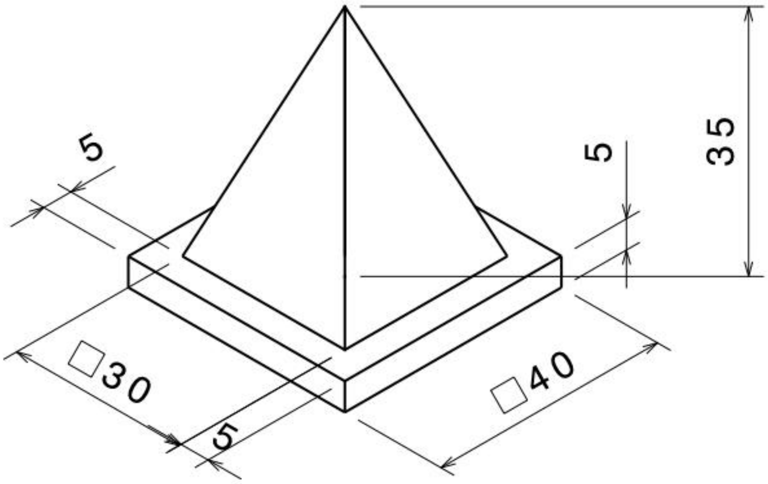
10. Develop the Model & check the dimensional accuracies of the object using different instruments like Vernier caliper, Scale, Vernier height gauge, Micrometer, Depth Gauge, Bevel Protractor, Sine bar and Dial Indicator, Profile Projector etc.

AM: PART MODELLING BY 3-D PRINTING MACHINING

EXPERIMENT :6

AIM: Develop an AM Process required to produce the given Component on a 3-D Printing machine.



APPARATUS:

1. **CAD SOFTWARE**: CATIA-V5, Autodesk, Unigraphics, Solid works, Solid edge, 3DS Max etc.,
2. **RAW MATERIALS:** ABS (Acrylonitrile Butadiene Styrene), Polylactide (PLA), Polyethylene Terephthalate (PET), Polycarbonate (PC), Nylon etc.
3. **SLICING SOFTWARE:** Cura, Slice3r, Craft Ware etc.,

PROCEDURES:

1. The solid model in CAD Software (CATIA, Autodesk, Unigraphics, Solid works etc.,) as for the given dimensions.
2. The digital design (Cad part) is to be converted to STL file using slicer software (Cura, Idea maker etc.,)
3. Select suitable material for creating the object.
4. Perform machine setting: Levelling of the built Plate (Bed), Lubrications, Set the desired print speed, Set the required temperature of the built plate & printer nozzle.
5. Feed the filament in to the extruder of the printer.
6. Select the G-code file in the printer to start the print.
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8. **PART REMOVING:** Final created object can be removed by use of liquid solutions to weaken the bond between print bed & plastic object and also using a good quality scraper to remove the object from print bed. Create
9. **POST PROCESSING:** It is the final stage of the 3D printing. It has the following
    - **STEPS CLEANING:** Remove the support material from the object.
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    - **COLORING:** Painting can be done manually a brush or spray. It will improve the aesthetic characteristics of the model.
10. Develop the Model & check the dimensional accuracies of the object using different instruments like Vernier caliper, Scale, Vernier height gauge, Micrometer, Depth Gauge, Bevel Protractor, Sine bar and Dial Indicator, Profile Projector etc.

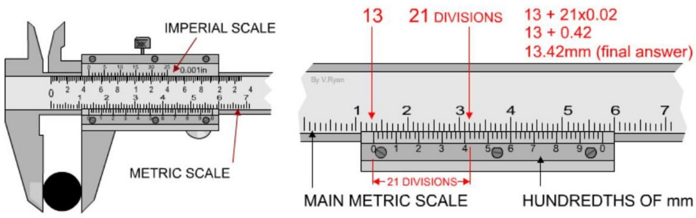
AM: QUALITY CHECK AND INSPECTION

AIM :

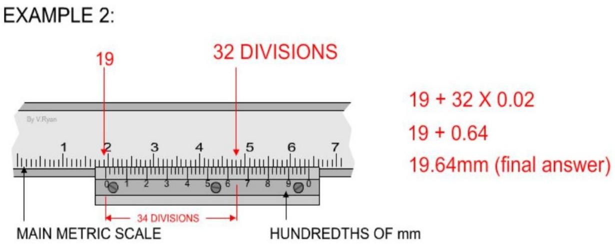
1. Determination of Linear\Angular dimensions of a part using non-precision measuring instruments. Vernier Calliper, Vernier Height Gauge, Micrometer, Digital Vernier Caliper, Digital Micrometer
2. Determination Precision Angular Measurements using, sine bar, Bevel Protractor.
3. Determination Diameter of given component, thread pitch etc of the component is measured by profile projector.

APPARATUS: Vernier Calliper, Vernier Height Gauge, Micrometer, Digital Vernier Calliper, Digital Micrometre. Vernier bevel protractor (0° to 360°), least count=0°- 5°, sine bar, profile projector

A. **VERNIER CALLIPER:** The principle of vernier is that when two scales or divisions slightly different in size are used, the difference between them can be utilized to enhance the accuracy of measurement. The Vernier Calliper essentially consists of two steel rules and these can slide along each other. The details are shown in fig. below



EXAMPLE 2: (To zoom in to see the scale - right click mouse and select zoom)

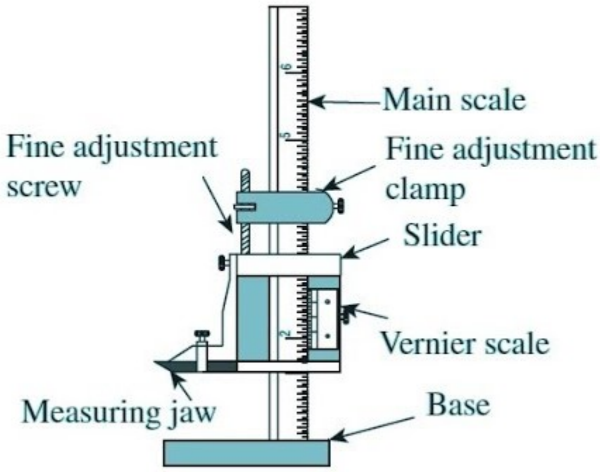


1. Outside jaws: used to measure external diameter or width of an object
2. Inside jaws: used to measure internal diameter of an object
3. Depth probe: used to measure depths of an object or a hole
4. Main scale: gives measurements of up to one decimal place (in cm).
5. Main scale: gives measurements in fraction(in inch)
6. Vernier gives measurements up to two decimal places(in cm)
7. Vernier gives measurements in fraction(in inch)

Least country main scale division-vernier scale division. Least count = value of 1msd/total no. Of vsd
1 msd = 0.1mm, total no. Vsd = 5 therefore LC = 0.02mm t

Suppose 50 vernier scale I division coincide with 49 divisions on main scale, and 1 msd=1 mm.Then 1 VSD = 49/50 of MSD = 49/50MM.and LC = 1-49/50= 0.02 mm. Alternatively, it is just as easy to read the 13 on the main scale and 42 on the hundredths scale. The correct measurement being 13.42mm.(1 cmm = 10mm)

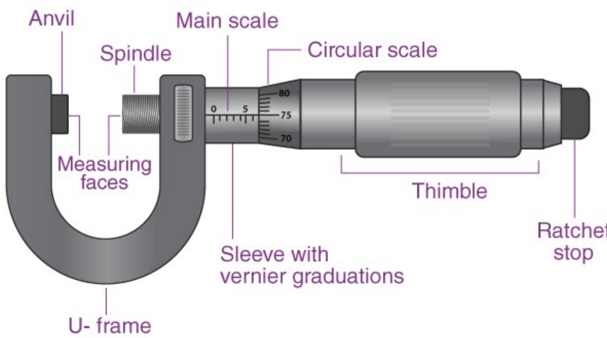
B. VERNIER HEIGHT GUAGE: This is also a sort of a vernier caliper equipped with a special base back and other attachments which make the instrument suitable for height measurement.



Along with the sliding jaw assembly arrangement is provided to carry a removable clamp.

The upper and the lower surface of the measuring jaw are parallel to the base so that it can be used for measurement over or under the surface. The vernier height guage is merely used to scribe lines of certain distance above surface. However, dial indicator can be attached in the clamp and many useful measurements can be exactly made as it exactly gives the indication when dial tip just touches the surfaces. For all these measurements, use of surface plates as datum surface is very essential.

C. MICROMETER: The micrometer essentially consists of U shaped frame. The component to be measured is held between fixed anvil and movable spindle. The spindle can be moved with the help of thimble. There are two scales on micrometer, a main scale and a circular scale. The barrel is graduated in unit of



0.5 mm whereas thimble has got 50 divisions around its periphery. One revolution of thimble moves 0.5 mm which is the lead of the screw and also the pitch.

2.5 mm+ (46*0.01) = 2.96 mm (for Figure 3)

DIGITAL MICROMETER:

- It is used where high accuracy is required.
- It is based on electronic technology.
- It can be zeroed at any position, which greatly speeds the process of inspection.

D. VERNIER DEPTH GAUGE

This is similar to vernier height gauge. It consists of main scale, vernier scale, jaws, and lock nut fine adjustment screw like vernier caliper as shown in fig. In vernier depth gauge, graduated scale can slide through the base and vernier scale remains fixed. The vernier scale is fixed to the main body of the depth gauge and is read in the same way as vernier caliper. In vernier depth gauge, graduated scale can slide through the base and vernier scale remains fixed. The main scale provides the datum surface from which the measurements are taken. Vernier depth gauge is used to measure depth of holes, distance from a plane surface to a projection and recess.

PROCEDURE:

For Vernier Calliper/Micrometer/Height gauge :

1. Check the zero of main and vernier scale to be coinciding.
2. Read the instrument for at least three random vernier positions.
3. Measure the samples at indicated places and record as per the format

OBSERVATION TABLE:

For Vernier Calliper:

S. NO.	ACTUAL READING (mm)	MEASURED READING (mm)	ERROR(mm)
1.			
2.			

For Micrometer:

S. NO.	ACTUAL READING(mm)	MEASURED READING(mm)	ERROR (mm)
1.			
2.			

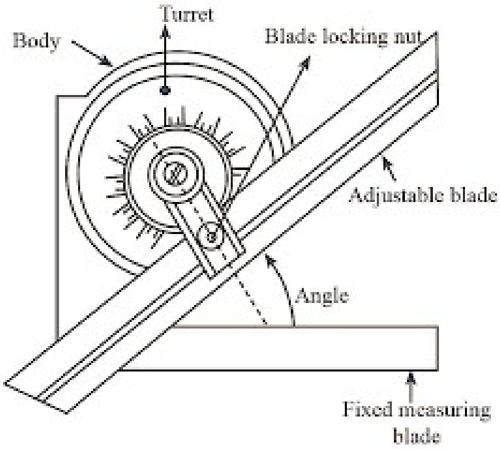
For Digital Height Gauge: LC : 0.001

S. NO.	ACTUAL READING	MEASURED READING	ERROR
1.			
2.			

For Vernier Depth Gauge:

S. NO.	ACTUAL READING	MEASURED READING	ERROR
1.			
2.			

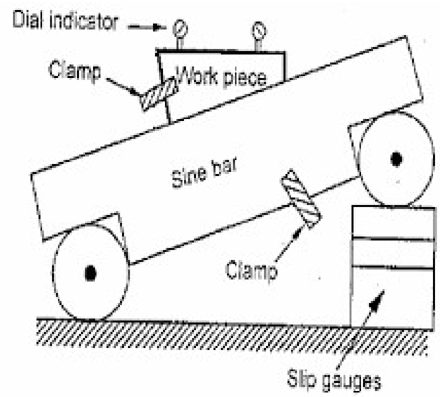
THEORY:



A sine bar is a tool used to measure angles in metalworking. It consists of a hardened, precision ground body with two precision ground cylinders fixed at the ends. The distance between the centers of the cylinders is precisely controlled, and the top of the bar is parallel to a line through the centers of the two rollers as shown in Fig. 1.

The dimension between the two rollers is chosen to be a whole number (for ease of later calculations) and forms the hypotenuse of a triangle when in use. Generally, the centre distance between two cylindrical rollers is 10 inch or 100 mm sine bar (however, in the U.S., 5 inch sine bars are the most commonly used).

A Bevel Protractor, a graduated circular protractor having a pivoted arm and used for measuring or marking off angles, is shown in Fig. 2. Sometimes vernier scales are attached to give more accurate readings.



Angles are measured using a sine bar with the help of gauge blocks and a dial gauge or a spirit level. sine of the angle of inclination of the wedge is the ratio of the height of the slip gauges used and the distance between the centres of the cylinders.

Sine Centre is a special type of sine bar, which is used for conical objects having male and female parts, as shown in Fig. 3. It cannot measure the angle more than 45 degrees. Sine table (or sine plate) is used to measure angles of large work pieces. Compound sine table is used to measure compound angles of large work pieces. In this case, two sine tables are mounted one over the other at right angles. The tables can be twisted to get the required alignment.

PROCEDURE:

1. Study the bevel protractor and identify its main parts.
2. Introduce the adjustable blade in the slot of body and clamp it with the help of knob In the convenient position.
3. Place the working edge of the stock on one surface of the job and rotate the turret holding the blade so that the working edge of the blade coincides with another surface of the job. Fix the turret and read the
4. angle. And now measure the angles of the sample pieces with the bevel protractor and record the reading.

OBSERVATION:
1. Length of sine bar=L=200 mm 2. size , h=68.6 specimen angle with vernier bevel protractor=68.6 centre distance=200 mm 5. ø=sin-1(h/L)= 20.097 angle of specimen=20.1 least count of dial indicator=0.001 mm

APPARATUS: PROFILE PROJECTOR

THEORY: By using lenses and beams of light, profiles of small shapes can be magnified. The enlarged image can be compared with accurate drawing made to the scale of magnification. Such a comparison can reveal any deviations in the sizes and contours of the objects and to get a numerical assessment of such deviations, measurements can be made on the enlarged shadow. The measured dimensions on the shadow will then have to be divided by the multiplication factor. The projection apparatus used for this purpose is termed as an optical profile projector.

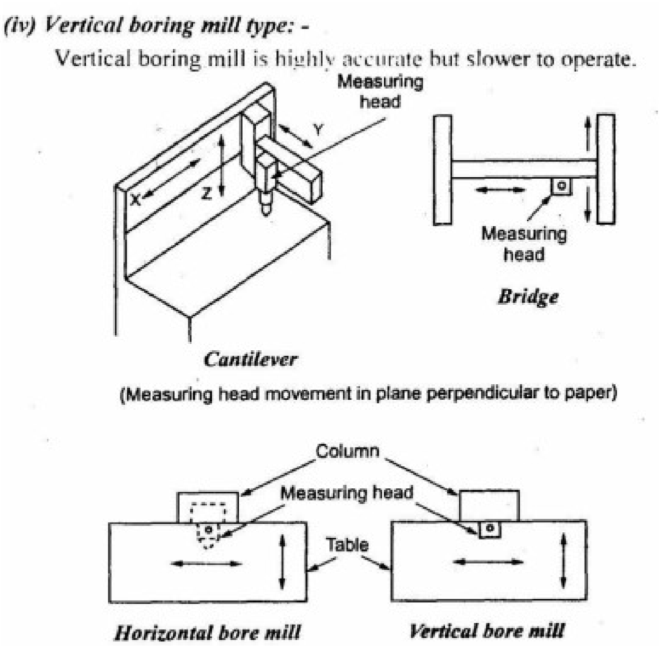
The essential features of a profile projector are that, it should be accurately as stated and that there should be maximum latitude in holding and adjusting the work piece and examining the projected shadow.

OBSERVATION TABLE:
SPECIMEN 1

S NO	PARAMETER	INITIAL READING (mm)	FIANL READING (mm)	ACTUAL READING (mm)
1.	MAJOR DIAMETER			
2.	BORE DIAMETER			
3.	THICKNESS OF SLOT			
4.	LENGTH OF SLOT			

CONCLUSION: Thus, diameter of given component thread pitch etc of the component is measured by profile projector.

CO-ORDINATE MEASURING MACHINES Measuring machines are used for measurement of length over the outer surfaces of a length bar or any other long member. The member may be either rounded or flat and parallel. It is more useful and advantageous than vernier calipers, micrometer, screw gauges etc. the measuring machines are generally universal character and can be used for works of varied nature. The co-ordinate measuring machine is used for contact inspection of parts. When used for computer-integrated manufacturing these machines are controlled by computer numerical control. General software is provided for reverse engineering complex shaped objects. The component is digitized using CNC, CMM and it is then converted into a computer model which gives the two surface of the component. These advances include for automatic work part alignment on the table. Savings in inspection 5 to 10 percent of the time is required on a CMM compared to manual inspection methods



Working Principle CMM is used for measuring the distance between two holes. The work piece is clamped to the worktable and aligned for three measuring slides x, y and z. The measuring head provides a taper probe tip which is seated in first datum hole and the position of probe digital read out is set to zero. The probe is then moved to successive holes, the read out represent the co-ordinate part print hole location with respect to the datum hole. Automatic recording and data processing units are provided to carry out complex geometric and statistical analysis. Special co-ordinate measuring machines are provided both linear and rotary axes. This can measure various features of parts like cone, cylinder and hemisphere. The prime advantage of co-ordinate measuring machine is the quicker inspection and accurate measurements

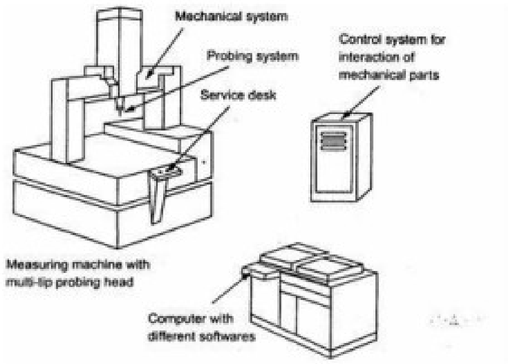


Fig.: **Column Type**

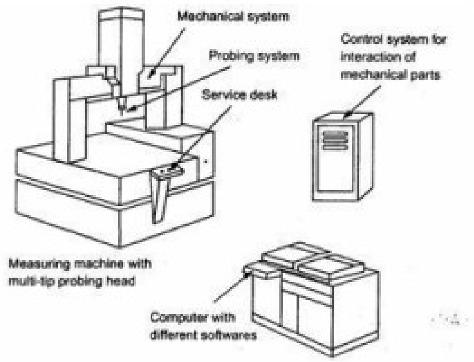
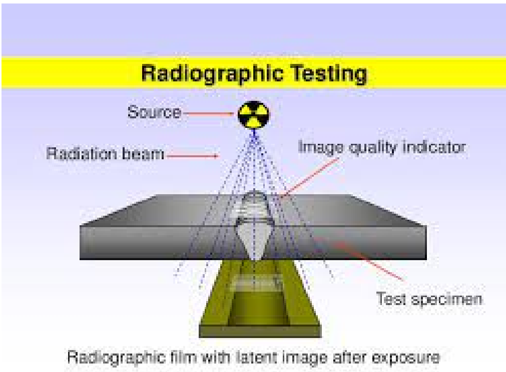


Fig.: **Bridge Type**

AM: NON DESTRUCTIVE TESTING METHODS

RADIOGRAPHIC TESTING uses radiation passed through a test piece to detect defects. X-rays are commonly used for thin or less dense materials while gamma rays are used for thicker or denser items. In Radiography Testing the test-part is placed between the radiation source and film (or detector). The material density and thickness differences of the test-part will attenuate (i.e. reduce) the penetrating radiation through interaction processes involving scattering and/or absorption. The differences in absorption are then recorded on film(s) or through an electronic means. In industrial radiography there are several imaging methods available, techniques to display the final image, i.e. Film Radiography, Real Time Radiography (RTR), Computed Tomography (CT), Digital Radiography (DR), and Computed Radiography (CR). There are two different radioactive sources available for industrial use; X-ray and Gamma-ray. These radiation sources use higher energy level, i.e. shorter wavelength, versions of the electromagnetic waves. Because of the radioactivity involved in radiography testing, it is of paramount importance to ensure that the Local Rules is strictly adhered during operation.



BENEFITS

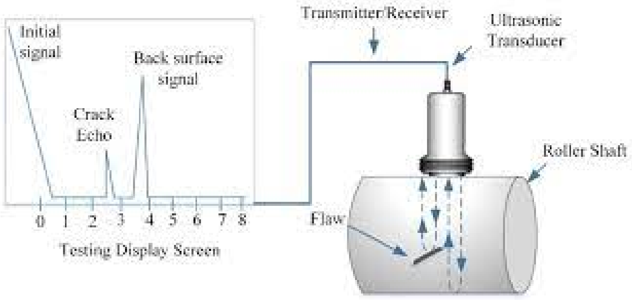
1. Can inspect assembled components
2. Minimum surface preparation required
3. Detects both surface and subsurface defects
4. Provides a permanent record of the inspection
5. Verify internal flaws on complex structures

6. Isolate and inspect internal components
7. Automatically detect and measure internal flaws
8. Measure dimensions and angles within the sample without sectioning
9. Sensitive to changes in thickness, corrosion, flaws and material density changes

APPLICATIONS

1. Aerospace industries
2. Military defence
3. Offshore industries
4. Marine industries
5. Power-gen industries
6. Petrochem industries
7. Waste Management
8. Automotive industries
9. Manufacturing industries
10. Transport industries

ULTRASONIC TESTING (UT): Ultrasonic Testing ultrasonic testing (UT) is one of the more common non-destructive testing methods performed on materials. This testing utilises high frequency mechanical energy, i.e. high frequency sound waves into a material to interact with features within the material that reflect or attenuate it. Ultrasonic testing is broadly divided into Pulse Echo (PE), Through Transmission (TT) and Time of Flight Diffraction (ToFD). Typically the UT inspection system consists of a ultrasonic transducer, pulser/receiver, and display unit. A pulser/receiver is an electronic device that can produce high voltage electrical pulses to the transducer. When driven by the pulser, the transducer generates high frequency ultrasonic sound energy into the material in the form of sound waves. When there are discontinuities such as inclusions, porosity, cracks, etc. in the sound path, part of the mechanical energy will be reflected from the discontinuities' (reflectors') surface. The reflected sound waves signal received by the transducer is then transformed back into an electrical signal and its intensity is shown on the display unit. The sound waves travel time can be directly related to the distance that the signal has travelled. From the signal, information about reflector location, size, orientation and other features can be determined.



Benefits

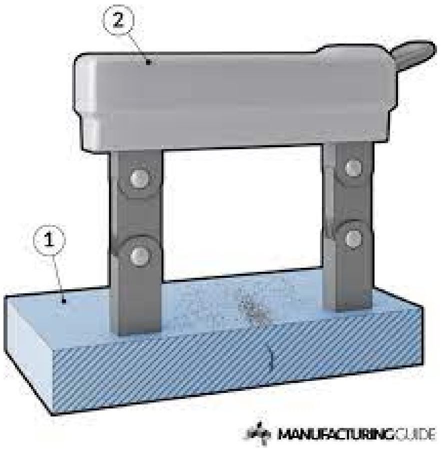
1. Some of the various advantages of this UT method is;
2. Capable of portable or highly automated operation
3. Can be performed on all types of materials
4. High accuracy and reproducibility in flaws detection
5. Generally only one surface needs to be accessible
6. Fluid level check in enclosure
7. Materials characterisation

Applications

1. Ultrasonic Testing is widely used for;

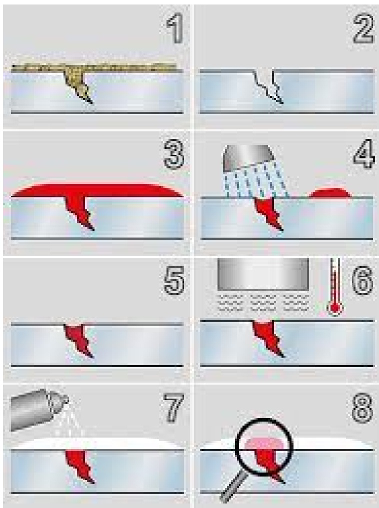
2. Checking the quality of welds in pipes for the offshore oil industry
3. Flaw detection and evaluation of materials
4. Aerospace industries
5. Military defence
6. Offshore and marine industries

Magnetic Particle Testing (MT): This NDT process uses magnetic fields to find discontinuities at or near the surface of ferromagnetic materials. The magnetic field can be created with a permanent magnet or an electromagnet, which requires a current to be applied. The magnetic field will highlight any discontinuities as the magnetic flux lines produce leakage, which can be seen by using magnetic particles that are drawn into the discontinuity**.**



Magnetic particle inspection is a non-destructive testing process designated to detecting defects /discontinuities invisible to the naked eye located on surfaces and in shallow subsurface up to 2 mm deep. The objective of magnetic particle testing is to create a magnetic field above the defect and to detect the defect by presence of a flux leakage field. In order to detect magnetic fields above defects on inspected areas of the tested item there are applied ferromagnetic particles, suspended in a liquid or in air (dry method). Magnetic particle inspection is used for detecting defects (discontinuities in surfaces and shallow subsurfacaes) in ferromagnetic materials.
By magnetization of the inspected area there is created a magnetic field. Magnetic flux does not change its direction in the defect-free area of the tested item. But if there is a defect occurs on the way of the magnetic flux, such as for example a discontinuity of the metal (cracks, non-metallic inclusions, pores, etc.), then some of magnetic lines come out of the item. In places where magnetic lines come out and come back there appear local magnetic poles N, S and a magnetic field above the defect. A number of forces influence ferromagnetic particles in the magnetic field above the defect. As a result of this influence ferromagnetic particles are getting magnetized and attracted to each other, they join into chains and move toward the defect where they group in strips. The width of strips of the settled powder is significantly more then the width of cracks, hair cracks, therefore magnetic particle inspection can detect the tiniest cracks with opening width of 0.001 mm, depth of 0.01 mm and more, as well as other defects.

Liquid Penetrant Testing (PT): Liquid penetrant testing involves the applic ation of a fluid with low viscosity to the material to be tested. This fluid seeps into any defects such as cracks or porosity before a developer is applied which allows the penetrant liquid to seep upwards and create a visible indication of the flaw. Liquid penetrant tests can be conducted using solvent removable penetrants, water washable penetrants or post-emulsifiable penetrants.



Liquid Penetrant Inspection Process
Surface Preparation: One of the most critical steps of a liquid penetrant inspection is the surface preparation. The surface must be free of oil, grease, water, or other contaminants that may prevent penetrant from entering flaws. The sample may also require etching if mechanical

operations such as machining, sanding, or grit blasting have been performed. These and other mechanical operations can smear metal over the flaw opening and prevent the penetrant from entering.

Penetrant

Application: Once the surface has been thoroughly cleaned and dried, the penetrant material is applied by spraying, brushing, or immersing the part in a penetrant bath. Penetrant Dwell: The penetrant is left on the surface for a sufficient time to allow as much penetrant as possible to be drawn from or to seep into a defect . Penetrant dwell time is the total time that the penetrant is in contact with the part surface. Dwell times are usually recommended by the penetrant producers or required by the specification being followed. The times vary depending on the application, penetrant materials used, the material, the form of the material being inspected, and the type of defect being inspected for. Minimum dwell times typically range from five to 60 minutes. Generally, there is no harm in using a longer penetrant dwell time as long as the penetrant is not allowed to dry. The ideal dwell time is often determined by experimentation and may be very specific to a particular application.

Excess Penetrant

Removal: This is the most delicate part of the inspection procedure because the excess penetrant must be removed from the surface of the sample while removing as little penetrant as possible from defects. Depending on the penetrant system used, this step may involve cleaning with a solvent, direct rinsing with water, or first treating the part with an emulsifier and then rinsing with water.

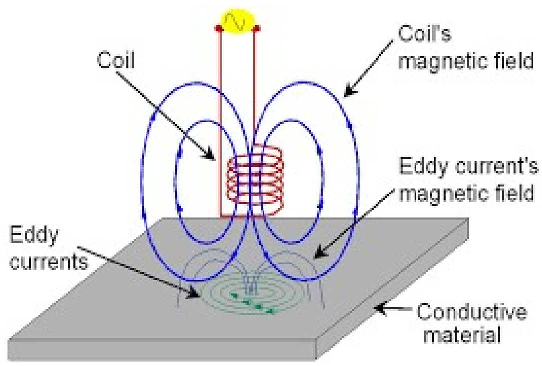
Developer Application: A thin layer of developer is then applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible. Developers come in a variety of forms that may be applied by dusting (dry powdered), dipping, or spraying (wet developers).

Indication Development: The developer is allowed to stand on the part surface for a period of time sufficient to permit the extraction of the trapped penetrant out of any surface flaws. This development time is usually a minimum of 10 minutes. Significantly longer times may be necessary for tight cracks.

Inspection: Inspection is then performed under appropriate lighting to detect indications from any flaws which may be present.

Clean Surface: The final step in the process is to thoroughly clean the part surface to remove the developer from the parts that were found to be acceptable.

Electromagnetic Testing (ET): This testing method uses an electric current or magnetic field which is passed through a conductive part. There are three types of electromagnetic testing, including eddy current testing, alternating current field measurement (ACFM) and remote field testing (RFT).



Eddy current testing uses an alternating current coil to induce an electromagnetic field into the test piece, alternating current field measurement and remote field testing both use a probe to introduce a magnetic field, with RFT generally used to test pipes.

Alternating current field measurement (ACFM) is an electromagnetic technique used for the detection and sizing of surface breaking cracks in metallic components and welds. It combines the advantages of the alternating current potential drop (ACPD) technique and Eddy Current Testing (ECT) in terms of defect sizing without calibration and ability to work without electrical contact respectively.

The ACFM probe introduces an electric current locally into the part and measures the associated electromagnetic fields close to the surface. The presence of a defect disturbs the associated fields and the information is graphically presented to the system operator. The ends of a defect are easily identified to provide information on defect location and length. Through wall extent of the flaw plays an important role in determining structural integrity and the same is calculated using mathematical computation thus allowing an immediate evaluation of the implication of the indication. ACFM inspection can be performed through paint and coatings, hence it is considered to be a faster and economic technique than others (E.g. magnetic particle inspection (MPI).

Benefits

1. Applicable for base material or welds, ferritic or non-ferritic conductive metals
2. Can be used on hot surfaces, underwater, or in irradiated environments
3. Provides both depth and length information
4. Accurate sizing of defects up to 25mm in depth
5. Requires minimal surface preparation and can be applied over paint and other coatings
6. Applicable for under water inspection as well as normal inspection
7. Inspection data can be stored and analysed offline
8. Inspection can be encoded

Applications

1. Detection and sizing of fatigue cracks and hydrogen cracking
2. Inspection of fillet welds in mobile offshore drilling Units
3. Inspection of fillet welds in highway bridges
4. Inspection of rail components
5. Inspection of gear box, gear teeth, crank shafts, cylinder heads, turbines etc. in aerospace industries
6. Detection of cracks and corrosion in vessels, storage tanks and piping in oil and gas and power generation industries
7. Inspection of drilling

Visual Testing (VT): Visual testing also known as visual inspection is one of the most common techniques which involves the operator looking at the test piece. This can be aided by the use of optical instruments such as magnifying glasses or computer-assisted systems (known as 'Remote Viewing').

This method allows for the detection of corrosion, misalignment, damage, cracks, and more. Visual testing is inherent in most other types of NDT as they will generally require an operator to look for defects.

Material handling in Advanced Manufacturing (Robotics)

AUTOMATED GUIDED VEHICLE (AGV)

AGV NAVIGATION MECHANISMS:

- Magnetic guide tape — some AGVs have magnetic sensors and follow a track using magnetic tape.
- Wired navigation — some AGVs follow wire paths embedded into the facility floor. The wire transmits a signal that AGVs detect via an antenna or sensor.
- Laser target navigation — with this method, reflective tape is mounted on objects such as walls, fixed machines and poles. AGVs are equipped with a laser transmitter and receiver. The lasers reflect off of the tape within the line of sight and used to calculate the object's angle and distance from the AGV.

- Inertial (gyroscopic) navigation — some AGVs are controlled by a computer system with the aid of transponders embedded into the facility floor to verify that the AGV is on the proper course.
- Vision guidance — No modification is required to the infrastructure for vision-guided AGVs. Cameras record the features along the route, and AGVs rely on these recorded features to navigate.

- Geoguidance — Like vision-guided AGVs, no infrastructure modifications are required for AGVs that use geoguidance. Geoguided AGVs recognize objects in their environment to establish their location in real-time to navigate throughout the facility.
- LiDAR — LiDAR (Light Detection and Ranging) is a sophisticated navigation technology utilizing sensors that transmit laser pulses to measure the distance between the robot and objects in its environment. This data is compiled to create a 360-degree map of the environment, allowing robots to navigate the facility and avoid obstacles without the need for any additional infrastructure. 6 River Systems uses LiDAR navigation technology to enable their AGVs to navigate a warehouse without requiring changes to infrastructure as well as to adapt to new environments should the layout of a warehouse floor change.

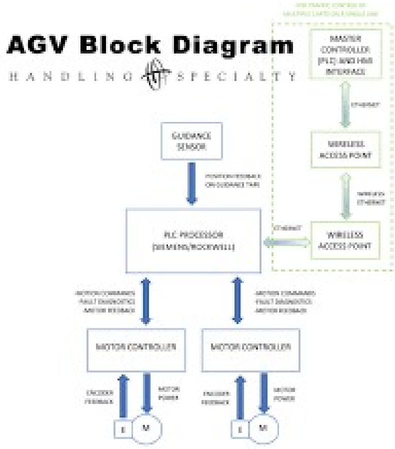
AGV STEERING: AGV steering is controlled by differential speed control, steered wheel control or a combination of the two:

- Differential speed control — This is the most common type of steering control used by AGVs. Differential speed control uses two independent drive wheels. Each drive wheel is driven at a different speed to turn. To go forward or backwards, the two drives are driven at the same speed. The simplest steering control option for AGVs, differential speed control doesn't require additional steering motors or mechanisms. It is commonly used for AGVs that operate in tight spaces or for those that operate near machines. It is not used for towing applications, as it can cause a trailer to jackknife while turning.

- Steered wheel control — This type of steering control is similar to the steering control in a car or truck. In steered wheel control, the drive wheel is the turning wheel. Steered wheel control is more precise than differential speed control and offers smoother turning. It is often used for towing applications and may also be operator-controlled.
- Combination steering — This is a combination of differential speed control and steered wheel control. AGVs using combination steering have two independent steer/drive motors on diagonal corners of the AGV and swiveling castors on the other two corners. AGVs using combination steering can turn in any direction like a car and also drive in differential steering mode in any direction.

AGV TRAFFIC CONTROL: Traffic control measures include zone control, collision avoidance or a mix of both:

- Zone control — Simple to install and easy to expand, zone control is a commonly used traffic control method for AGVs. A wireless transmitter transmits signals in defined areas, and the AGV contains a sensor that receives the signal and transmits it back to the transmitter. If the area is clear, a "clear" signal is sent that allows the AGV to enter or pass through the area. If another AGV is in the area, a "stop" signal is sent that alerts other AGVs attempting to enter that the area is not clear. In this case, the waiting AGVs will stop and wait until the first AGV moves out of the zone and a "clear" signal is sent by the transmitter. Another way zone control can be used is by equipping each AGV with its own transmitter, allowing it to send a "do not enter" signal to other AGVs approaching the zone.



- Collision avoidance — AGVs using collision avoidance zone control are equipped with sensors that transmit a signal and wait for a reply to determine if an object is in front of it. These sensors may be sonic, which work like radar, or optical, which uses infrared sensors. Both work in a similar manner. Bumper sensors are another type of collision avoidance sensor. Many AGVs are equipped with bumper sensors as a fail-safe. Bumper sensors stop to avoid a collision when they sense physical contact.
- Combination control — AGVs that use combination control are equipped with both Collison control sensors and zone control sensors in order to offer more robust collision prevention in all situations. For instance, an AGV may use zone control as its primary traffic control system but also have collision avoidance sensors as a backup in case the zone control system malfunctions

AGVs provide automated material movement for a variety of industries including:

- Automotive
- Beverage
- Chemicals
- Commercial printing
- Food
- Hospital
- Manufacturing
- Newspaper
- Paper
- Pharmaceutical
- Plastics
- Warehousing and distribution

AUTOMATED STORAGE AND RETRIEVAL SYSTEMS: (AS/RS)

Automated Storage and Retrieval Systems (also referred to as ASRS systems) are most commonly used in manufacturing and distribution facilities. AS/RS, are made of a variation of computer-controlled systems that automatically place and retrieve loads from set storage locations in a facility with precision, accuracy and speed.. They typically replace large areas of shelving to save floor space, improve safety and increase productivity.

Generically speaking, AS/RS refers to a variety of computer-controlled methods for automatically depositing and retrieving loads to and from defined storage locations. Within an AS/RS environment one would find one or more of the following technologies:

- Unit-load AS/RS – Machines that store large loads (usually 1,000+ pounds), typically on pallets with storage rack structure, reaching 100 feet or more tall.
- Mini-load AS/RS – Operating the same as a unit-load AS/RS, a mini-load AS/RS handle lighter loads, usually weighing less than 1,000 pounds
- Vertical lift modules (VLMs) – VLMs consist of a column of trays in the front and back of the module with an automatic inserter/extractor in the center that stores and retrieves the required trays
- Shuttles – Shuttles are used for the automated handling of totes, trays, cartons or all three in the same system – for either warehousing or manufacturing.
- Horizontal carousels – Ideal for storing small parts and pieces, horizontal carousels are comprised of a series of bins that rotate horizontally around a track.
- Vertical carousels – Rotating vertically, like a Ferris wheel, vertical carousels house a series of shelves or carriers to provide high-density storage.
- Cube-based storage – Ultra-high density goods-to-person piece picking system which utilizes robots to store and retrieve inventory bins from a cubical storage grid.
-

Automated storage and retrieval systems are used in a variety of areas to support processing and picking throughout a facility:

- Order picking: Retrieving and presenting required inventory to pickers
- Storage: Providing dense long-term buffering for small or large items that are slow- to medium-movers
- Kitting: Providing an area to group component parts for assembly
- Consolidation: Providing a dynamic area to hold parts and items until all pieces of an order can be merged ready for shipment. Often used for consumer, B2B and store orders.
- Assembly: Storing work piece components for later production
- Production: Storing tooling and component parts for manufacturing processes
- Replenishment: Storing excess inventory for restocking of ancillary picking systems
- Security: Providing an enclosed storage environment with software access controls
- Retail: Providing a large quantity of parts and items at a customer service desk. Keeps workers in front of customers instead of walking and searching in back rooms.

CONCEPTS OF INDUSTRIAL ROBOTS

- Industrial robots are those numerical control systems that can be automatically controlled, and are reprogrammable, multipurpose manipulators that can move along in three or more axes. Some robots are programmed to carry out specific action repeatedly without variation, and with a high degree of accuracy.

IMPACTS OF ROBOTS IN MANUFACTURING

- Robotics in manufacturing is being used in multiple different areas due to automation. Robot applications in manufacturing include welding, assembly, shipping, handling raw materials, and product packing. For this reason, multiple manufacturers are leveraging robotic automation for an increased number of tasks.

APPLICATION OF ROBOTS TYPES OF ROBOTS

- Arc Welding: Arc welding, or robot welding, became commonplace in the 1980s. One of the driving forces for switching to robot welding is improving the safety of workers from arc burn and inhaling hazardous fumes.
- Spot Welding: Spot welding joins two contacting metal surfaces by directing a large current through the spot, which melts the metal and forms the weld delivered to the spot in a very short time (approximately ten milliseconds).
- Materials Handling: Material handling robots are utilized to move, pack and select products. They also can automate functions involved in the transferring of parts from one piece of equipment to another. Direct labor costs are reduced and much of the tedious and hazardous activities traditionally performed by human labor are eliminated.
- Machine Tending: Robotic automation for machine tending is the process of loading and unloading raw materials into machinery for processing and overseeing the machine while it does a job.
- Painting: Robotic painting is used in automotive production and many other industries as it increases the quality and consistency of the product. Cost savings are also realized through less rework.
- Picking, Packing and Palletizing: Most products are handled multiple times prior to final shipping. Robotic picking and packaging increases speed and accuracy along with lowering production costs.
- Assembly: Robots routinely assemble products, eliminating tedious and tiresome tasks. Robots increase output and reduce operational costs.
- Mechanical Cutting, Grinding, Deburring and Polishing: Building dexterity into robots provides a manufacturing option that is otherwise very difficult to automate. An example of this is the production of orthopedic implants, such as knee and hip joints. Buffing and polishing a hip joint by hand can normally take 45-90 minutes while a robot can perform the same function in just a few minutes.
- Gluing, Adhesive Sealing and Spraying Materials: Sealer robots are built with numerous robotic arm configurations that enable the robot to apply adhesives to any type of product. The primary benefit in this application is increased quality, speed and consistency of the final product.

FANUC Arcmate 120ic
Reach: 1811 MM
Payload: 20 KG

FANUC Arcmate 100ic
Reach: 1420 MM
Payload: 10 KG

FANUC LR Mate 200ic
Reach: 704 MM
Payload: 5 KG

FANUC M-10ia
Reach: 1420 MM
Payload: 10 KG

Motoman MH50
Reach: 2061 MM
Payload: 50 KG

FANUC M-710ic/50
Reach: 2050 MM
Payload: 50 KG

ABB IRB 4400-45/2.05
Reach: 2050 MM
Payload: 45 KG

FANUC R-2000ib/165F
Reach: 2655 MM
Payload: 165 KG

- Other Processes: These include inspection, waterjet cutting and soldering robots.

AN ARTICULATED ROBOT

- An articulated robot is a robot with rotary joints (e.g. a legged robot or an industrial robot). Articulated robots can range from simple two-jointed structures to systems with 10 or more interacting joints and materials. They are powered by a variety of means, including electric motors.

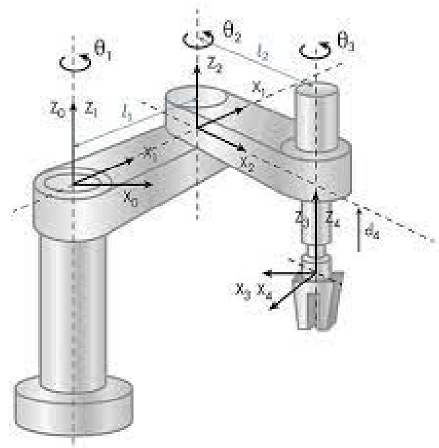
- Articulated robots are the most common types of industrial robots. Their resemblance to a human arm is perhaps one of the reasons they stand out so much in our minds. However, the mechanical benefits of this design are the real reason for their ubiquity and longevity. The arm design combines an extensive range of rotation motion and linear reach with the advantages of precision movement. Articulated arms are ideal for welding, material handling, pick-and-place operations, and dispensing. Their numerous axes and degrees of freedom mean that there is virtually no point in their work envelope that they cannot reach. This makes articulated robots one of the most versatile, flexible, and compact designs on the market.

WORK ENVELOPE OF AN ARTICULATED ROBOT

- With any industrial robot, the work envelope is a significant factor in assessing its usefulness. Articulated arm robots can use a majority of their work envelope, which is one of their greatest advantages. The only part of the envelope they can't use is the back where the cables are located. However, some modern designs feature internally routed power and data cables that eliminate this problem and let the articulated arm take advantage of its entire sphere of reach.
- Regardless of how the cables are routed, even the most basic articulated robot can maximize the usable space for its footprint on the factory floor. This is a major advantage to factories that have to consider production flow, safety, and floor space.

SCARA ROBOTS

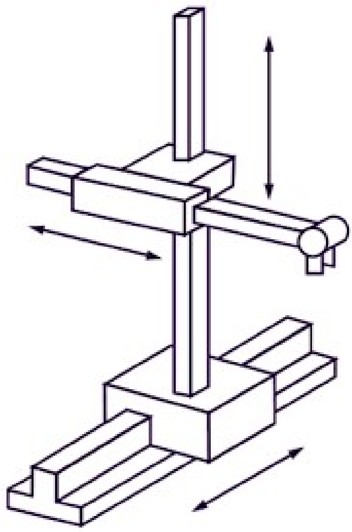
- The SCARA acronym stands for Selective Compliance Assembly Robot Arm or Selective Compliance Articulated Robot Arm.
- Scara is a type of Industrial robot.
- The SCARA robot is most commonly used for pick-and-place or assembly operations where high speed and high accuracy is required. Generally a SCARA robot can operate at higher speed and with optional cleanroom specification.
- Industrial robots are defined as 'multi-functional manipulators designed to move parts through various programmed motions'. As such, robots provides **consistent reliable performance, repetitive accuracy** and are able to handle heavy work loads and perform in harsh environments. Additionally, robots can be **quickly reprogrammed** to reflect changes in production needs and cycles



- The SCARA robot is a manipulator with four degrees of freedom. This type of robot has been developed to improve the speed and repeatability ON PICK&PLACE TASKS from one location to another or to speed and improve the steps involved in assembly. This is why it is often used with FlexiBowl®.
- Morover these robots are used in the automotive field, as well as electronic, and other industrial fields where manufacturers needs to feed bulk components of all sizes; in these areas FlexiBowl® is performing so good that is replacing others parts feeders.
- SCARA kinematics makes this robot particularly suitable to perform assembly tasks with tight tolerances, such as putting a shaft into a hole, thanks to the capability to adjust the movement on the horizontal plane, while at the same time maintaining high rigidity on the vertical direction.

- The mechanics of the SCARA arm is generally quite strong and can withstand without problems unexpected stress and collisions.
- In a SCARA robot junctions of the shoulder and elbow are vertical and the wrist moves vertically. This configuration minimizes the effects of gravity on the robot by downloading them to the ground and allowing the use of this machine in cases of strong pressures as in vertical perforations.

CARTESIAN ROBOT

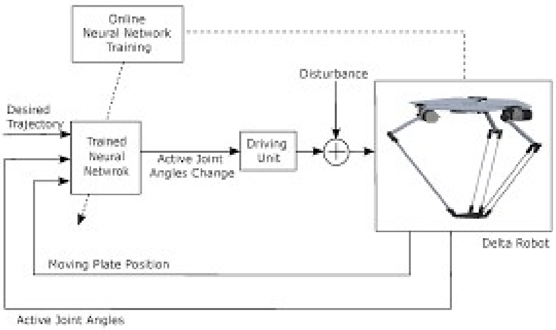


- First, a Cartesian system is one that moves in three, orthogonal axes — X, Y, and Z — according to the Cartesian coordinates. (Although it should be noted that a rotary axis — in the form of an end effector or end of arm tooling — is sometimes included on the outermost axis of a Cartesian robot.)
- What makes a Cartesian robot a *robot* is that the axes perform coordinated motion, through a common motion controller.
- The axes of a Cartesian robot are made from some form of linear actuator — either purchased as a pre-assembled system from a manufacturer or custom-built by the OEM or end user from linear guide and drive components.
- The primary difference between gantry and Cartesian robots is that a Cartesian robot uses one linear actuator on each axis, whereas a gantry robot is always constructed with two base (X) axes, with the second (Y) axis spanning them. This configuration prevents the second axis from being cantilevered (more on that below) and allows gantries to have much longer stroke lengths — and in many cases, larger payloads — than Cartesian robots.
- The second type of multi-axis linear system that does *not* fall under the definition of Cartesian robot is the XY table. The difference between Cartesian robots and XY tables lies in the mounting and loading arrangement. In a Cartesian robot, the second or third (Y or Z) axis is cantilevered, being supported at only one end by the axis below it. In addition, the load on the outer axis is generally cantilevered from that axis.
- This arrangement creates not only a moment load on the outer axis, due to the applied load, but also a significant moment load on the supporting axis, due to the combined effect of the applied load along with the outer axis. The mounting and loading arrangement limits the load-carrying capability of Cartesian robots and is a primary factor in determining the maximum stroke length for the outer (cantilevered) axis.
- In contrast, XY tables consist of two axes centered on top of each other, often with similar stroke lengths. In addition, the load is generally centered on the Y axis. This axis configuration and load positioning results in very little cantilevered loading on either axis (and often no cantilevered loading on the Y axis).
- Cartesian robots overlap SCARA and 6-axis (articulated) robots in some technical specifications and can be applied in some of the same applications, but Cartesian robots have several benefits over SCARA and 6-axis types. First, Cartesian designs provide a rectangular work envelope in which a significant percentage of the robot's footprint is used as active work area. SCARA and 6-axis types, on the other hand, have circular or oval work envelopes that often result in a lot of dead (unused) space, especially when the required travel, or reach, is very long.

- Cartesian robots can be constructed from virtually any type of linear actuator with any variety of drive mechanisms — belt, ball or lead screw, pneumatic actuator, or linear motor. (Note that rack and pinion drives are also possible, but are more commonly used in gantry systems with very long strokes.) This means they can, and often do, have better positioning accuracy and repeatability than SCARA and 6-axis types. Cartesian robots also have an ease-of-use advantage in terms of programming because their kinematics are simpler (three Cartesian axes, rather than multiple rotational axes).
- In the recent past, pre-assembled Cartesian robots were rare, with most units being custom-built by an OEM, a robot integrator, or even the end user. But now, many linear actuator manufacturers also provide pre-configured, pre-assembled Cartesian systems, with myriad options to fit common travel, payload, speed, and precision requirements. And manufacturers of traditional 6-axis and SCARA robots are getting in on the action as well, recognizing that for many industrial automation and assembly applications, Cartesian robots offer a better tradeoff between load capacity and footprint than SCARA and 6-axis designs.

DELTA ROBOTSDEMONSTRATION

- Delta robots are robots with a base connected to jointed parallelograms. These parallelograms perform motions in a solitary End of Arm Tooling (EOAT), within a workspace that is dome-shaped. This type of robot is well-known in the industrial field for its ability to execute minute, precise motions. Watch video https://youtu.be/zSUQvTvmhtk
- With delta robots all motors are located in the main body above the work area. This keeps all the main weight of the robot stationary. All movement comes from the extremely light robot arms, allowing for low inertia for incredibly fast operating speeds and accelerations.
- The Delta robot actuators are interconnected by a RS-232 network with the computer, where the control algorithm is running on ROS. This implementation was shown to improve the robustness, speed, actuator coordination and reliability (reduced fail proability).
- The main advantage of delta robots compared to traditional robotic arms is that delta robots have motors attached to the main body instead of the arms. This allows delta's arms to move at high speed which makes the delta robot ideal for lightweight pick and place operations.



LIGHTS-OUT MANUFACTURING

- Lights out manufacturing (also known as a “dark factory”) is a production method that requires little to no human interaction—essentially running on its own, even in a dark and otherwise empty factory. In order to achieve this, you need to be able to automate every single step of the manufacturing process.
- Perhaps the most well-known example of lights-out manufacturing is FANUC, a Japanese robotics company, which has been operating this way since 2001. It can reportedly operate unsupervised for up to 30 days at a time. Philips is another manufacturer that operates with mostly machines
- Lights-out operations refers to the management of a remote (and largely unmanned) recovery data center through the use of remote management software. Active management of the recovery data

center may be to support recovery plan exercising, or to orchestrate a postdisaster event operations recovery.

- The core benefits of lights out manufacturing are reducing costs and driving greater efficiency, but also include: Reduce accidents and increase worker safety. Improve operational efficiency. Reduce scrap and rework via greater production consistency.

TRANSFORMATIONS IN CYBERSECURITY

- The Cybersecurity Transformation solution helps you gain insight into your organization's cybersecurity maturity and cyber risk to the enterprise. It takes a cross-functional view of the organization's security capabilities and helps you design, deliver and maintain cybersecurity programs.

- Phases of the Cybersecurity Lifecycle. As defined by the National Insitute of Standards and Technology (NIST), the Cybersecurity Framework's five Functions: Identify, Protect, Detect, Respond, and Recover, are built upon the components of the framework model
- The five C's of cyber security are five areas that are of significant importance to all organizations. They are change, compliance, cost, continuity, and coverage. The top priority of organizations all over is having security protective of their digital and physical assets
- The cyber security principles
    - Govern: Identifying and managing security risks.
    - Protect: Implementing controls to reduce security risks.
    - Detect: Detecting and understanding cyber security events to identify cyber security incidents.
    - Respond: Responding to and recovering from cyber security incidents.
- The Seven Layers Of Cybersecurity
    - Mission-Critical Assets. This is data that is absolutely critical to protect. ...
    - Data Security. ...
    - Endpoint Security. ...
    - Application Security. ...
    - Network Security. ...
    - Perimeter Security. ...
    - The Human Layer.

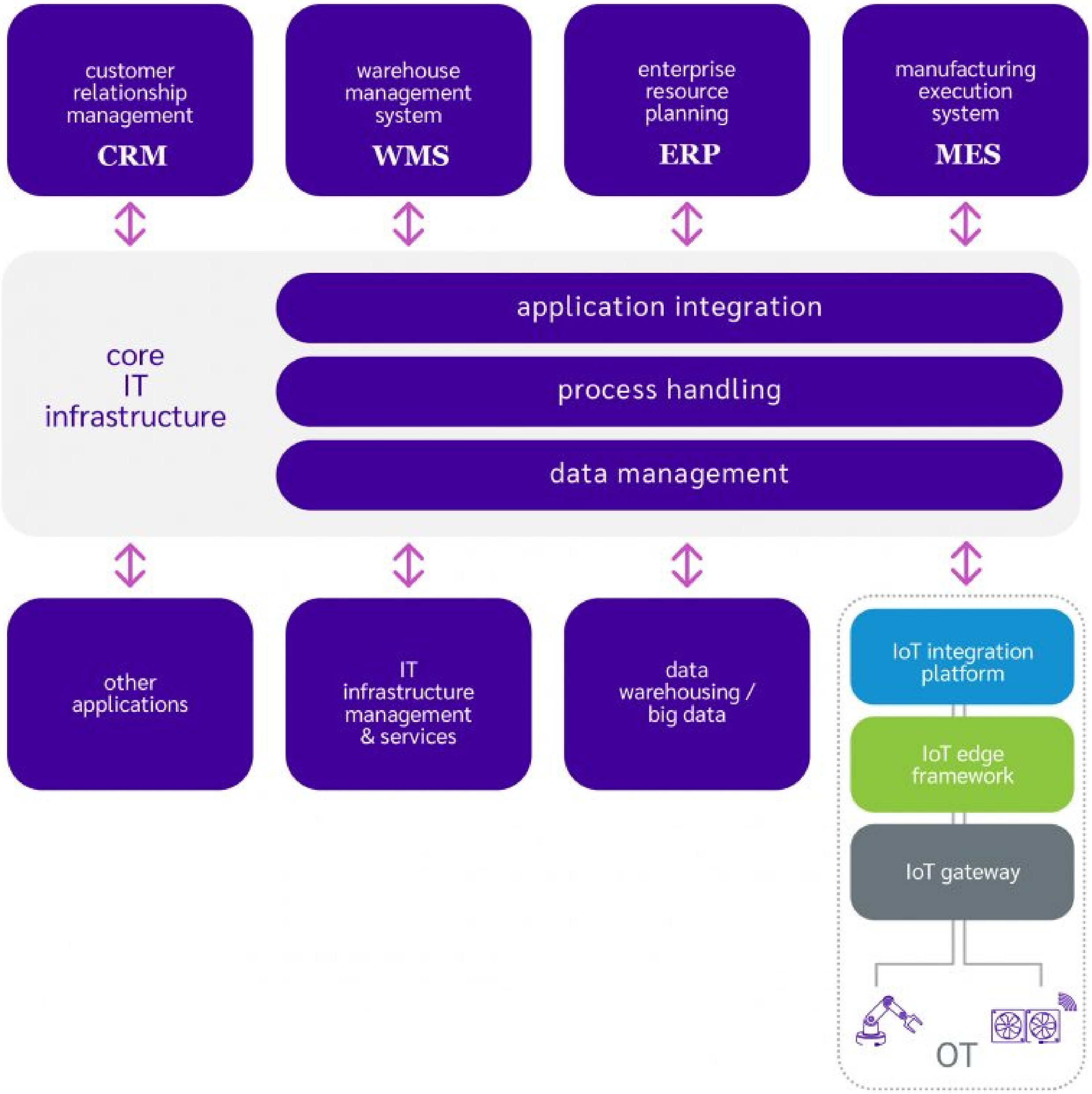
COLLABORATIVE INDUSTRIAL ROBOTS- COBOTS

- A collaborative robot, also known as a cobot, is a robot that is capable of learning multiple tasks so it can assist human beings. In contrast, autonomous robots are hard-coded to repeatedly perform one task, work independently and remain stationary.

- Collaborative robots are a form of robotic automation built to work safely alongside human workers in a shared, collaborative workspace. In most applications, a collaborative robot is responsible for repetitive, menial tasks while a human worker completes more complex and thought-intensive tasks.

- Collaborative robots are commonly known as cobots and possess the innate ability to work in tandem with humans, whereas traditional industrial robots work in place of humans. While collaborative robots are efficient Industrial IoT (IIoT) solutions, some projects may be better suited for traditional robotic technology.

CONVERGENCE OF IT (INFORMATION TECHNOLOGY) AND OT (OPERATION TECHNOLOGY)



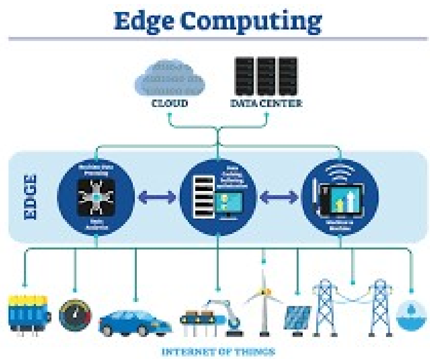
- IT/OT convergence connects IT systems to OT systems, allowing them to transmit data to each other. The goal of IT/OT convergence is to use this connectivity to enhance the value these systems deliver.

- The Internet of Things (IoT) and the digital transformation have brought the need for the companies – across all sectors including Industrial, Transportation, Energy and Utilities, Medical and Communications – to collect actionable data from their assets, processes, and products. This requires the connection between the OT (Operational Technology) domain, that involves industrial and factory automation, supply chain management and asset monitoring – where data are generated – and the IT (Information Technology) domain, that embraces business process and office automation, enterprise web and mobile applications, etc. – where data are consumed.

- Enabling **integration between OT and IT** domains is a mandatory requirement. Seamless connectivity is realized by an **IoT edge framework** (that works as middleware at the edge of an IoT network) and an **integration platform**, normally located in the cloud or on premise in a data center. This combination is used to separate data generation from data usage.

EDGE COMPUTING

- Edge computing is an emerging computing paradigm which refers to a range of networks and devices at or near the user. Edge is about processing data closer to where it's being generated, enabling processing at greater speeds and volumes, leading to greater action-led results in real time.



- Edge computing is already in use all around us – from the wearable on your wrist to the computers parsing intersection traffic flow. Other examples include smart utility grid analysis, safety monitoring of oil rigs, streaming video optimization, and drone-enabled crop management.
- The edge refers to devices at or near the physical location of either the user or the source of the data. Cloud computing is the act of running workloads within clouds, while edge computing is the act of running workloads on edge devices
- Edge computing is a distributed computing framework that brings enterprise applications closer to data sources such as IoT devices or local edge servers. This proximity to data at its source can deliver strong business benefits: faster insights, improved response times and better bandwidth availability.

DEMONSTRATE ADOPTION OF IIOT TECHNOLOGY • PREDICTIVE MAINTENANCE.

Predictive maintenance for industry 4.0 is a method of preventing assets failure by monitoring production data to recognize patterns and estimate concerns before they happen. Previously factory managers and system operators carried out scheduled maintenance, other processes and regularly repaired machine parts to prevent downtime.

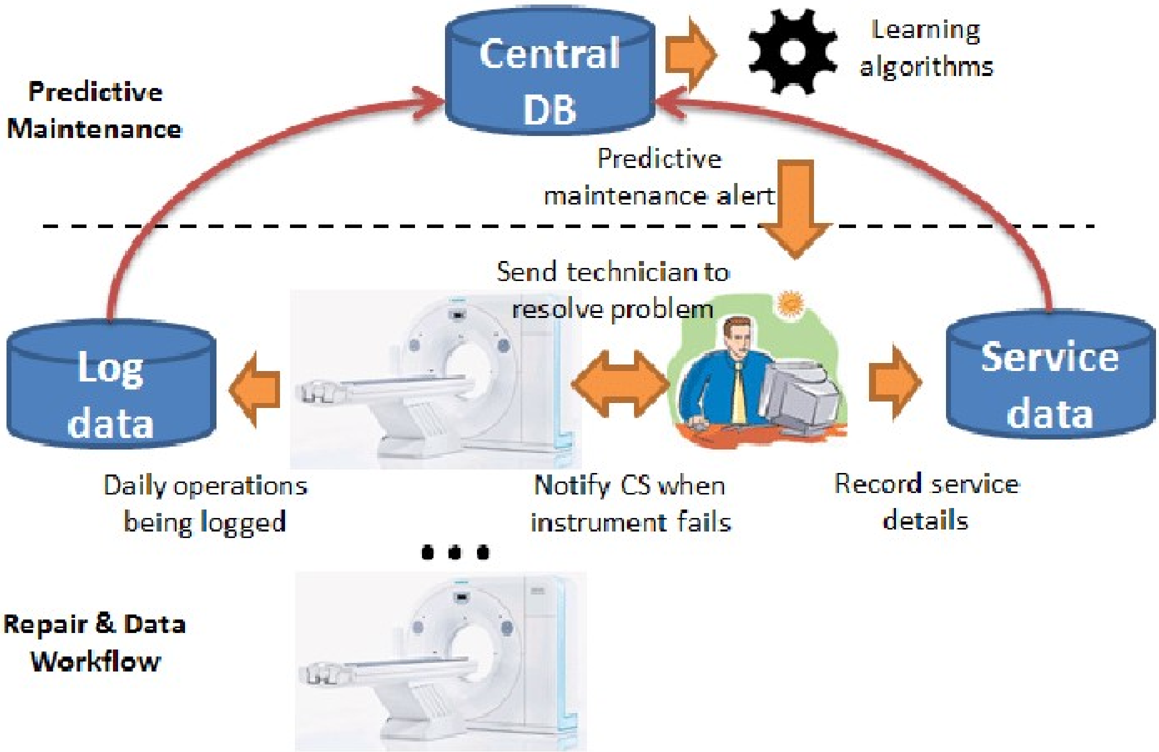
Predictive maintenance has rapidly emerged as a leading Industry 4.0 use case for manufacturers, factory managers and asset managers. By implementing IIOT technology to analyze asset nature, optimize maintenance schedules and gaining real-time alerts to operational risks, enables manufacturers to reduce service costs, enhance uptime and improve production throughput.
objectives of predictive maintenance

- Improving Production efficiency: Based on readings from a machine, production efficiency can be improved either by increasing the time when machines are running through predictive maintenance or by predicting the number of goods that will pass or fail in quality inspection. That enables manufactures to reduce maintenance costs, expand equipment life, decrease downtime and enhance production quality by addressing problems before they cause equipment failures.
- Improving Maintenance efficiency: Analyzing for future failure enables maintenance to be designed before failure occurs. That improves maintenance efficiency of equipment and of entire system.

IIOT- PREDICTIVE MAINTENANCE WORKS

For predictive maintenance to be carried out following are the important components that are essential:

- Sensor: Data collecting sensors situated in machine.
- Data Communication: The system that allows data to travel safely in between the analyzed asset



and stored data.
- Central data store: It is the central data store where asset data from operational technology and business data from information technology are stored, monitored and processed for the further operations.
- Predictive analytics: Analytics algorithms when applied to the whole data to identify patterns and then generate the insights in the form of alerts.

- Root cause analysis: This tool is used by process engineers to check the insights and determine the preventive action to be performed.

IIOT - REMOTE PRODUCTION CONTROL.

- Remote monitoring means leveraging IoT devices and AI-enabled reporting platforms so that organizations can do more with less, maximize resources, and set new standards of machine efficiency that lead to cost savings through the supply chain.
- Remote monitoring is vital in today's competitive landscape, especially as the Covid-19 pandemic has shown us the necessity of remote work. It optimizes machine function, extends uptime, and removes downtime losses, one of the biggest profitability threats. This article explains what remote monitoring is, how it works, and how to add it to your production line.
- Remote monitoring works using technology based on IoT and artificial intelligence (AI). IoT sensors oversee machine operation and productivity, sending data to the AI platform, analyzing the information. Personnel can access real-time data on machine functions at any time. They also receive detailed reports informing them about how their machines are performing over time, including data on whether a breakdown is imminent.

- Reducing downtime is a necessary part of keeping costs down and manufacturing levels up. Remote machine monitoring can collect data about any given unit's operations and transmit it back via the cloud, enabling machine builders to provide peak-level service response time. A remote monitoring system allows machine builders anywhere, not just at the production line, to visualize the issues. Troubleshooting even minor modifications in a tool path can be done quickly and simply.
- Beyond service, response predicts and even prevents breakdowns that severely impact a manufacturer's production cycle by reviewing and analyzing the data produced. With predictive maintenance, the equipment can review available data, detect any exceptions or historical patterns and service the machines before a problem occurs, limiting the impact. It also ensures that a manufacturer doesn't need to maintain an extensive inventory of replacement parts but instead works on a just-in-time basis.

ASSET TRACKING.

- Asset tracking system is the combination of desktop software where helpful in tracking with help of Barcodes scanners, barcode labels, and mobile devices which will help in tracking the asset from the point of acquisition to retirement in an organization asset tracking system plays a vital point in the organization.
- Barcode having a unique identifier for each asset so that they can be individually recognized and tracked Barcodes includes information that is critical to the business, such as a category of the asset and the project name and more.

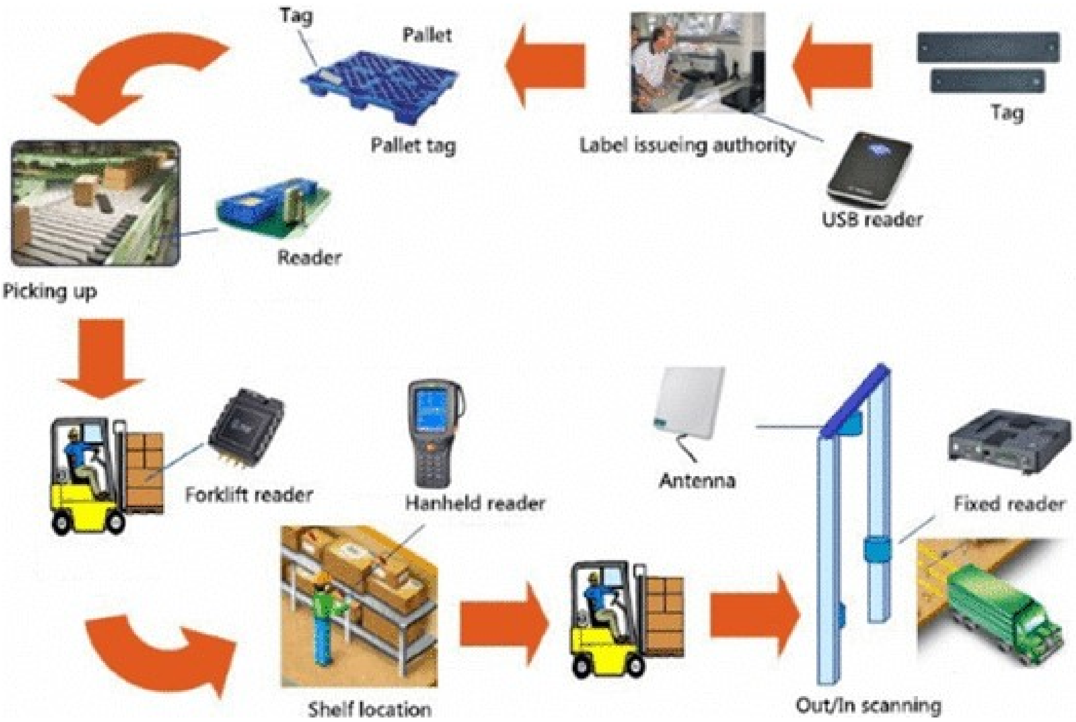
- The GPS systems are todays most well known location tracking systems. Well these systems are not capable of pinpointing exact locations or locations of an entity within a building or on a particular floor or room. So here we propose a smart asset tracking system that allows to track location of objects, goods, personnel within a building or any facility. Our proposed system makes use of rf technology along with IOT to achieve this system. The system has the capability to pinpoint the location of any entity to exact room it is currently located in. The system uses mini rf circuits to be used as tracking devices. We use tracking microcontroller based circuits to track those rf circuits. The tracker cuircuits are battery powered circuits to be mounted on objects/entities. The monitoring circuits are to be placed in individual rooms. Now as soon as any tracker objects enter any room the tracker circuits come in 2-3 meters range of the monitoring circuit for that room. The monitoring system now transmits the location of that tracker circuit to the online system. We here use IOTGecko to handle the IOT tracking part. The transmitted data is now displayed by IOTGecko to pinpoint which room a particular object/entity is located in.

Benefits of using asset tracking system

- Enable asset recovery and Positioning: To trace an asset from hundreds or thousands assets one gets detached from a big batch and tracing it can be quite problematic you need to spend a lot of manpower and lose productive time looking for the asset and it will affect your business production
- Improve Customer Service: When a customer signs an agreement with you to do business he would expect a positive return on investment among the things customer will expect the information about the location of their asset in real-time.
- Asset tracking software help to keep a tab on customers assets all the time. You can track which items are moving through internal processes for improving production.
- Real-Time Asset Management: Accurate asset tracking is an efficient data management system that can easily spot errors and remove them from the system. By using the asset tracking software you will have clear idea of your business assets by tracking items ones they arrive.

- Increase Productivity and Reduce labor cost: Asset tracking application will help you to keep track the different items are passing through in your department if the asset is tagged with RFID tags the asset is tracked automatically as they move from different stages of the process with the help of asset tracking and RFID will eliminate the need of having labors manually scanning and logging their movements.
- Ensure Regulatory Compliance: Asset Tracking helps the organization follow the regulatory requirements such as equipment maintenance and calibration and testing. This advanced asset tracking software streamlined completely your reporting requirements by using advanced asset tracking software. Previously it has to take months to generate the report for the same data manually.

LOGISTICS MANAGEMENT.



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- Logistics is often a poster child Applications for new technologies. Not surprisingly, the Industrial Internet of Things (IIoT) found early adoption in this sector. While this post highlights some of the success stories of IIoT adoption in logistics, it also underscores an opportunity for IIoT to have a significant impact on mitigating the problem of global hunger.
- In October 2001, nearly a decade before the Internet of Things (IoT) started capturing the minds of business strategists, a thought-leading article "Supply Chain Versus Supply Chain: The Hype & The reality" appeared in the *Supply Chain Management Review.* The authors—James Rice Jr. from MIT and Richard Hoppe from McKinsey—critiqued the proposition that the nature of competition won't be between companies, but rather between supply chains. The core of supply chain is logistics: freight transportation, warehousing operations and last-mile delivery. The race for dramatic improvements in operating efficiency in supply chain and logistics had just started.
- Just as CNC machines and SCADA were precursors to IIoT on the shop floor to improve agility, productivity and quality, so too were hand-held scanners, bar codes and RFID tags in logistics. (SCADA, hand-held scanners, building automation systems and sensors are essentially data

monitoring and data acquistion systems.) With data acquisition infrastructure already in place in warehousing and freight operations, the transition to embrace IIoT was rapid in logistics.

IIoT for Freight Operations

- In 2012, annual cargo thefts in the USA and Europe were reported at 946 and 689 respectively. Thefts cost shippers and insurance providers billions of dollars each year, from both the impact of inventory delays as well as the cost of stolen goods.
- Through IoT, logistics providers not only get real-time visibility on the movement of goods but also item-wise monitoring. This ensures that each item arrives on time, at the right place, and intact. We can relate to this when we fly across the world with multiple change-overs. The probability of a passenger's baggage not being on the designated conveyor belt at the arrival airport is reducing each year.

IIoT in Warehouse Operations

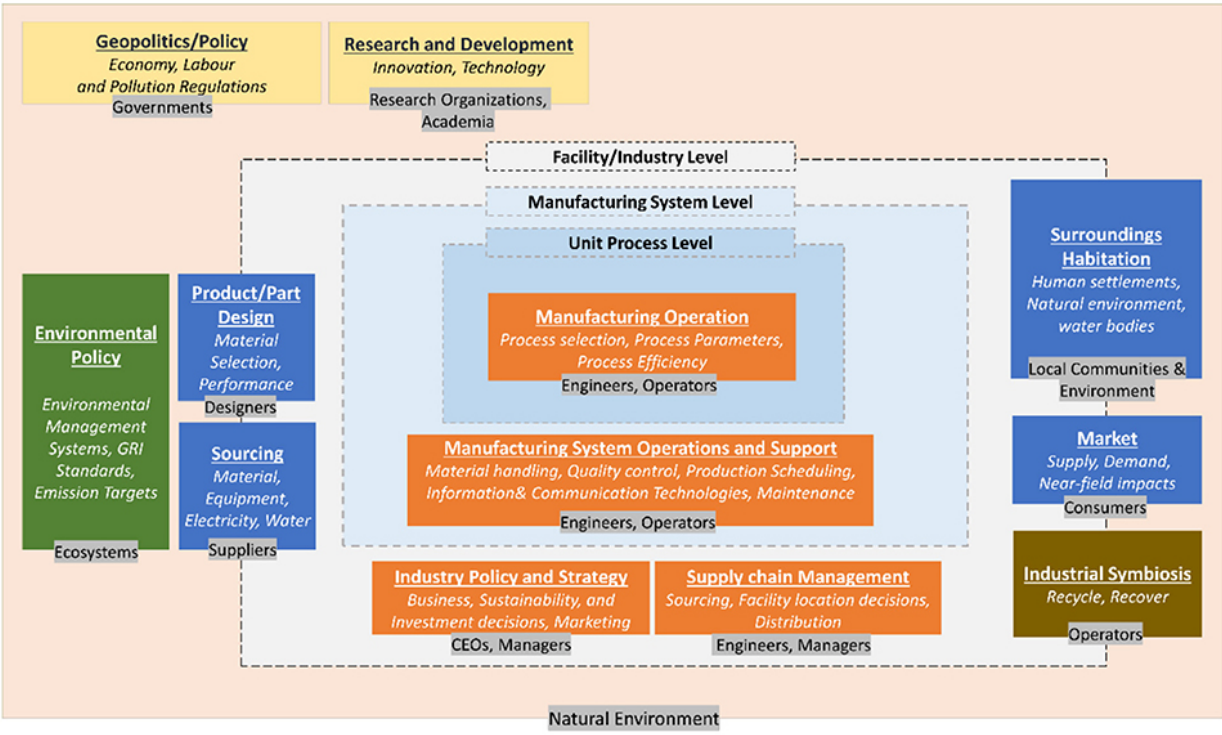
- The widespread adoption of hand-held scanners and item-level tagging—using low-cost devices such as RFID—has paved the way for IoT-driven warehouse operations. While use of wireless readers to capture data from pallets has been around for some time and has eliminated the time-consuming task of manual counting and volume scanning of pallets, IoT-driven warehouse management now provides real-time visibility into inventory levels, thus preventing costly out-of-stock situations. For quality management, sensors monitor the condition of an item and alert warehouse managers when temperature or humidity thresholds are about to be breached.

IIoT for Food Logistics in Emerging Markets

- It's grim reading that India ranks 63 out of 78 hungriest countries in the Global Hunger Index published by the International Food Policy Research Institute. The tragedy is that India's food problem (which translates to nearly 50 percent of children under three being grossly malnourished and underweight) can be eradicated if India did not have 70 percent of fruits and vegetables wasted in the supply chain. This waste accounts for 40 percent by value (approx US $8B) of annual production, making market prices twice as high.
- While policy initiatives have been towards increased food production, it's time to shift focus towards more efficient distributions. India already has a great example in milk distribution: the story of Amul is well documented where refrigerated storage and transportation and quality monitoring has been in place for long. The emergence of high-speed networks at lower tariffs, dropping prices of sensors, ease of installation and their versatility in monitoring every relevant parameter in food storage, transportation and last-mile delivery can further improve what we have already seen with Amul milk distribution.
- Beyond full-condition monitoring by intelligent sensors, it's sensor analytics that would ensure complete integrity during transportation. Example: as delivery takes place, sensors in the vehicle would detect weight reduction, transmit messages to the temperature control system, such that cooling may be reduced based on ambient temperature and remaining distance to be covered, to improve energy efficiency without impacting food quality. Analytics is key to IIoT and could play a pivotal role in food supply chains and eradicating hunger from emerging markets.

IIOT FOR SUSTAINABILITY ASSESSMENT OF MANUFACTURING INDUSTRY

- Sustainable manufacturing is the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources. Sustainable manufacturing also enhances employee, community and product safety.
- sustainability assessment can be defined as the process of identifying, measuring, and evaluating



the potential impacts of alternatives for sustainability

Barriers to Sustainable Manufacturing

- Economic and financial misperception. ...
- Lack of innovation. ...
- Poor systems for monitoring and evaluation. ...
- Lack of expertise within the institution. ...
- How a Leading Pharma Company Reduced Unnecessary Waste.

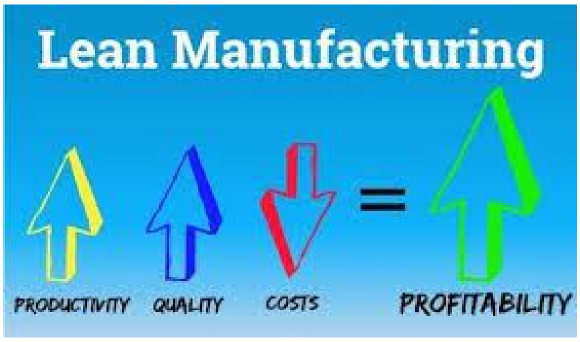
Sustainable manufacturing

- Sustainable Manufacturing can be defined as the integration of processes and systems capable to produce high quality products and services using less and more sustainable resources (energy and materials), being safer for employees, customers and communities surrounding, and being able to mitigate environmental and social impacts throughout its whole life cycle. Benefits of sustainable manufacturing include cost reduction through resource efficiency and regulatory compliance improvement, better brand reputation, new market access, less labour turnover by creating attractive workplaces, and long-term business approach by creating opportunities to access financing and capital (Veleva and Ellenbecker 2001; Gunasekaran and Spalanzani 2012; Bonvoisin, Stark, and Seliger 2017; EPA 2018).

- Bonvoisin, Stark, and Seliger (2017) define the sustainable manufacturing scope in four areas with its respective objects and applied disciplines, which were used to classify the papers in the sample:
- Manufacturing technologies (how things are manufactured) with focus on process and equipment (machine-tool, facility); linked disciplines are production engineering, factory planning, and operations management;
- Product lifecycles (what is to be produced) with focus on product and services' design; linked discipline is engineering design;
- Value creation networks (organisational context) with focus on organisations of companies and manufacturing networks; linked disciplines are business economics and knowledge management;
- Global manufacturing impacts (transition mechanisms towards sustainable manufacturing) with focus on studies about manufacturing impacts on the world, including society, environment, and economy.
- Different aspects can contribute to a positive sustainable manufacturing strategy implementation, among others, the development of sustainability indicators, policies and procedures, companies cultures and internal conditions for sustainability, sustainable design strategies, and stakeholders' engagement for sustainability and technologies
- By reducing waste and water usage, adjusting energy loads, and tapping into renewable resources, the factories of the future have the potential to drive measurable sustainability outcomes as well as reduced costs.

LEAN PRODUCTION SYSTEM

- In lean manufacturing, organizations prioritize minimizing waste while maximizing productivity. The lean manufacturing production method is a philosophy that works seamlessly with the innovations of Industry 4.0 which serve to support efficiency initiatives at every stage of the manufacturing process.



- It underlines which links are stronger for the different capability levels. Also, it clarifies which Lean principles are poorly impacted by Industry 4.0 technologies. A management team can point out which technology they should deploy to improve specific Lean principles according to the targeted capacity level.
- Differences between Lean and Industry 4.0. There are also many differences between lean and Industry 4.0. Working with People is an essential part of lean, and lean looks at their needs and how they interact with each other. Industry 4.0, however, focuses on computers, automation, and robotics

The key aspects of lean production that you should be aware of are:

- Time based management.
- Simultaneous engineering.
- Just in time production (JIT)
- Cell production.
- Kaizen (Continuous improvement)

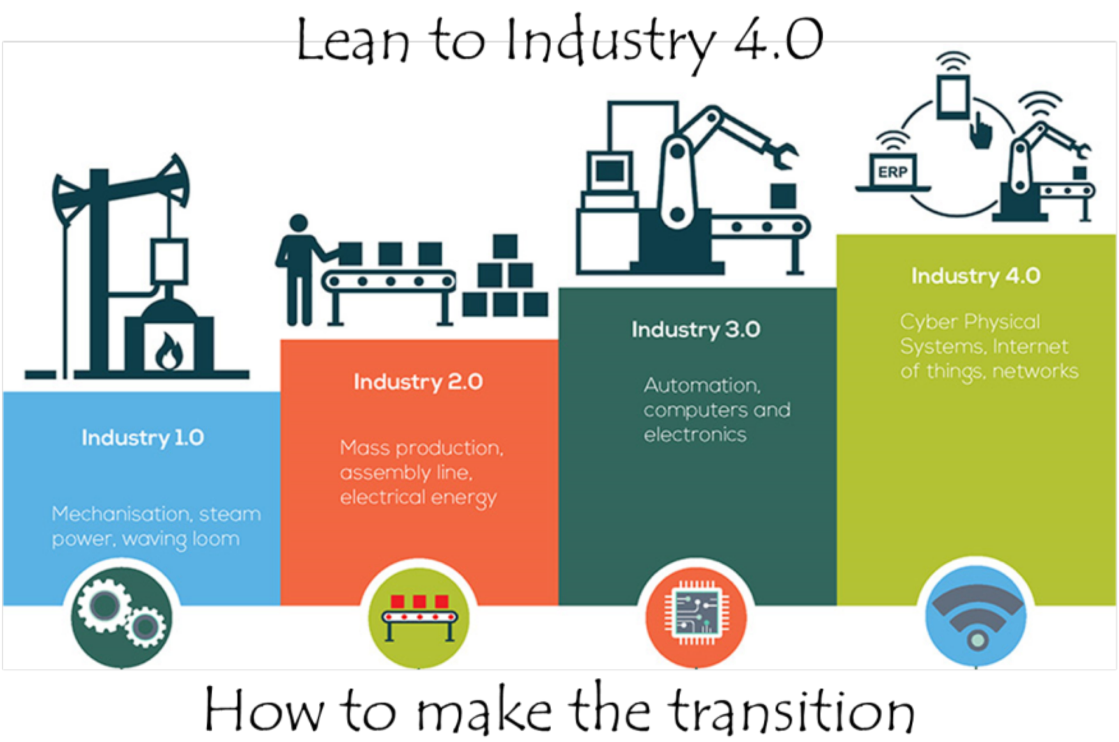
- Quality improvement and management.

The ten rules of lean production (AO1)

- Eliminate waste.
- Minimise inventory.
- Maximise flow.
- Pull production from customer demand.
- Meet customer requirements.
- Do it right the first time.
- Empower workers.
- Design for rapid changeover.

Given the large number of articles about Industry 4.0, IIOT (Industrial Internet of Things), Cloud Computing, AI, Machine Learning, Digital Twins, RPA (Robotic Process Automation), etc. and the large number of companies springing up to sell you specialized software or services and equipment, it's easy to be confused over where to start. Individual tools may be tempting to apply. Be careful that they do not become silos of optimization. Speeding up one function of a production process doesn't improve the system output unless it is the bottleneck process.

An easy way to recognize the potential of cyber-physical systems in manufacturing is to look at the



transition of the taxi industry. There were a multitude of barriers that we took for granted when you needed a taxi. Some areas of a city would have enough taxis roaming around that you could hail one from the curb. The other option was finding a phone (attached to the wall or phone booth), finding a phone book (those were the paper things you used before Google to find a phone number), looking up in the phone book the number for the taxi service, dialing the number (putting money into the payphone), waiting for an answer, telling the dispatcher where you were and where you wanted to go.

The dispatcher would find an open taxi to send to your address (be ready to wait 30 minutes), you would reconfirm the location to go, they would start the meter (the fee was based on miles and time, which ever was more), when you arrived you would pay in cash whatever the meter read. These barriers we just accepted as part of the system.
Compare the old taxi methods (all the steps) to today's options. You take out your smart phone, open ride hailing app, enter location you want to go, and accept price offered. On many apps you can see the taxi's current location and estimated time of arrival

SMART FACTORIES

In the manufacturing sector, the rise of Industry 4.0 is evolving at a rapid pace and technological advancements are the backbone of this evolution. Key technologies such as Artificial Intelligence, Machine Learning, Automation and Industrial Internet of Things (IIOT) are essential. As part of connected and adaptive manufacturing, Smart Factories are a new opportunity to adopt exciting technology in order to achieve demanding production goals.

- Smart Factories rely heavily on smart manufacturing, with the use of data, they are a highly digitalised and connected production facility. They are designed to drive the adoption of digital manufacturing processes and create better outcomes for productivity, delivery, reduced labor and energy costs.
- As part of Industry 4.0, new technologies will be introduced as part of intelligent manufacturing and they can also be found in Smart Factories, for example:
- Adopting robotics at a deeper level such as drones that would replace current human workloads.
- Use of machine learning to analyse data gathered by sensors and monitoring devices in order to make real-time decisions to improve the efficiency of production.
- Utilising IIoT to create a system of connected devices with predictive capabilities to make autonomous decisions based in an intelligent, decision-making environment.
- IoT focuses a lot more on connectivity, data analytics and automation as part of a huge digital ecosystem. “In IIoT technology, sensors are attached to physical assets,” says Robert Schmid, Deloitte Digital IoT Chief Technologist. “Those sensors gather data, store it wirelessly, and use analytics and machine learning to take some kind of action.”
- IIoT can transform linear manufacturing supply chains into interconnected digital supply networks (DSN), making factories more efficient, saving on costs and reducing risk for human operators.
- The most notable feature of IIoT systems is the use of sensors to detect, for example, if a machine goes down or reaches a temperature that’s too high, sensors then track the source of the issue and trigger a service request. This is known as ‘Predictive Manufacturing’, a fascinating system that converts data into information and make intelligent decisions about the machine or process
- An interconnected network of machines, communication mechanisms, and computing power, the smart factory is a cyber-physical system that uses advanced technologies such as artificial intelligence (AI) and machine learning to analyze data, drive automated processes, and learn as it goes.
- The defining characteristics of the smart factory are visibility, connectivity and autonomy. Factories have long relied on automation, but smart factories take this concept much further and are able to run without much human intervention.

- Smart factories optimize efficiency and productivity by extending the capabilities of both manufacturing devices and people. By focusing on creating an agile, iterative production process through data collection, smart factories can aid decision-making processes with stronger evidence.
- Smart factories include main Industry 4.0 (I4. 0) technologies such as additive technologies, visualization, digital twins, Internet of Things (IoT), Cloud computing, Radio-Frequency Identification (RFID), and their vertical and horizontal integration.
- Smart Manufacturing means bringing the elements of smart technology – sensing inputs, computing power, always-on connectivity, artificial intelligence, and advanced data analytics – to the traditional production process.

9 Pillars Of Technological Advancements

- Big Data And Analytics. ...
- Autonomous Robots. ...
- Simulation/ Digital Twin. ...
- Industrial Internet Of Things (IIoT) ...
- SUGGESTED READ: DIGITAL CONNECTED AND COLLABORATIVE: MANAGING THE SMART FACTORY OF TOMORROW.
- Augmented Reality. ...
- Additive Manufacturing. ...
- Cybersecurity.