1238

Code : 20ME53I

Register Number

V Semester Diploma Examination, June/July-2023

ADVANCED MANUFACTURING TECHNOLOGIES

Time : 3 Hours] **[Max. Marks : 100**

Instruction : Answer **one** full question from each section.

SECTION – I

1. (a) The materials used in the manufacturing of aircraft have changed significantly from the construction of the first aircraft. With its objective of flying using air support while, resisting gravitational force, the materials used for the construction of aircraft must have some specific characteristics. Which are the advanced materials used in aircraft and what specific characteristics are present in these materials ? **10**

   (b) How will you decide to recommend specific advanced machining process (es) for **10**

   (i) Cutting a glass plate in two parts

   (ii) Making a hole in Mild Steel (MS) work-piece ?

2. (a) An iron work-piece is subjected to electro-chemical machining using copper as electrode and sodium chloride solution (specific resistant = 5.0 ohm-cm) as electrolyte. The supply voltage is 16 V DC and current is 6000 A. If a gap between the tool and work-piece is 0.05 cm, calculate the MMR and Electrode feed rate. **10**

   (for Iron Atomic weight = 56, Valency = 2 and Density = 7.87 g/cm^3)

   (b) Laser Beam Machining (LBM) is a well established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult to machine by conventional machining processes. Discuss the process parameters required in LBM process. **10**

   Suggest a suitable process parameter that need to be considered for this case and justify.

SECTION – II

3. (a) Ultrasonic machining offers a solution to the expanding need for machining brittle materials such as single crystals, glasses and polycrystalline ceramics, and for increasing complex operations to provide intricate shapes and work-piece profiles. Illustrate the working of USM. What factors influence the metal removal rate in ultrasonic machining ? **10**

   (b) It is necessary to provide a L shape through hole in a steel work-piece of 12 mm thickness. The dimension of "L" is 25 mm × 15 mm. The steel is good conductor of electricity. Keeping this in mind, suggest a suitable non-traditional machining process for the above application. Explain the principle and working of this non-traditional machining process with the help of a sketch. **10**

4. (a) Suggest a suitable non-conventional machining process for manufacturing complex and precise components in the vacuum environment. **10**
   Illustrate with neat sketch about the suitable machine.

   (b) An electric discharge machining operation is being performed on tungsten.
   (i) Determine the amount of metal removed in the operation after one hour at a discharge amperage = 20 amps.
   (ii) If the work material were tin, determine the amount of material removed in the same time. **10**

   Use metric units and express the answer in mm^3.
   The melting temperature 3410 °C for tungsten and 232 °C for tin.
   (Take K = 664)

SECTION – III

5. (a) Illustrate how Additive Manufacturing can overcome the limitations of traditional manufacturing methods with needs and benefits of AM. **10**

   (b) In Additive Manufacturing, the material properties are being established alongside the geometry of the part. There are different classes of a materials used in additive manufacturing. Discuss these (any three) different materials with respect to their properties and applications. **10**

6. (a) Additive Manufacturing Techniques are classified based on the state of raw materials as solid based, liquid based and powder based. Mention which category the Fused Deposition Modeling (FDM) comes under. Illustrate the process with a neat sketch. **10**

   (b) The binding technique determines the process speed and part properties in Additive Manufacturing Process. Discuss the various binding technique used in Additive Manufacturing Process. **10**

SECTION – IV

7. (a) Two vernier caliper are used to measure a 10.000 mm gage block. Five measurements are taken with each caliper. For caliper A, the five measurements were 10.01 mm, 10.00 mm, 10.02 mm, 10.02 mm and 10.01 mm. **10**

For caliper B, the five measurements were 10.01 mm, 9.98 mm, 9.98 mm, 10.01 mm and 9.99 mm.

Determine :

(i) The mean and standard deviation of the error for each of the calipers.

(ii) Which caliper has the better accuracy ?

(iii) Which caliper has the better precision

(b) Safety and reliability are prime importance for AM produced parts, which are used in aviation and power industries. The parts are tested using non-destructive testing methods. Discuss the different NDT methods and suggest the best non-destructive testing and support you selection. **10**

8. (a) A sine bar is used to determine the angle of a part feature. The length of the sine bar is 6.000 in. The rolls have a diameter of 1.000 in. **10**

All inspection is performed on a surface plate. In order for the sine bar to match the angle of the part, the following gage blocks must be stacked :

2.0000, 0.5000, 0.3550.

Determine the angle of the part feature and why sine bar is not suitable for measuring angle above 45 degree.

(b) 3D printing is finally crossing the threshold from prototype to production. However, there are still a few challenges that hold AM back such as quality measures and quality control. These are essential for repeatability, consistency, scalability and overall confidence in the process. **10**

Discuss the machine which measures the physical geometrical characteristics of an object in three dimensions (or directions).

SECTION – V

9. (a) Industry 4.0 paradigm shift, made possible by technological advances. Explore conservative benefits exists in industry 4.0 and what are the risks of an industry 4.0 solution. **10**

(b) Automation in manufacturing is the process of using production management software or robotic tools to operate a factory when making a physical product. Discuss the various levels of automation in Advanced Manufacturing. **10**

[Turn over

10. (a) Why should you be concerned about the work envelope shape when installing a robot for a particular application in advanced manufacturing industry ? **10**

Discuss the working of most popular pick and place SCARA robot configuration with neat sketch.

(b) Driverless vehicles and navigation systems are improving day after day and are contributing to boost the AGV (Automated Guided Vehicle) market worldwide. Illustrate the working principle of AGV. **10**

V Semester Diploma Examination, June/July-2023

Advanced Manufacturing Technologies

SUB CODE: 20ME53IT MAX MARKS : 100

***Instruction**: Answer one full question from each section*

REVISED SCHEME OF VALUATION

SECTION-I

1(a) Introduction and overview of advanced materials used in aircraft manufacturing = 2 marks.
Description and explanation of any four advanced materials used in aircraft manufacturing = 2*4=8 Marks

1(b) Identification of suitable processes for cutting a glass plate = 5 marks.
Identification of suitable processes for making a hole in Mild Steel (M.S) = 5 marks.

2(a) Calculate the Material Removal Rate (MMR) (Formula + Substitution + Final Answer =2+2+1) = 5Marks
Calculate the Electrode Feed Rate (Formula + Substitution + Final Answer =2+2+1) = 5Marks

2(b) List plus Explanation of process parameters in LBM – (2+3) = 5 Marks
Identification and Justification of most suitable parameter that need to be considered for the case (2+3) = 5 Marks

SECTION-II

3(a) Explanation of the working of USM – (Sketch + Working) = 3 + 3 = 6 Marks
Identification and Explanation of factors influencing the MRR in USM (2+2) = 4 Marks

3(b) Selection of Suitable Non-Traditional machining Process: 2 Marks
Principal of EDM: 2 Marks
Working of EDM + Sketch: 3 Marks + 3 Marks

4(a) Selection of Suitable Non-Traditional machining Process: 2 Marks
Explanation of EBM: 2 Marks
Importance of Vacuum environment 2 Marks
Working of EBM + Sketch: 2 Marks + 2 Marks

4(b) Calculating the Volume of MRR for Tungsten-(Formula + Substitution + Final Answer =2+2+1) = 5Mark
Calculating the Volume of MRR for Tin- (Formula + Substitution + Final Answer =2+2+1) = 5Marks

SECTION-III

5(a) Clearly mentioning ANY FIVE Need and Benefits of AM to overcome limitations of traditional manufacturing methods = 5 * 2 Marks = 10 Marks

5(b) Briefly introduce additive manufacturing and its connection between material properties and part geometry. (1 Mark)
Discussion any three material properties + application (3 x 3 = 9)

6(a) Mentioning FDM Category -2 Marks
Description of FDM Process – 4 Marks
Any FDM Sketch – 4 Marks

6(b) Provide a brief introduction to the importance of Binding technique in AM – 2 Marks
Discussing Four Binding technique – 4 * 2 = 8 Marks

SECTION-IV

7(a) Calculation of Error for Caliper A and Caliper B (2+2=4 marks)
Calculation of Mean and Standard Deviation for Caliper A (2 marks)
Calculation of Mean and Standard Deviation for Caliper B (2 marks)
Comparison and Analysis for better accuracy caliper (1 mark)
Comparison and Analysis for better precision caliper (1 Mark)

7(b) Discussion of NDT Methods (5 marks):
Selection of the Best NDT Method (5 marks)

8(a) Calculation of Angle using Sine bar (Formula + Substitution + Final Answer =2+2+2) = 6 marks
Explanation of Sine Bar Limitation for Angles above 45 Degrees (4 marks)

8(b) Introduction and Importance of Quality Measures and Quality Control in AM-(2Marks)
Description of the Machine: CMM – (3 Marks)
Explanation of CMM - (5 marks)

SECTION-V

9(a) Brief explanation of the Industry 4.0 paradigm shift – (2 Mark)
Conservative Benefits of Industry 4.0 (4 marks)
Risks of Industry 4.0 Solutions (4 marks):

9(b) Levels of Automation in Advanced Manufacturing (each level 5 * 2) = 10 Marks

10(a) Importance of Work Envelope in Robot Installation (2 marks)
Description of SCARA Robot Configuration + Sketch 3+3 (6 marks):
Benefits and Applications of SCARA Robots (2 marks):

10(b) Introduction of AGV- 2 Marks
Working Principle of AGV – 6 Marks
Benefits and Significance of AGV - 2 marks

MODEL ANSWER

(This is the model answer; any relevant or similar answer may be considered.)

SECTION-I

1(a). The materials used in the manufacturing of aircraft have changed significantly from the construction of the first aircraft. With its objective of flying using air support while, resisting gravitational forces, the materials used for the construction of aircraft must have some specific characteristics. Which are the advanced materials used in aircraft and what specific characteristics are present in these materials?

Answer:

The materials used in the manufacturing of aircraft have changed significantly from the construction of the first aircraft. With its objective of flying using air support while, resisting gravitational forces, the materials used for the construction of aircraft must have a small weight, high specific strength, heat resistant, fatigue load resistant, crack resistant and corrosion resistant.

Back in the days, aircraft were constructed using wood and fabrics. But aircraft that are made up of wood and fabric were subject to rapid deterioration and high maintenance. Thus, the search for better materials began. Now, aluminum, steel, titanium and composite materials are preferred in the construction of aerospace structures.

The advanced materials used in aircraft manufacturing include aluminum, steel, titanium, and composite materials. These materials possess specific characteristics that make them suitable for aircraft construction.

- **<u>Aluminum</u>**: Aluminum is favored for its low density (2.7 g/cm^3), high strength properties, good thermal and electric conductivity, technological effectiveness, and high corrosion resistance. However, it loses strength at high temperatures, so it is not typically used on the skin surface of an aircraft.
- **<u>Steel</u>**: Steel, an alloy of iron and carbon, is approximately three times stronger and heavier than aluminum. It is commonly used in the landing gear due to its strength and hardness, as well as in the skin surface of aircraft because of its high heat resistance.
- **<u>Titanium</u>**: Titanium and its alloys are widely used in aircraft construction due to their high strength properties, high-temperature resistance, and excellent corrosion resistance compared to steel and aluminum. Despite being expensive, titanium is utilized in panel and swivels wing assemblies, hydraulic systems, and other critical parts.
- **<u>Composite materials</u>**: Composite materials are increasingly favored in aircraft production due to their high tensile strength, high compression resistance, low weight, and excellent corrosion resistance. These materials consist of a base material reinforced with a resin matrix. They improve fuel efficiency, enhance aircraft performance, and reduce operating costs. Fiberglass, composed of glass fibers and a resin matrix, is a commonly used composite material.

While advanced materials offer numerous benefits, there are also some drawbacks. Composite materials tend to be expensive, and immediate repair is often required in case of damage. Additionally, it is crucial to avoid fire when using composites, as the resin used can weaken and release toxic fumes.

1(b): How will you decide to recommend specific advanced machining process(es) for

i) Cutting a glass plate in two parts
ii) Making a hole in Mild Steel (M.S) workpiece?

Answer:

To recommend specific advanced machining processes for cutting a glass plate in two parts and making a hole in a Mild Steel (M.S) workpiece, the following considerations can be made:

<u>i) CUTTING A GLASS PLATE IN TWO PIECES:</u>

- Glass is **<u>electrically non-conductive</u>** material hence certain processes (ECM, EDM, PAM) are out because they can’t be employed for cutting electrically non-conductive workpiece (Ignoring one version of PAM)

- LBM and EBM can be ignored, being **expensive** processes. Chemical machining need not be considered because it is for very special applications and it is **very slow process**.
- AFM, MAF and other finishing processes need not be considered. These processes cannot perform cutting/machining operation.
- **AJM, AWJM, ECSM and USM can be used. Which one to use will depends on the size of the workpiece, size of the available machine, and kind of the accuracy required.**

ii) MAKING A HOLE IN A MILD STEEL WORKPIECE

- Drop out the finishing processes (MAF, AFM etc.) and chemical machining process.
- More suitable for comparatively brittle materials, one can drop out AJM and USM also.
- WJM is good for softer materials hence it can be excluded. AWJM system is quite expensive however it is quite fast and can be used if the AWJM machine is available.
- Mild Steel (M.S) being electrically conductive, ECM, EDM and PAM can be employed. LBM and EBM can also be employed but they will be much more expensive than others. At this point, one should know the requirements of the hole in terms of dimensions, tolerances and surface integrity. If it is not a micro hole, one can easily adopt ECM or EDM. If surface integrity required is high, ECM should be used and so on.

Ultimately, the selection of the machining process should take into account the material properties, cost considerations, available machinery, and the desired outcomes for the specific cutting or hole-making operation.

2(a) ***An iron workpiece is subjected to electro-chemical machining using copper as electrode and sodium chloride solution (specific resistant = 5.0 ohm-cm) as electrolyte. The supply voltage is 16 V DC and current is 6000 A. If a gap between the tool and workpiece is 0.05cm. Calculate the MMR and Electrode feed rate. (for Iron Atomic Weight=56, Valency=2 and Density=7.87 g/cm^3)***

Solution:

To calculate the Material Removal Rate (MMR) and Electrode Feed Rate for the given scenario, we need to use the following formulas:

Take

For iron

$$\textbf{Atomic weight } N = 56$$

$$\textbf{Valency } n = 2$$

$$\textbf{Density } \rho = 7.87 \text{ g/cm}^3$$

Given

$$\text{Specific resistant, } \rho_s = 5 \text{ ohm} - \text{cm}$$

$$= 5 \times 10^{-2} \text{ ohm-m}$$

$$\text{Voltage, V} = 16 \text{ V}$$

$$\text{Current, I} = 6000 \text{ A.}$$

Gap between the tool and work piece

$$h = 0.05 \text{ cm}$$
$$= 0.05 \times 10^{-2} \text{ m}$$
$$\text{Atomic weight, N} = 56$$
$$\text{Valency, } n = 2$$
$$\text{Density, } \rho = 7.87 \text{ g/cm}^3$$
$$= 7.87 \text{ g} / 10^{-6} \text{ m}^3$$

To find

1. Metal Removal Rate (MRR)
2. Electrode feed rate

Solution

We know that,

$$\text{Metal Removal Rate (MRR)} = \frac{EI}{FA\rho}$$

Where

$$\text{E – Equivalent weight of a substance dissolved} = \frac{N}{n}$$
$$= \frac{56}{2} = 28$$

I – Current flowing through the electrolyte-amp

F – Faraday's constant = 96500 coulombs

ρ – Density of the workpiece-kg/m^3

$$\Rightarrow \text{MRR} = \frac{EI}{FA\rho}$$
$$= \frac{28 \times 6000}{96{,}500 \times \frac{7.87}{10^{-6}}} \qquad [\because A = 1 \text{ m}^2]$$

$$\boxed{\text{MRR} = 2.12 \times 10^{-7} \text{ m}^3/\text{s}}$$

$$\text{Electrode feed rate, } f = \frac{V}{\rho_s h} \times \frac{E}{F \times \rho}$$

$$= \frac{16}{5 \times 10^{-2} \times 0.05 \times 10^{-2}} \times \frac{28}{96{,}500 \times \frac{7.87}{10^{-6}}}$$

$$\boxed{f = 2.35 \times 10^{-5} \text{ m/min}}$$

Result

Metal removal rate $= 2.12 \times 10^{-7}$ m^3/s

Electrode feed rate $= 2.35 \times 10^{-5}$ m/min

2(b) : Laser Beam machining (LBM) is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to-machine by conventional machining processes. Discuss the process parameters required in LBM process? Suggest a suitable process parameter that need to be considered for this case and justify.

Answer:

Laser beam machining is a non-conventional machining process in which a laser is directed towards the workpiece for machining. This process uses thermal energy to remove metal from metallic or nonmetallic surfaces.

In laser beam machining, several process parameters play a crucial role in achieving desired machining outcomes.

The following are important process parameters:

1. **Cutting Speed (Vc):** It refers to the travel of a point on the cutting edge relative to the surface of the cut in a unit of time during the machining process. Cutting speed is expressed in mm/min and influences the rate of material removal and the quality of the machined surface.
2. **Gas Pressure (P):** Pressure represents the force exerted on a surface per unit area. In laser beam machining, gas pressure, typically measured in Kg/cm^2, is used as an assist gas to blow away the molten material and control the cutting process.
3. **Laser Power (P):** Laser power is the rate at which energy is emitted from the laser. It is measured in watts and determines the intensity of the laser beam. Higher laser power results in faster material removal but may affect the quality of the cut.
4. **Nozzle Diameter and Stand-Off Distance**: The nozzle in laser beam machining is responsible for delivering the assist gas. The diameter of the cutting nozzle and the stand-off distance between the nozzle and the workpiece surface affect the gas flow, stability, and quality of the cutting process.
5. **Focal Position**: The focal point is crucial for achieving optimal cutting results. The small spot size obtained by focusing the laser beam requires precise positioning of the focal point relative to the workpiece surface. Different materials and thicknesses may require adjustments to the focal point position.
6. **Focusing of Laser Beam:** The focal length of the lens used to focus the laser beam onto the workpiece affects the size of the focal spot and the beam intensity. A small focal spot size and high beam intensity are necessary for achieving high-quality cuts.

Based on the given case, the most suitable process parameters to consider are **Nozzle Diameter** and **Focal Position**. The nozzle diameter influences gas flow and stability, while the focal position ensures precise focusing for optimal cutting results. These parameters are particularly important when machining geometrically complex or hard material parts that are difficult to machine using conventional processes.

Justification:

Nozzle Diameter: The nozzle diameter determines the gas flow rate and assists in maintaining stability during the cutting process. It affects the efficiency of the gas delivery and the removal of molten material. Choosing an appropriate nozzle diameter based on the specific requirements of the workpiece helps achieve desired machining outcomes.
Focal Position: Achieving the correct focal point position is essential for obtaining high precision and quality in laser beam machining. Precise control of the focal position ensures that the laser beam is focused accurately on the workpiece surface. It allows for optimal energy concentration and depth of focus, resulting in improved cutting performance.

Considering these factors, Nozzle Diameter and Focal Position are important process parameters that need to be considered in the given case to ensure successful laser beam machining of geometrically complex or hard material parts.

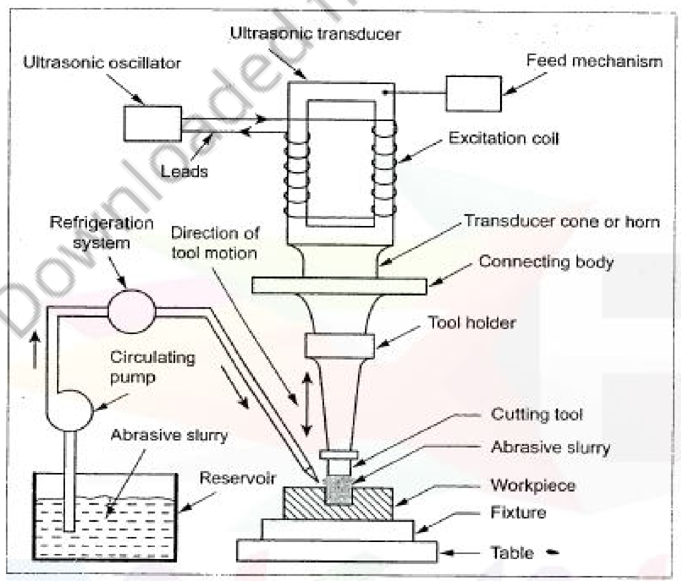
SECTION-II

3(a): Ultrasonic machining offers a solution to the expanding need for machining brittle materials such as single crystals, glasses and polycrystalline ceramics, and for increasing complex operations to provide intricate shapes and workpiece profiles. Illustrate the working of USM. What factors influence the metal removal rate in Ultrasonic machining.

Answer:

Working of Ultrasonic Machining (USM):

Ultrasonic machining (USM) is a non-conventional machining process that utilizes the action of abrasive grains to remove material from brittle workpieces.



The process involves the following steps:

1. **Ultrasonic Transducer**: An ultrasonic transducer is used to convert electrical energy into mechanical vibrations. The transducer is excited by a high-frequency electrical current, typically in the range of 20 kHz to 30 kHz, resulting in the generation of ultrasonic waves.
2. **Vibrating Tool**: The mechanical vibrations produced by the transducer are transmitted to the cutting tool through a transducer cone, connecting body, and tool holder. The tool vibrates in a longitudinal direction at the ultrasonic frequency.

3. **Abrasive Slurry**: An abrasive slurry, consisting of small abrasive particles suspended in a suitable medium, is pumped from a reservoir. The slurry flows under pressure through the gap between the tool and the workpiece.
4. **Material Removal**: As the tool vibrates at high frequency, the abrasive slurry flowing through the workpiece-tool gap leads to the removal of material from the workpiece. The impact force generated by the tool vibrations and the flow of slurry causes the abrasive grains to abrade and remove the workpiece material.
5. **Cooling System**: A refrigerated cooling system is used to maintain the temperature of the abrasive slurry at around 5 to 6 degrees Celsius. Cooling helps to control the temperature rise during the machining process and improve the effectiveness of material removal.
6. **Copying Process**: The ultrasonic machining process is a copying process, where the shape of the cutting tool is replicated on the workpiece. The intricate shapes and profiles of the cutting tool are transferred to the workpiece, allowing for the production of complex geometries.

Factors Influencing Metal Removal Rate in Ultrasonic Machining:

Several factors influence the metal removal rate (MRR) in ultrasonic machining. These factors include:

1. **Grain Size of Abrasive:** The size of the abrasive grains affects the cutting efficiency and the rate of material removal. Finer abrasive grains can provide higher cutting precision but may have a lower MRR compared to coarser grains.
2. **Abrasive Materials:** The choice of abrasive material influences the cutting action and MRR. Different abrasive materials have varying hardness, friability, and cutting efficiency, which affect the rate at which material is removed.
3. **Concentration of Slurry:** The concentration of abrasive particles in the slurry impacts the effectiveness of material removal. An optimal concentration ensures sufficient abrasion and material removal without excessive tool wear.
4. **Amplitude of Vibration:** The amplitude of the ultrasonic vibrations produced by the transducer affects the intensity of the impacts between the abrasive particles and the workpiece surface. Higher amplitudes generally result in a higher MRR.
5. **Frequency of Ultrasonic Waves:** The frequency of the ultrasonic waves determines the number of impacts per unit time. The frequency needs to be optimized for the specific material being machined to achieve an appropriate MRR and avoid excessive tool wear.

It is important to note that these factors are interrelated, and their optimal combination depends on the specific material and machining requirements. Proper control and adjustment of these factors help achieve the desired metal removal rate in ultrasonic machining.

3 (b): ***It is necessary to provide a L shape through hole in a steel workpiece of 12 mm thickness. The dimension of "L" is 25 mm X 15 mm. Steel is good conductor of electricity. Keeping this in mind, suggest a suitable non-traditional machining process for the above application. Explain the principle and working of this non- traditional machining process with the help of a sketch.***

Answer:

Selection of Suitable Non-Traditional Machining process for given application:

To create an L-shaped through hole with dimensions 25mm x 15mm in a steel plate of 12mm thickness, the suitable non-traditional machining process that can be used is **Electrical Discharge Machining (EDM).**

Principle of EDM:

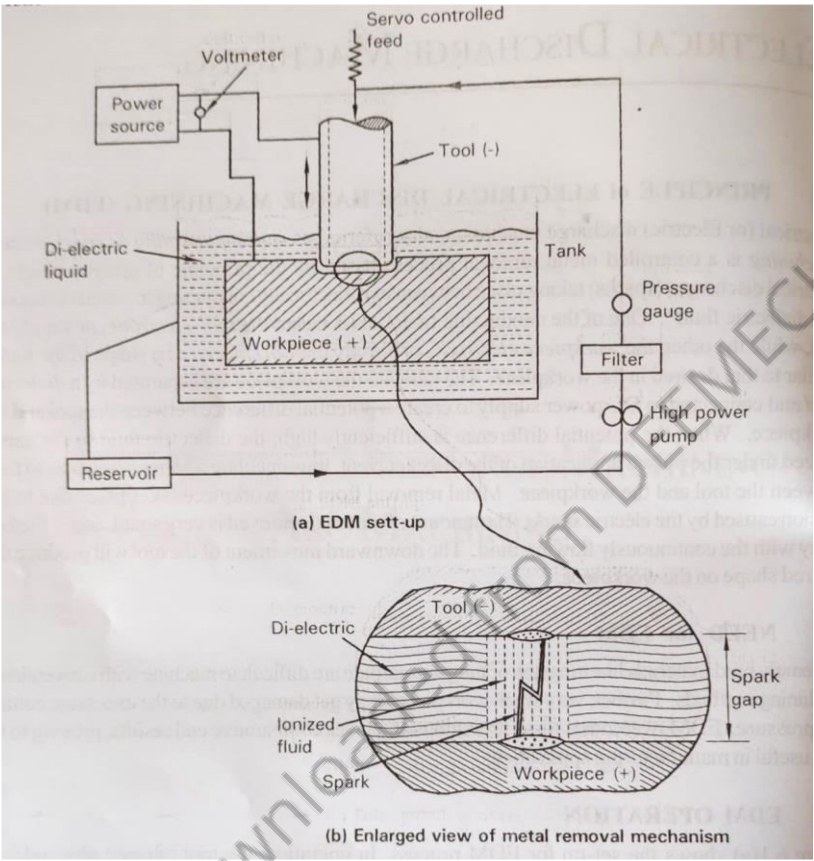
EDM is a controlled metal removal process that utilizes the erosive effects of electrical discharges (sparks) between two electrically conducting materials immersed in a dielectric fluid. Material removal occurs through the application of a pulsating high-frequency current between the electrode (tool) and the workpiece.

Working of EDM: The EDM equipment consists of several components, including a power supply source (power generator), dielectric medium, tool electrode, servo feed mechanism, pumps, and filters.
During operation, the shaped electrode (tool) is connected to the negative terminal (cathode) of the power source, while the workpiece is connected to the positive terminal (anode). A small gap, known as the spark gap, filled with dielectric fluid separates the tool and the workpiece.

When a sufficiently high potential difference is applied between the tool and the workpiece, transient sparks discharge through the dielectric fluid, removing a small amount of material from the workpiece.

Initially, the gap between the tool and the workpiece, filled with non-conductive dielectric fluid, is not conductive. However, the application of pulsed DC current ionizes the dielectric fluid, allowing sparks to jump between the tool and the workpiece. The sparks generated impinge on the elevated surface of the workpiece at an extremely high temperature, causing melting and vaporization of a small portion of the workpiece.

The electric and magnetic fields created by the spark generate tensile forces that tear particles of molten and softened metal from the work surface, resulting in material removal. The continuous flow of dielectric fluid flushes away the excess material removed from the machining gap.



4 (a) ***Suggest the suitable non-conventional machining process for manufacturing complex and precise components in the vacuum environment. Illustrate with neat sketch about the suitable machine.***

Answer:

Suitable Non-Conventional Machining Process for Manufacturing Complex and Precise Components in a Vacuum Environment: **Electron Beam Machining (EBM)**

Electron Beam Machining (EBM) is a non-conventional machining process that involves focusing and concentrating high-velocity electrons onto a small spot on the metal workpiece. The kinetic energy of the electrons is converted into heat energy, which melts the workpiece. EBM is particularly suitable for manufacturing complex and precise components in a vacuum environment.

EBM is performed in a vacuum chamber with a vacuum level of approximately 10^{-5} to 10^{-6} mm of mercury. This vacuum environment serves several purposes:

1. To avoid collision of accelerated electrons with air molecules.
2. To protect the cathode from chemical contamination and heat losses.
3. To prevent the possibility of an arc discharge between the electrons.

Working of EBM Process:

The EBM process involves several components, including an electron gun, diaphragm, focusing lens, deflector coil, tungsten filament, vacuum chamber, power source, and a movable work table.

Working Steps:

1. When a high voltage DC source is applied to the electron gun, the tungsten filament wire heats up, reaching temperatures up to 2500°C.
2. As a result of this high temperature, electrons are emitted from the tungsten filament. These electrons are directed by a grid cup to travel downwards and are attracted by the anode.
3. The electrons passing through the anode are accelerated to achieve high velocity, reaching up to half the velocity of light (approximately 1.6 x 10^8 m/s) by applying a voltage of 50 to 200 Kv at the anode.
4. The high-velocity electron beam maintains its velocity as it travels through the vacuum.
5. After leaving the anode, the electron beam passes through a tungsten diaphragm and then through an electromagnetic focusing lens.
6. The focusing lens is used to concentrate the electron beam onto the desired spot of the workpiece.
7. When the electron beam impacts the surface of the workpiece, the kinetic energy of the high-velocity electrons is immediately converted into heat energy. This high-intensity heat melts and vaporizes the work material at the point of beam impact.
8. Due to the high power density (approximately 6500 billion W/mm2), it only takes a few microseconds to melt and vaporize the material.
9. The process is carried out in repeated pulses of short duration, with pulse frequencies ranging from 1 to 16000 Hz and durations ranging from 4 to 65000 microseconds.
10. By alternately focusing and turning off the electron beam, the cutting process can be continued as long as necessary.
11. The machine is equipped with a suitable viewing device that allows the operator to observe the progress of machining.

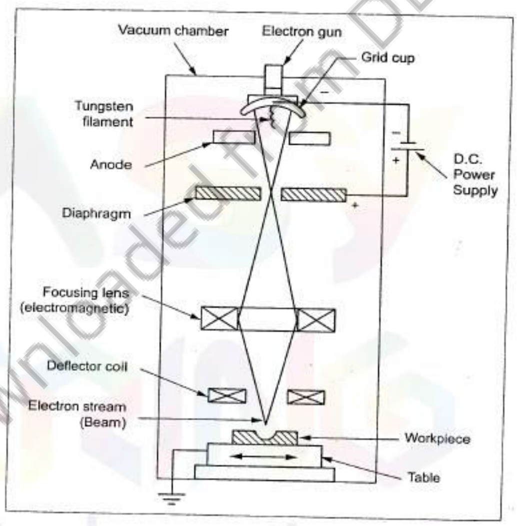


Fig. 5.1. Arrangement of Electron Beam Machining

***4(b)* An electric discharge machining operation is being performed on tungsten.**

(i) ***Determine the amount of metal removed in the operation after one hour at a discharge amperage = 20 amps.***

(ii) ***If the work material were tin, determine the amount of material removed in the same time.***

Use metric units and express the answer in mm^3.

The melting temperatures 3410℃ for tungsten and 232℃ for tin.

(Take K=664)

Solution:

To determine the amount of metal removed in an electric discharge machining operation, we need to calculate the volume of material removed for both tungsten and tin. The formula for calculating the volume of material removed is:

$$MRR=KI/T_m^{\ 1.23}$$

Where:

MRR = Volume of material removed (in mm^3)

I = Discharge amperage (in amps)

T = Melting Temperatures of materials

K = 664(Constant)

Let's calculate the volume of material removed for tungsten and tin:

(a) Tungsten:

Discharge amperage (I) = 20 amps

Time of operation (T) = 1 hour = 3600 seconds

Melting temperature of tungsten(T_M) = 3410°C

Using the formula:

MRR= K*I/ $T_m^{\ 1.23}$

= 664*20/3410 $^{1.23}$

= 13280/22146

= 0.5997 mm^3/S

MMR= Time of Operation * MRR per Second

= 3600 * 0.5997

= 2159 mm^3

Therefore, the amount of tungsten removed in one hour of operation is approximately 2159 mm^3

(b) Tin:

Discharge amperage (I) = 20 amps

Time of operation (T) = 1 hour = 3600 seconds

Melting temperature of tin (T_M) = 232°C

Using the formula:

MRR= K*I/ $T_m^{\ 1.23}$

= 664*20/232 $^{1.23}$

= 13280/812

= 16.355 mm^3/S

MMR= Time of Operation * MRR per Second

= 3600 * 16.355

= 58878 mm^3

Therefore, the amount of tin removed in one hour of operation is approximately 58878 mm^3

SECTION-III

5(a) Illustrate how Additive manufacturing can overcome the limitations of traditional manufacturing methods with Needs and Benefits of AM?

Answer:

Additive Manufacturing (AM) is a revolutionary technology that can overcome the limitations of traditional manufacturing methods and offer numerous benefits. Here are the needs and benefits of AM:

1. **Create parts with greater complexity**: AM allows the production of highly complex parts with improved functionality that would be challenging or impossible to manufacture using traditional methods. This opens up new design possibilities and enhances product performance.

2. **Minimal material waste**: One significant advantage of AM is the ability to optimize material distribution, resulting in lightweight parts and minimal material waste. This is achieved by adding material only where it is needed, reducing overall material consumption and costs.
3. **Simplified assembly**: AM enables part consolidation, which means multiple components can be produced as a single piece. This eliminates the need for complex assembly processes, reduces the number of parts, and simplifies supply chains.
4. **Material innovation:** Additive manufacturing has driven advancements in materials research, leading to the development of new materials specifically designed for 3D printing. These materials, such as TPU filaments and metal superalloy powders, offer unique properties and characteristics that may be challenging to achieve with traditional manufacturing methods.
5. **Cost-effective customization:** AM enables cost-effective customization by allowing quick and multiple design iterations without additional costs. With digital files as the basis for production, customization becomes easier and faster, reducing lead times and enabling personalized products at a reasonable cost.
6. **Minimum support structures:** AM allows for optimized part orientation during the design stage, minimizing the need for support structures. Although some complex parts may still require supports, designing with minimal supports reduces post-processing time and material usage, streamlining the overall manufacturing process.

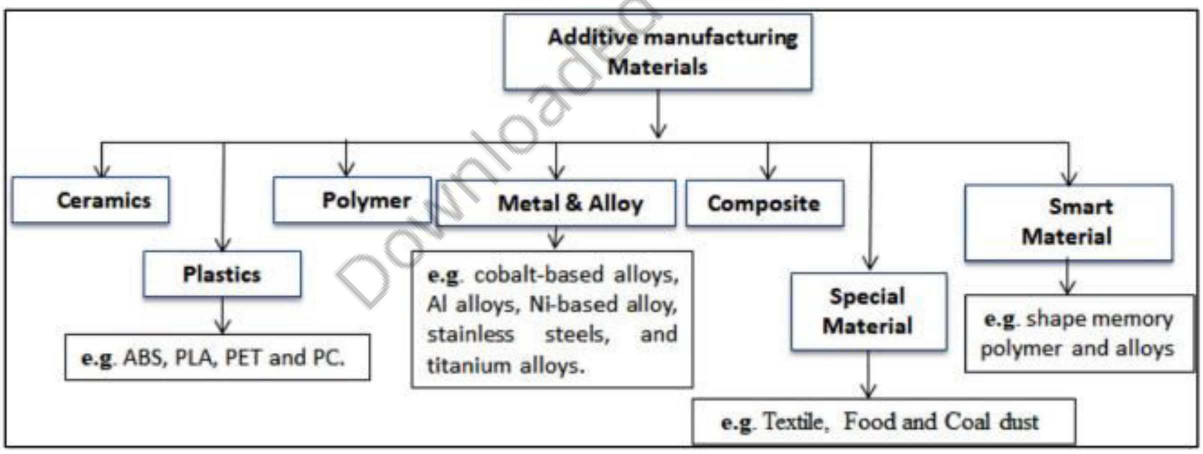
By addressing these needs and providing these benefits, additive manufacturing revolutionizes production capabilities and offers new opportunities for design, cost savings, customization, and material innovation.

***5(b)* In additive manufacturing, the material properties are being established alongside the geometry of the part. There are different classes of materials used in additive manufacturing. Discuss these (any three) different materials with respect to their Properties and Applications.**

Answer:

(ANY THREE MATERIALS)

In additive manufacturing, different classes of materials are utilized to create parts, each with their unique properties and applications. Let's discuss these materials in terms of their properties and applications:



Ceramics: Ceramic materials offer excellent mechanical properties and can withstand high temperatures. Some common ceramic materials used in additive manufacturing are alumina, zirconia, and bioactive glasses. Ceramics exhibit the following properties:

- High strength: Ceramics possess excellent mechanical strength, making them suitable for applications requiring durability.
- Heat resistance: Ceramics can withstand high temperatures without deforming or losing their properties, making them ideal for high-temperature applications.
- Electrical insulation: Ceramics have excellent electrical insulation properties, making them useful for electronic components.

Ceramics find applications in various industries, including construction, aerospace, dental, and biomedical.

Plastics/Polymer: Plastics or polymers are versatile materials widely used in additive manufacturing due to their ease of processing and wide range of properties. Different types of plastics used include:

- **Acrylonitrile Butadiene Styrene (ABS):** ABS exhibits high tensile, impact, and flexural strength. It is commonly used for conceptual modeling, functional prototyping, production tools, and end-use parts.
- **Polylactide (PLA):** PLA is a biodegradable and bio-based polymer derived from renewable resources. It is popular for its ease of use, low toxicity, and suitability for prototyping, educational purposes, and consumer products.
- **Polyethylene Terephthalate (PET):** PET is a strong, transparent, and lightweight polymer. It is commonly used in the production of bottles and containers. In additive manufacturing, PET is suitable for prototyping, packaging, and mechanical parts.
-

Plastics find applications in diverse industries, including automotive, consumer goods, and electronics.

Metals and Alloys: Metals and alloys are commonly used in additive manufacturing to produce parts with excellent mechanical properties and high strength. Some commonly used metals and alloys include:

- **Stainless Steel:** Stainless steel is known for its corrosion resistance, high strength, formability, and impact resistance. It finds applications in various industries, including automotive, aerospace, and consumer goods.
- **Titanium Alloys:** Titanium alloys exhibit high strength-to-weight ratios, excellent corrosion resistance, and biocompatibility. They are widely used in aerospace, medical, and automotive industries, producing components such as blades, fasteners, and implants.
- **Aluminum Alloys:** Aluminum alloys are lightweight, have good strength-to-weight ratios, and excellent corrosion resistance. They find applications in aerospace, automotive, and structural components.
- **Cobalt-based Alloys:** Cobalt-based alloys offer excellent corrosion resistance and high-temperature performance. They are used in applications such as gas turbine parts, medical implants, and dental prosthetics.
- **Nickel-based Alloys:** Nickel-based alloys, such as Inconel, exhibit high strength, heat resistance, and corrosion resistance. They find applications in aerospace, petrochemical, and high-temperature environments.

Metals and alloys are widely used in industries such as aerospace, automotive, healthcare, and engineering.

Composites: Composites are materials made by combining two or more different types of materials to achieve specific properties. In additive manufacturing, composites are often used to enhance the strength, stiffness, or lightweight characteristics of the parts. Some examples include:

- Carbon Fiber Reinforced Polymers (CFRP): CFRP composites combine carbon fibers with polymers to create lightweight and high-strength parts. They are commonly used in aerospace, automotive, and sporting goods industries.
- Glass Fiber Reinforced Polymers (GFRP): GFRP composites utilize glass fibers for improved strength and stiffness. They find applications in construction, marine, and automotive industries.

Composites are employed in various sectors that require lightweight and strong components.

Special Materials: Additive manufacturing also allows for the use of special materials with unique properties. Examples include:

- **Conductive Materials:** Additive manufacturing enables the creation of parts with conductive properties, making them suitable for electronic applications such as sensors and circuits.
- **Magnetic Materials:** Magnetic materials can be used in additive manufacturing to create components for applications involving magnetic fields.
- **Optical Materials:** Additive manufacturing techniques can produce parts with optical properties, enabling the fabrication of lenses, waveguides, and other optical components.

Special materials open up possibilities for applications in electronics, optics, and specialized industries.

Smart Materials: Smart materials are capable of changing their properties in response to external stimuli. While their use in additive manufacturing is still developing, there are potential applications such as:

- Shape Memory Alloys (SMA): SMAs can return to their original shape when heated or subjected to other stimuli. They find applications in aerospace, robotics, and medical devices.
- Piezoelectric Materials: These materials generate an electric charge when subjected to mechanical stress and are used in applications like sensors, actuators, and energy harvesting.

Smart materials have the potential to revolutionize industries such as robotics, aerospace, and healthcare.
These materials, along with continuous advancements in additive manufacturing technologies, offer diverse opportunities for creating complex geometries and tailor-made components for a wide range of applications.

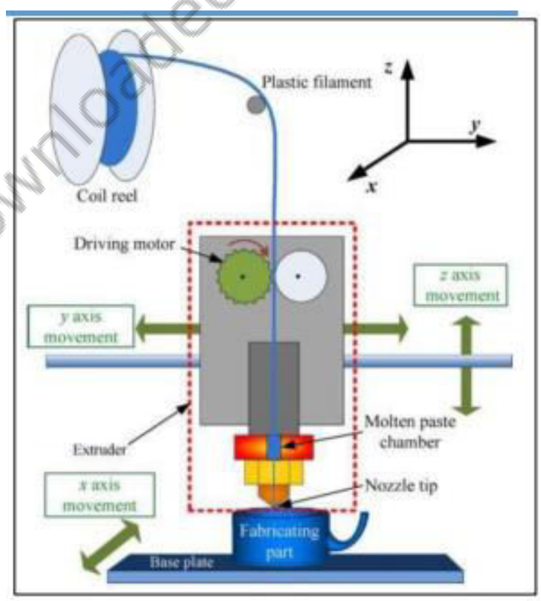
6(a) Additive manufacturing techniques are classified based on the state of raw materials as solid based, liquid based and powder based. Mention which category the Fused Deposition Modelling (FDM) comes under. Illustrate the process with a neat sketch.

Answer:

Fused Deposition Modeling (FDM) comes under the category of Solid Based Additive Manufacturing Technique.

Process of Fused Deposition Modeling (FDM):

1. Filament Preparation: The process begins with a thermoplastic filament, which is typically stored on a spool.
2. Filament Feeding: The filament is fed into an extruder system, which consists of a heated nozzle and a motor-driven filament feeder.
3. Heating and Melting: The filament passes through the heated nozzle, where it is heated to its melting point, becoming molten and flowable.
4. Layer-by-Layer Deposition: The molten filament is extruded through the nozzle in a controlled manner, layer by layer, onto the build platform.
5. Platform Movement: The build platform is lowered incrementally after each layer is deposited to accommodate the height of the newly added layer.
6. Cooling and Solidification: As each layer is deposited, the molten material quickly cools and solidifies, bonding to the previous layers.
7. Build Completion: The process continues layer by layer until the entire 3D object is formed.

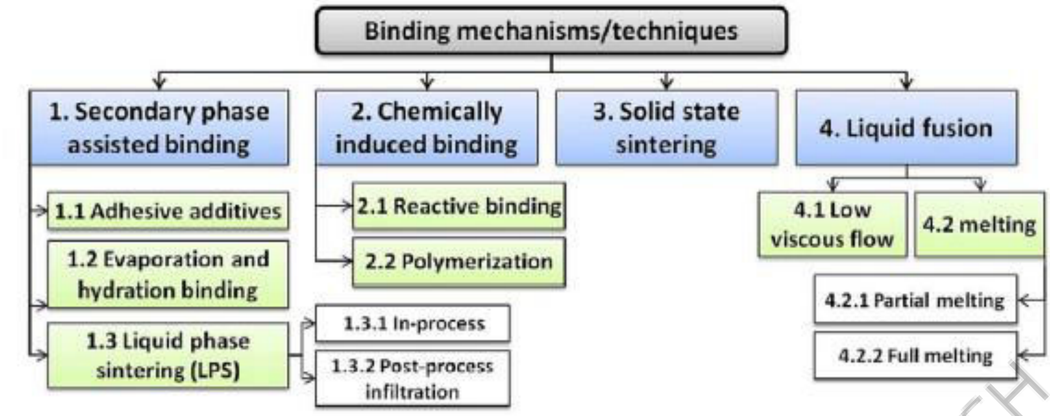


Fused Deposition Modeling is widely used in various industries for prototyping, rapid manufacturing, and producing functional end-use parts.

6(b) ***The binding technique determines the process speed and part properties in Additive Manufacturing process. Discuss the various binding techniques used in Additive Manufacturing Process.***

Answer:

The binding techniques used in additive manufacturing processes play a crucial role in determining process speed and part properties. Let's discuss the various binding techniques:



<u>Secondary phase assisted binding</u>

Many AM processes (e.g., binder jetting, SLS, sheet lamination, etc.) **<u>use a secondary phase to bind the materials together</u>**. Secondary binding phases (in the forms of liquids, powders, coatings, etc.) can be added using different techniques such as mixing, coating, nozzle injection, etc. The binding is accomplished through **adhesive additives**, **evaporation and hydration binding**, or **liquid phase sintering** (LPS)

<u>Chemically induced binding</u>

Some AM processes (such as vat photopolymerization process-es, material jetting, etc.) use the chemical reactivity of material constituents to bind the layered material **<u>without the use of any secondary phases</u>**. This so-called chemically induced binding can be divided into reactive binding and polymerization

<u>Solid state sintering (SSS)</u>

Solid state sintering (SSS) is a **solid diffusion binding mechanism**. However, solid state sintering is mostly applied as a ***post-processing technique***, e.g., furnace post-sintering to densify porous ceramics after removing/debinding the polymer binder.

<u>Liquid fusion</u>

Most AM processes (material extrusion, material jetting, directed energy deposition and powder bed fusion) **use a liquid fusion binding mechanism**. Liquid fusion is a **<u>rapid mass transport mechanism</u>** that may include low-viscosity flow in polymers and melting in metals.

It is important to note that different additive manufacturing processes may utilize multiple binding techniques, depending on the specific requirements of the materials and the desired properties of the final parts. The choice of binding technique has a significant impact on the process speed and the properties of the manufactured parts.

SECTION-IV

7(a)) Two vernier calipers are used to measure a 10.000 mm gage block. Five measurements are taken with each caliper. For caliper A, the five measurements were 10.01 mm, 10.00 mm, 10.02 mm, 10.02 mm, and 10.01 mm.
For caliper B, the five measurements were 10.01 mm, 9.98 mm, 9.98 mm, 10.01 mm, and 9.99 mm.
Determine:
(i) The mean and standard deviation of the error for each of the calipers
(ii) Which caliper has the better accuracy?
(iii) Which caliper has the better precision.

Solution :

To determine the mean and standard deviation of the error for each caliper, we need to calculate the differences between each measurement and the true value (10.000 mm). Let's perform the calculations for both calipers:

Caliper A:
Error = Measurement - True Value

Measurement 1: 10.01 mm - 10.000 mm = 0.01 mm
Measurement 2: 10.00 mm - 10.000 mm = 0.00 mm
Measurement 3: 10.02 mm - 10.000 mm = 0.02 mm
Measurement 4: 10.02 mm - 10.000 mm = 0.02 mm
Measurement 5: 10.01 mm - 10.000 mm = 0.01 mm

(a) Mean of the Error for Caliper A:

Mean = (Error1 + Error2 + Error3 + Error4 + Error5) / 5
Mean = (0.01 mm + 0.00 mm + 0.02 mm + 0.02 mm + 0.01 mm) / 5
Mean = 0.06 mm / 5
Mean = 0.012 mm

To calculate the standard deviation, we need to find the differences between each error and the mean, square them, sum the squared differences, divide by (n-1), and take the square root:

Squared Differences:

(0.01 mm - 0.012 mm)^2 = 0.000004 mm^2
(0.00 mm - 0.012 mm)^2 = 0.000144 mm^2
(0.02 mm - 0.012 mm)^2 = 0.000064 mm^2
(0.02 mm - 0.012 mm)^2 = 0.000064 mm^2
(0.01 mm - 0.012 mm)^2 = 0.000004 mm^2

Sum of Squared Differences = 0.000280 mm^2

Standard Deviation (σ) for Caliper A:
σ = √(Sum of Squared Differences / (n - 1))
σ = √(0.000280 mm^2 / (5 - 1))
σ = √(0.000280 mm^2 / 4)
σ = √0.000070 mm^2
σ = 0.008 mm

Caliper B:

Error = Measurement - True Value

Measurement 1: 10.01 mm - 10.000 mm = 0.01 mm

Measurement 2: 9.98 mm - 10.000 mm = -0.02 mm
Measurement 3: 9.98 mm - 10.000 mm = -0.02 mm
Measurement 4: 10.01 mm - 10.000 mm = 0.01 mm
Measurement 5: 9.99 mm - 10.000 mm = -0.01 mm

(a) Mean of the Error for Caliper B:
Mean = (Error1 + Error2 + Error3 + Error4 + Error5) / 5
Mean = (0.01 mm - 0.02 mm - 0.02 mm + 0.01 mm - 0.01 mm) / 5
Mean = -0.03 mm / 5 Mean = -0.006 mm

Squared Differences:

(0.01 mm - (-0.006 mm))^2 = 0.000529 mm^2
(-0.02 mm - (-0.006 mm))^2 = 0.000256 mm^2
(-0.02 mm - (-0.006 mm))^2 = 0.000256 mm^2
(0.01 mm - (-0.006 mm))^2 = 0.000529 mm^2
(-0.01 mm - (-0.006 mm))^2 = 0.000025 mm^2

Sum of Squared Differences = 0.001595 mm^2

Standard Deviation (σ) for Caliper B:
$\sigma = \sqrt{(\text{Sum of Squared Differences} / (n - 1))}$
$\sigma = \sqrt{(0.001595 \text{ mm}^2 / (5 - 1))}$
$\sigma = \sqrt{(0.001595 \text{ mm}^2 / 4)}$
$\sigma = \sqrt{0.000399 \text{ mm}^2}$
$\sigma = 0.020$ mm

(b) **<u>Better Accuracy</u>**: To determine which caliper has better accuracy, we compare the means of the errors. A caliper with a mean error closer to zero indicates better accuracy. In this case, Caliper A has a mean error of 0.012 mm, while Caliper B has a mean error of -0.006 mm. Therefore, **Caliper B has better accuracy since its mean error is closer to zero.**

(c) **<u>Better Precision</u>**: To determine which caliper has better precision, we compare the standard deviations. A smaller standard deviation indicates better precision. In this case, Caliper A has a standard deviation of 0.008 mm, while Caliper B has a standard deviation of 0.020 mm. Therefore, **Caliper A has better precision since it has a smaller standard deviation.**

<u>In summary:</u>

(a) Mean and Standard Deviation of Error:

- Caliper A: Mean = 0.012 mm, Standard Deviation = 0.008 mm
- Caliper B: Mean = -0.006 mm, Standard Deviation = 0.020 mm

(b) Better Accuracy: Caliper B (mean error closer to zero)
(c) Better Precision: Caliper A (smaller standard deviation)

***7(b)** Safety and reliability are of prime importance for the AM-produced parts, which are used in aviation and power industries. The parts are tested using Non-destructive testing methods. Discuss the different NDT methods and suggest the best Non-Destructive testing and support your selection.*

Answer:

Safety and reliability are indeed crucial for AM-produced parts used in aviation and power industries. Non-destructive testing (NDT) methods play a significant role in ensuring the quality of these parts without causing any damage. Let's discuss the different NDT methods and determine the best one, supported by a selection rationale.

Liquid Penetrant Testing:

- Principle: This method uses liquid penetrant materials to detect surface discontinuities.
- Application: It is widely used in aircraft maintenance to detect surface defects or structural damage in various materials.
- Advantages: Fast, simple to use, inexpensive, and easily portable. Can detect small surface discontinuities. Suitable for use on aircraft or in workshops.
- Limitations: Requires proper cleaning before and after the test.

Magnetic Particle Testing:

- Principle: This method utilizes magnetic fields and ferromagnetic particles to detect surface and near-surface defects in ferromagnetic materials.
- Application: Effective for inspecting components such as engines, landing gear, shafts, and bolts.
- Advantages: Simple in principle, easily portable, and fast. Suitable for detecting surface and subsurface defects in ferromagnetic materials.
- Limitations: Only applicable to ferromagnetic materials. Requires a demagnetization procedure. Positional limitations due to the directional nature of the magnetic field.

Eddy Current Testing:

- Principle: This method uses electromagnetic induction to detect surface and near-surface defects in conductive materials.
- Application: Commonly used for inspecting materials such as aluminum alloys and stainless steel.
- Advantages: Can detect small defects near the surface. Provides rapid inspection results.
- Limitations: Limited to conductive materials. Depth of penetration is limited.

Ultrasonic Testing:

- Principle: High-frequency sound waves are used to detect internal defects, measure material thickness, and assess material properties.
- Application: Suitable for inspecting various materials, including metals and composites.
- Advantages: High sensitivity, ability to detect both surface and subsurface defects, and capability to measure material thickness.
- Limitations: Requires skilled operators. Complex equipment.

After considering the above NDT methods, the ***best non-destructive testing method for AM-produced parts in aviation and power industries would be Ultrasonic Testing.*** This selection is based on the following justifications:

1. **Sensitivity:** Ultrasonic testing provides high sensitivity, capable of detecting both surface and subsurface defects, ensuring thorough inspection of AM-produced parts.
2. **Versatility:** It is suitable for inspecting a wide range of materials used in aviation and power industries, including metals and composites.
3. **Reliability:** Ultrasonic testing is known for its accuracy and reliability in detecting defects, making it highly suitable for ensuring the safety and reliability of AM-produced parts.
4. **Material Thickness Measurement**: Ultrasonic testing can also measure material thickness, which is crucial in assessing the integrity and quality of AM-produced parts.

Considering these factors, Ultrasonic Testing emerges as the best NDT method for AM-produced parts in aviation and power industries, ensuring the highest level of safety and reliability during testing and inspection processes.

8(a)* *A sine bar is used to determine the angle of a part feature. The length of the sine bar is 6.000 in. The rolls have a diameter of 1.000 in. All inspection is performed on a surface plate. In order for the sine bar to match the angle of the part, the following gage blocks must be stacked: 2.0000, 0.5000, 0.3550. Determine the angle of the part feature and why sine bar is not suitable for measuring angle above 45 degrees?

Solution :

To determine the angle of the part feature using a sine bar, we need to calculate the sine of the angle based on the lengths of the sine bar and the stacked gage blocks. Let's perform the calculations:

Length of the Sine Bar: 6.000 in Roll Diameter: 1.000 in Stacked Gage Blocks: 2.0000 in, 0.5000 in, 0.3550 in

Total Stacked Height: 2.0000 in + 0.5000 in + 0.3550 in = 2.8550 in

Angle Calculation: Sine of the Angle = Total Stacked Height / Length of the Sine Bar Sine of the Angle = 2.8550 in / 6.000 in Sine of the Angle ≈ 0.4758

To find the angle, we can use the inverse sine function (sin^(-1)) on a calculator or lookup table.

Angle = sin^(-1)(0.4758) Angle ≈ 28.7 degrees

The angle of the part feature is approximately 28.7 degrees.

Why the Sine Bar is not suitable for measuring angles above 45 degrees: The sine bar is not suitable for measuring angles above 45 degrees ***because the height of the stacked gage blocks exceeds the length of the sine bar*** when the angle is larger. In such cases, the gage blocks will not fit within the length of the sine bar, making it impossible to accurately measure the angle using this setup. Additionally, the stability and accuracy of the measurement may be compromised as the length of the stacked gage blocks increases, leading to potential errors in the measurement. ***For measuring angles above 45 degrees, alternative measuring devices or methods, such as angle plates or angle measuring instruments, are typically used.***

OR

Solution: $H = 2.0000+0.5000 + 0.3550 = 2.8550$ in

$A = \sin^{-1}(H/L) = \sin^{-1}(2.8550/6.000) = \sin^{-1}(0.4758) = \mathbf{28.41°}$

8(b) ***3D printing is finally crossing the threshold from prototype to production. However, there are still a few challenges that hold AM back such as quality measures and quality control. These are essential for repeatability, consistency, scalability, and overall confidence in the process. Discuss the machine which measures the physical geometrical characteristics of an object in three directions.***

Answer:

The machine that measures the physical geometrical characteristics of an object in three directions is a Coordinate Measuring Machine (CMM). CMMs are widely used in various industries, including additive manufacturing (AM), to ensure quality control and measure the dimensional accuracy of objects.

A Coordinate Measuring Machine is a precision measurement device that determines the spatial coordinates of points on an object's surface. It consists of three main components: a measuring probe, a movable arm or bridge, and a computer system for data analysis and visualization.

Here's how a CMM works:

- Probing: The CMM's measuring probe, which can be a touch-trigger probe or a non-contact probe, is positioned near the object being measured.
- Reference Points: The CMM establishes a reference point or a coordinate system on the object's surface, typically using a known reference feature or by aligning the machine with a reference frame.
- Scanning: The CMM moves its measuring probe along the object's surface, collecting data points at specific positions. The probe may make contact with the object or use non-contact methods such as laser or vision systems.

- Data Acquisition: As the CMM probes the object, it captures the three-dimensional coordinates of the measured points. These coordinates are recorded and stored for further analysis.

- Data Analysis: The recorded data is processed by the CMM's computer system, which analyzes the spatial coordinates to determine the object's physical geometrical characteristics, such as dimensions, shapes, and deviations from the intended design.

- Visualization: The CMM's software generates visual representations of the measured data, such as 3D models, surface profiles, or dimensional reports. These visuals aid in understanding the object's dimensional accuracy and identifying any deviations or defects.

Coordinate Measuring Machines offer several advantages for quality control in additive manufacturing:

1. Precise Measurements: CMMs provide highly accurate and precise measurements of complex geometric features, ensuring repeatability and consistency in the manufacturing process.

2. 3D Measurement: By measuring an object in three directions (X, Y, and Z axes), CMMs capture the complete geometry, including length, width, height, angles, and curvatures.

3. Data Comparison: CMMs can compare the measured data against the intended design specifications or a reference model, allowing for verification and identification of any deviations or variations.

4. Quality Assurance: CMMs play a vital role in quality assurance by detecting defects, errors, or inconsistencies in the manufactured objects, thereby improving overall confidence in the AM process.

In conclusion, a Coordinate Measuring Machine (CMM) is a powerful tool for measuring the physical geometrical characteristics of objects in three directions. It enables accurate and precise dimensional analysis, helps ensure quality control, and contributes to the repeatability, consistency, scalability, and confidence in additive manufacturing processes.

SECTION-V

9(a) Industry 4.0 paradigm shift, made possible by technological advances. Explore conservative benefits exists in Industry 4.0 and what are the risks of an Industry 4.0 solution?

Answer:

Industry 4.0, also known as the Fourth Industrial Revolution, represents a paradigm shift in manufacturing and other industries, driven by technological advancements such as automation, connectivity, and data analytics. While there are numerous benefits associated with Industry 4.0, it is essential to consider both the conservative benefits and the risks that come with this transformation. Let's explore them in detail:

Conservative Benefits of Industry 4.0:

1. **Increased Efficiency and Productivity**: Industry 4.0 technologies enable the integration of machines, processes, and systems, leading to improved efficiency and productivity. Automation and optimization of manufacturing processes can streamline operations, reduce downtime, and enhance overall output.
2. **Cost Reduction**: The implementation of Industry 4.0 solutions can lead to significant cost savings. Automation reduces labor costs, minimizes errors, and improves resource allocation. Predictive maintenance and real-time analytics help optimize maintenance schedules, avoiding unnecessary downtime and reducing maintenance costs.
3. **Enhanced Quality Control**: Industry 4.0 technologies enable real-time monitoring and data analysis, allowing for proactive quality control. By capturing and analyzing data at various stages of production, companies can identify defects or anomalies early on, minimizing waste and ensuring consistent product quality.
4. **Supply Chain Optimization**: Industry 4.0 facilitates improved supply chain management through enhanced visibility, tracking, and data-driven decision-making. It enables real-time monitoring of inventory, demand forecasting, and optimized logistics, leading to reduced inventory costs, faster response times, and increased customer satisfaction.

5. **Customization and Flexibility**: Industry 4.0 technologies enable the customization of products and processes to meet individual customer needs. With smart factories and digital manufacturing, companies can adapt quickly to changing market demands, offering personalized products at scale.

Risks of Industry 4.0 Solutions:

1. **Cybersecurity Vulnerabilities**: The increased connectivity and reliance on data networks in Industry 4.0 raise concerns about cybersecurity. Connected systems and devices become potential targets for cyberattacks, leading to data breaches, intellectual property theft, and operational disruptions. Strong security measures and continuous monitoring are crucial to mitigate these risks.
2. **Workforce Displacement**: Automation and robotics in Industry 4.0 have the potential to replace certain jobs, leading to workforce displacement and economic inequality. Companies need to consider the social implications and ensure appropriate reskilling and upskilling programs to transition workers into new roles that leverage their skills in collaboration with advanced technologies.
3. **Data Privacy and Ethics**: The extensive collection and analysis of data in Industry 4.0 raise privacy concerns. Companies must handle and protect personal and sensitive data responsibly, adhering to relevant regulations and ethical guidelines. Maintaining transparency and obtaining informed consent from individuals whose data is collected is crucial.
4. **Interoperability and Standards**: Industry 4.0 involves integrating diverse systems, machines, and technologies from different vendors. The lack of interoperability and common standards can create challenges in data sharing, communication, and collaboration. Establishing industry-wide standards and protocols is essential to ensure seamless connectivity and compatibility.
5. **Infrastructure and Investment Requirements:** Implementing Industry 4.0 solutions often requires substantial investments in technology, infrastructure, and workforce training. Small and medium-sized enterprises (SMEs) may face challenges in adopting these technologies due to limited resources, potentially leading to an increased digital divide between large and small companies.

To fully leverage the benefits of Industry 4.0 while mitigating the risks, a holistic approach is necessary. Collaboration between industry, government, and academia is crucial to address challenges and create an enabling environment for the successful adoption and implementation of Industry 4.0 technologies.

9(b) Automation in manufacturing is the process of using production management software or robotic tools to operate a factory when making a physical product. Discuss the various levels of Automation in Advanced Manufacturing.

Answer:

Automation in manufacturing involves the use of production management software and robotic tools to operate a factory during the production of physical products. It encompasses various levels of automation in advanced manufacturing. Let's discuss these levels in detail:

Device Level:

- This is the lowest level in the automation hierarchy and includes the individual components of machines, such as actuators and sensors.
- Devices at this level are integrated into control loops, such as feedback control loops in CNC machines or industrial robots.

Machine Level:

- Hardware at the device level is combined to create individual machines, such as CNC machine tools, industrial robots, conveyors, and automated guided vehicles.
- Control functions at this level involve executing the sequence of steps in the program of instructions and ensuring their proper execution.

Cell or System Level:

- The manufacturing cell or system operates under instructions from the plant level.

- It comprises a group of interconnected machines or workstations supported by material handling systems and computer equipment.
- Functions at this level include part dispatching, machine loading, coordination among machines and material handling systems, and collection and evaluation of inspection data.

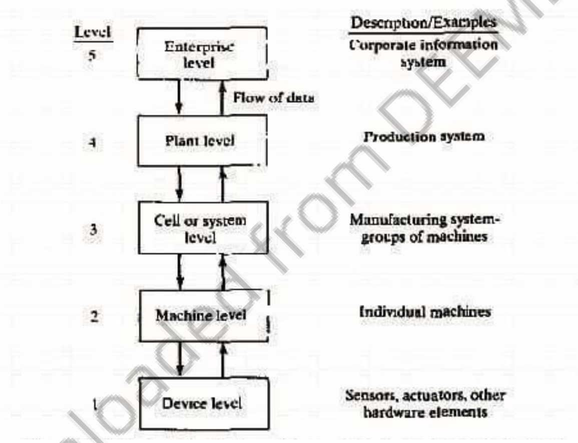
Plant Level:

- This level represents the factory or production systems level.
- It receives instructions from the corporate information system and translates them into operational plans for production.
- Functions at this level encompass order processing, process planning, inventory control, purchasing, material requirements planning, shop floor control, and quality control.

Enterprise Level:

- The highest level in the automation hierarchy is the enterprise level, which consists of the corporate information system.
- It manages various functions within the company, such as marketing and sales, accounting, design, research, aggregate planning, and master production scheduling.

These levels of automation in advanced manufacturing demonstrate how automation is applied at different stages, from individual device control to entire enterprise management. Implementing automation at multiple levels enables improved efficiency, productivity, and control throughout the manufacturing process.



10(a) ***Why should you be concerned about the work envelope shape when installing a robot for a particular application in advanced manufacturing industry?***

Discuss the working of most popular pick and place SCARA robot configuration with neat sketch?

Answer:

Now, let's ***discuss why the shape of the work envelope (or volume) is important when installing a robot for a particular application in the advanced manufacturing industry:***

1. **Reachability**: The shape of the work envelope determines the reachable area within which the robot can operate. It ensures that the robot can reach all the necessary positions and perform the required tasks within the designated workspace.

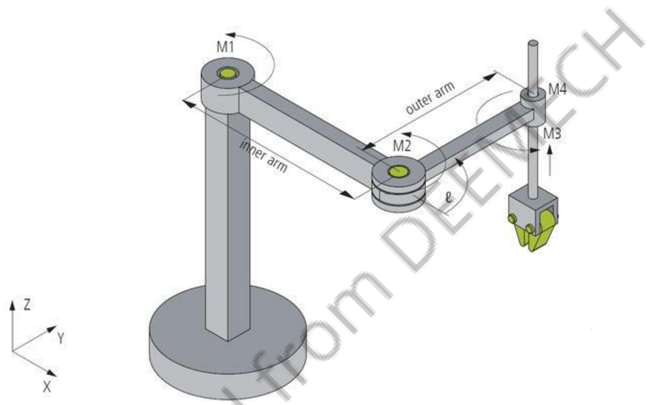
2. **Spatial Constraints**: The work envelope shape helps in identifying potential spatial constraints or limitations within the workspace. It allows for proper planning of the robot's installation and placement to avoid collisions or interference with other objects or equipment in the surroundings.

3. **Workspace Optimization**: By considering the work envelope shape, one can optimize the utilization of the workspace. It enables efficient placement of the robot and other equipment to ensure smooth operations and minimize wasted space.

4. **Task Requirements**: Different applications may have specific requirements in terms of the workspace shape and dimensions. By considering the work envelope, one can ensure that the robot is capable of meeting those requirements and performing the desired tasks effectively.

5. **Safety Considerations**: The shape of the work envelope is important for ensuring the safety of human operators and other equipment in the workspace. It helps in designing appropriate safety measures, such as barriers or sensors, to prevent accidents and maintain a safe working environment.

In summary, the shape of the work envelope is a crucial consideration when installing a robot for a particular application in the advanced manufacturing industry. It determines the reachable area, spatial constraints, workspace optimization, task requirements, and safety considerations. Understanding and aligning the work envelope shape with the specific application requirements is essential for successful robot integration and operation.



The SCARA (Selective Compliance Assembly Robot Arm) robot configuration is a popular design for pick and place applications in the advanced manufacturing industry. It is known for its simplicity and intuitive design.

The SCARA robot consists of two rotary joints and one translation joint. The movement of the robot can be split into two dimensions for the rotary joints, while the picking and placing functionality is achieved through the translation joint.

To build a SCARA robot, you would connect one end of each segment to the rotor and the other end to the stator. The motors are located inside the joints. For the translation movement, you would replace one of the segments with a translation joint.

The SCARA robot configuration allows for precise and controlled movement in a horizontal plane. It is well-suited for tasks that require pick and place operations, assembly, and sorting. The SCARA design provides good speed and accuracy, making it ideal for applications where fast and repetitive movements are needed.

10(b) ***Driverless vehicles and navigation systems are improving day after day and are contributing to boost the AGV (Automated guided Vehicle) Market worldwide. Illustrate the working principle of AGV.***

Answer:

Automated Guided Vehicle (AGV) is a self-operated vehicle designed to transport materials along predetermined paths between defined delivery points or stations. AGVs contribute to the growth of the AGV market by leveraging advancements in driverless vehicle technology and navigation systems.

The working principle of an AGV involves the following steps:

1. Cargo Handling Instructions: Upon receiving cargo handling instructions, the AGV prepares to carry out the designated task.

2. Route Calculation and Analysis: The central controller of the AGV performs vector calculations and route analysis based on the pre-drawn operation map, current coordinates, and forward direction of the AGV.

3. Optimal Route Selection: The central controller selects the best driving route based on the route analysis and controls the AGV's movement, turning, and steering along the path. This ensures that the AGV reaches the precise parking position for cargo loading.

4. Cargo Loading: Once the AGV arrives at the designated loading position, it automatically loads the cargo onto the vehicle using additional mechanisms specifically designed for loading and unloading operations, eliminating the need for human assistance.

5. Transport to Unloading Point: After loading the cargo, the AGV begins its movement towards the target unloading point, following the predetermined path.

6. Unloading: Upon reaching the precise location at the unloading point, the AGV stops and completes the unloading process. It then reports its position and status to the control computer or system.

7. Standby and Task Execution: The AGV proceeds to the standby area until it receives new instructions for its next task. It remains ready to execute further tasks based on the received instructions.

AGVs offer significant advantages in industrial production, improving safety and enhancing production efficiency. They operate autonomously, following programmed routes and executing cargo handling tasks without the need for continuous human intervention.

In conclusion, AGVs contribute to the growth of the AGV market worldwide. Their working principle involves receiving cargo handling instructions, calculating optimal routes, autonomously navigating along predefined paths, and executing cargo loading and unloading operations with minimal human assistance. AGVs improve safety and enhance production efficiency in various industrial applications.

<u>NOTE :</u> *This is the model answer; any relevant or similar answer may be considered.*

Register No. :

QP-Code : 20ME53I

Makeup Examination – Sept. 2023
V Semester Diploma Examination

ADVANCED MANUFACTURING TECHNOLOGIES

Exam Date / Time: 22nd Sep. 2023 / 2.00 PM

Time: 3 Hours **Max.Marks:** 100

Instructions: (1) Answer one full question from each section.
(2) One full question carries 20 marks.

SECTION – I

1 (a) Back in the days, aircrafts were constructed using wood and fabrics. But the aircrafts that are made of wood and fabrics were subjected to rapid deterioration and high maintenance. Thus, the search for better materials began. Now, aluminium, steel, titanium and composite materials are preferred in the construction of aerospace structures. Why such materials are used in aerospace structures? Where else do you find the applications of these materials? **10 Marks**

1(b) Explain the most widely used non-traditional machining method which performs cutting, welding, drilling, surface texturing, wire stripping in manufacturing and can create fine features that are difficult or impossible to make using traditional machining equipment. **10 Marks**

2(a) Superalloys are the materials best-suited for practical high temperature performance, these are materials that can survive hotter temperatures. Specifically, they are usually used for turbine blades. Why are Superalloys important and also, Special? **10 Marks**

2(b) In an aerospace application manufacturing of critical components of cryogenic engine is uphill task in conventional machining method. However, industries found the way by using Electron Beam Machining process. Illustrate the working of Electron Beam Machining. **10 Marks**

SECTION – II

3(a) Additive manufacturing (AM), also known as rapid prototyping or 3D printing, generally refers to techniques that produce three-dimensional parts by adding material gradually in a layer by layer fashion. In this sense, AM differs fundamentally from forming and subtractive techniques. There are different classes of materials used in additive manufacturing. Differentiate these different materials used in Additive manufacturing with respect to their Properties and Applications? **10 Marks**

3(b) The Fighter jet Aircraft ventilation distributor originally made by using composite of seven separate parts. The objective was to minimize the final delivery time by dramatically reducing manufacturing time through 3D printing, using sintering technology, also ensuring lower manufacturing costs. Illustrate how this Process can be achieved? **10 Marks**

4(a) Selective Laser Sintering (SLS) and 3D Printing (3DP) are two powerful and versatile AM techniques which are applicable to powder-based material systems. Differentiate and suggest the best technique among the two. Present arguments to support your selection. 10 Marks

4(b) Uniform wares explore the advantages of Additive Manufacturing (AM) technology, pushing the boundaries of design in an industry traditionally centred around heritage. What benefits exist in additive manufacturing? Differentiate the technologies available in additive manufacturing and list their applications.
10 Marks

SECTION – III

5(a) Like other conventional manufacturing, Additive Manufacturing (AM) components are also known to have various internal defects, such as balling, porosity, internal cracks and thermal/internal stress, which can significantly affect the quality, mechanical properties and safety of final parts. Therefore, inspection methods are important for reducing manufactured defects and improving the surface quality and mechanical properties of AM components. In this regard, discuss different inspection methods adopted in AM with their merits and demerits?
10 Marks

5(b) In most of the conventional methods, the tested materials may not be useful after testing, however, without destruction testing the properties of finished components are more economical. Why is Non-Destructive Testing (NDT) Important? What Tests are Available? What criterions are considered in selection of these NDT methods?
10 Marks

6(a) 3D printing is finally crossing that threshold from prototype to production. However, there are still a few challenges that hold AM back such as quality measures and quality control. These are essential for repeatability, consistency, scalability, and overall confidence in the process. Discuss the different Quality control methods adopted in AM with their merits and demerits?
10 Marks

6(b) AM-produced parts are being used by NASA in mission-critical situations and in the aviation and power industries where safety and reliability are of prime importance. These parts are tested using Non-Destructive testing methods. Suggest the best Non-Destructive testing method used in this case. Present arguments to support your selection.
10 **Marks**

SECTION – IV

7(a) Automation in manufacturing is the process of using production management software or robotic tools to operate a factory when making a physical product. Discuss the various levels of Automation in Advanced Manufacturing.
10 Marks

7(b) In manufacturing lead time, the highest time-consuming task is material handling. An automatic system may boost up the material movement and can reduce overall cost of the product. Explain the different types of automatic guided vehicles (AGV's) used in an Industry to transfer the material.
10 Marks

8(a) Industrial automation is the use of data-driven control systems, such as industrial computers, PLC controllers or robots, which reduces the need for human action by operating industrial processes or machinery. Does the convergence of these, Operation Technology (OT) and Information Technology (IT) is beneficial in advanced manufacturing? Justify your arguments.
10 Marks

8(b) Robots have existed for a few decades, and have been evolving with the advances in technology from a hardware and software standpoint. The evolution of these has produced robots that are superior to preceding generations due to their traits of improved perception, adaptability, mobility, and systems integration. Explain the functioning of advanced robots in Industry-4.0 Technologies. 10 Marks

SECTION – V

9(a) Electrochemical process is most commonly used method for mass production, and is able to cut extremely hard materials which are difficult to machine using conventional methods. Its use is limited to electrically conductive materials. Explain how this process works. 10 Marks

9(b) Electrical discharge machining (EDM) is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to machine by conventional machining processes. Discuss the process parameters required in an EDM process? Suggest, suitable process parameters that need to be considered for this case and justify. 10 Marks

10 (a) In an aerospace application, manufacturing the critical components of cryogenic engine is uphill task in conventional machining method. However, industries found the way by using Electron Beam Machining process. With a neat diagram explain the working of Electron Beam Machining. 10 Marks

10(b) An electric discharge machining operation is being performed on two work materials: tungsten and zinc. Determine the amount of metal removed in the operation after one hour at a discharge amperage = 20 amps for each of these metals. The melting temperature of tungsten and zinc are 6170°F and 420°F, respectively. 10 Marks

V Semester Diploma Examinations, Feb/March 2023

Advanced Manufacturing Technologies

SUB CODE: 20ME53IT **MAX MARKS:100**

SCHEME OF VALUATION

SECTION-I

1(a) List 1/2x4=2 Marks, Justification-3 Marks, Advantages-3 Marks, applications-2 Marks

1(b) Justification-4 Marks Advantages-4 Marks, Dis-advantages-2 Marks

2(a) Explanation- 6 Marks, applications-4 Marks

2(b) Any 5 important steps - 5X2=10 Marks

SECTION-II

3(a) Properties (any 4 type) 1.5x4=6M and applications (any 4 type 1/2x2) 1+1+1+1=4Marks

3(b) Benefits -4M, Different technologies 2M, Applications -1/2x8=4M

4(a) Formula 2+2 Marks, Substitution 2+2 marks, final answer 1+1 mar=1 0 Marks

4(b) Suggestion-2 Marks , Explainationt-8Marks

SECTION-III

5(a) List – 1/2x6=3 Marks, Explanation-3 Marks, Advantages 0.5x8=4M

5(b) Suggestion-5 Marks , Argument-5M

6(a) Importance- 4Marks, Benefits(any 3)- 3Marks, and need(any 3)-3marks

6(b) Line diagram-3marks, working priciple-7 marks

SECTION-IV

7(a) working principle with line diagram-10 Marks,

7(b) Each level 2x5=10 Marks

8(a) working principle with line diagram-10 Marks,

8(b)) Explanation of each 5x2=10Marks

SECTION-V

9(a) Sketch-5 Marks, working=5 Marks

9(b) Selection of **suitable process** 2, Steps- 6Marks, Justification-2 Marks

10(a) Sketch-4 Marks , working-4Marks, Drabacks-2Marks (Any 2)

10(b)Definitions each 2x2=4 Marks, any 6 difference 6x1=6 Marks

V Semester Diploma Examinations, Feb/March 2023

Advanced Manufacturing Technologies

SUB CODE: 20ME53IT **MAX MARKS:100**

MODEL ANSWERS

Note: The model answers only for reference, alternate answers can also be considered.

Section-1

1 a). The materials used in manufacturing of automobiles / locomotive have changed lot now as compared to early years. With objects of reducing weight and increase fuel efficiency, what are the advanced materials are used in manufacturing of Automobiles and Locomotive? Justify your answer with materials advantages and uses.

Ans: The advanced materials are used in manufacturing of automobiles and locomotive are

i) Laminated composites/composites.

ii) Magnesium

iii) Aluminium alloys

iv) Carbon fiber composites

v) Titanium etc

Justification: The growing challenges on fuel economy improvement and greenhouse gas emission control have become the driving force for automakers to produce lightweight automobiles. Also, the weight reduction may contribute to superior recyclability and/or vehicle performance. One effective strategy is to develop and implement lightweight yet high-performance materials as alternative solutions for conventional automotive materials such as cast iron and steel. Lightweight materials to produce next-generation automobiles is provided, including light alloys, high-strength steels, composites, and advanced materials reducing weight and increase fuel efficiency and also improved driving economy, braking behaviours, and crashworthiness.

Advantages of advanced materials.

i) Light weight.
ii) High strength.
iii) Good corrosion resistance.
iv) High-temperature resistance.
v) High compression resistance.

Applications of Advanced materials

Military aircraft. Automotive. Electronics industries. Space systems. Medical equipment. Construction of bridges. Corrosive Environments. Aerospace. Oil and gas industries. Sports items.

1 b). Discuss non-traditional manufacturing methods are better than traditional manufacturing methods. Justify your answer and also list advantages and disadvantages.

Ans: The greatly improved thermal, chemical, and mechanical properties of the new engineering materials made it impossible to machine them using the traditional machining processes of cutting and abrasion. This is because traditional machining is most often based on the removal of material using tools that are harder than the work piece. For example, the high ratio of the volume of grinding wheel worn per unit volume of metal removed (50–200) made classical grinding suitable only to a limited extent for production of poly crystalline diamond (PCD) profile tools.

The high cost of machining ceramics and composites and the damage generated during machining are major obstacles to the implementation of these materials. In addition to the advanced materials, more complex shapes, low-rigidity structures, and micromachined components with tight tolerances and fine surface quality are often needed. Traditional machining methods are often ineffective in machining these parts. To meet these demands, new processes are developed. These methods play a considerable role in the aircraft, automobile, tool, die, and mould making industries.

Advantages

i) Improved thermal, chemical properties
ii) Improved mechanical properties.
iii) No wear and tear of the tool materials.
iv) More complex shapes machining can do easily.
v) Micro-machined components with tight tolerances can get.
vi) Fine surface quality.
vii) clean working area.
viii) low-rigidity structures can machine easily.

Disadvantages.

i) Initial investment more
ii) Cost of the machine is very high
iii) Trained works are needs for operation.
iv) Low Material removal process

2 a) Point out super alloys and ceramics materials used in high temperature applications ? explain. List the applications.

Ans: **superalloys and ceramics** are generally known difficult to machine materials because of their toughness, high heat resistance and high operating temperatures, hardness, strength to weight ratio and chemical property to react with tool materials, low thermal conductivity and creep resistance. Although these whole properties are necessary design requirements, they cause a greater challenge to manufacturing engineers due to the high temperatures and stresses generated during machining. The tool materials with better hardness like carbides, ceramics and CBN are regularly used for machining of Super alloys. Betterments in machining productivity can be attaining with the advanced machining techniques such as rotary machining. The superalloys mainly used to turbine parts as well as high temperature elements.

Applications:

i) used in air craft
ii) power generation turbines
iii) rocket engines
iv) chemical processing
v) nuclear power plants
vi) aero gas turbine
vii) jet engines
viii) Turbine materials, both disc and blades
ix) applications in the oil and gas industry

2b) Discuss the importance of steps in chemical machining method.

Ans: Importance of steps are

i) Cleaning ii) Scribing iii) Masking iv) Etching v) Demasking

i) Clean: Preparing and precleaning the workpiece surface for chemical machining. This provides good adhesion of the masking material and assures the absence of contaminants that might interfere with the machining process.

i) Scribing: Scribing templates are used to define the areas for exposure to the chemical machining action. The most common workpiece scribing method is to cut the mask with a sharp knife followed by careful peeling of the mask from the selected areas.
ii) Masking: Maskants are generally used to protect parts of the workpiece where Chemical machining action is not needed. Synthetic or rubber base materials are frequently used.
iii) Etching: When the mask is used, the machining action proceeds both inwardly from the mask opening and laterally beneath the mask thus creating the etch, this process is called etching.
iv) Demasking: The process of removing the maskants from the machined parts, after the chemical machining.

Section-2

3a) In additive manufacturing, the material properties are being established alongside the geometry of the part. There are different classes of materials used in additive manufacturing. Differentiate these different materials used in AM with respect to their Properties and Applications.

Ans:

In additive manufacturing, however, the material properties are being established alongside the geometry of the part. The raw material has an impact (i.e. the chemical makeup of the polymer, the size and distribution of metal powder particles) but process parameters also play a role in factors such as strength, ductility, porosity and surface finish of the final part. This brings new challenges unique to additive, but also opportunities. When the material properties are determined alongside the geometry, it becomes possible to intentionally and precisely control those properties in specific regions of the part — to introduce properties such as porosity, or stiffness, or flexibility.

Materials are

Ceramics, Silicon carbides, Aluminium oxide, Cement

Properties are,

High hardness. • High elastic modulus. • Low ductility. • Good wear resistance.

Applications are,

In space industry. • In thermal insulator. • Electric application. • Modern industries.

Plastics

Acrylanitride Butadiene Styrene (ABS) 2. Polylactide (PLA) 3. Polycarborate (PC) 4. Polyvinyl Chloride (PVC)

Properties- • They are light weight and chemically stable. • Low thermal condectivity. • They don't rust. • Poor dimension stability.

Applications-

In elecrtical applications. • Manufacturing industries. Health care application. • Textile applications. • Medical equipments. • Agricaltural applications.

Polyethylene terephthalate (PET)-

Polyethylene terephthalate or PET is commonly seen in disposable plastic bottles. Due to higher chemical resistance and rigid compositions, PET is used in manufacturing plastic containers used in packaging food.

Properties are,

Good durablity. • recyclable material. • Good strength • temperature resistance.

Applications are,

food packaging industry. • Fruit container. • Sinthetic clocks • Electronic applications.

3b) Uniform wares explores the advantages of additive manufacturing(AM) technology, pushing the boundaries of design in an industry traditionally centred around maintenance. What are the benefits of additive manufacturing ? Defferentiate the technologies available in additive manufacturing and list their applications.

Ans:

Ans-

Additive technology is known as the use of 3d printing techniques to make part which traditionally was being made by fabrication or moulding technique.

The companies should adapt to this technology due to follwing reasons.

1. It reduces wastage to great extent.

2. It reduces the amount of labour and efforts required to make a product.

3. The chances of error are less.

4. The designs can be directly made by commanding the system.

5. The complex structures can be easily made.

6. The cost in the long run reduces a lot.

7. Innovations are rapidly taking place.

8. The structure of the part remains same throughout.

9. Maintenance required is less.

These are the few reasons because of which the companies should adapt to additive manufacturing.

The few points which need consideration are.

Financial issues.

This technology is till in development and testing phase for large scale utilization so judging it now according to its cost is not correct,once the technology becomes widespread usable then the cost involved will also reduce as more and more people would start using this technology on large scale.

Certifications and regulation.

The government has not completed accepted this technology and thus certification is limited as strength of the object made is considered to be compromised but the present day metal material has shown considerable amount fo improvement and if we consider the airplane parts then the parts are usually made of aluminum alloys and thus they can be easily made through this technique, the issues arise only with hard parts like iron and other hard metals. The technology is rapidly improving and thus certifications will also be available soon.

Repeatability.

Traditional moulding techniques were able to make similar parts quickly and rapidly but additive techniques are not able to do so quickly but the innovations taking place would be able to answer this question as well and thus similar pats would be made rapidly and the present day artificial intelligence an dmachine learning would also add to it.

Skill gap.

The skill gap can be easily handled by training individuals on the new technology and thus a chain of skilled workers can be made easily the technology being simple enough would help to narrow down the gap quickly. The companies can provide free trainings in order to showcase their system and thus the ignorance can be removed easily.

ADDITIVE MANUFACTURING TECHNIQUES -

they are,

* Liquid based additive manufacturing.

APPLICATIONS -

- Low volume production of complex parts.
- Rapid manufacturing.
- Architecture.
- Automotion parts.

* Polymerization.

APPLICATIONS -

- Dental models.
- Jewelry casting.
- Medical application.
- Automotive uses.
- In telecom industries.
- Manufacture rapid tools.

* Binding .

APPLICATIONS-

- Manufacturing of full-colour prototypes.
- Large sand-castimg cores and moldson the plastic/ceramics side and small.
- Functional parts on the metal side.

* Power based additive manufacturing .

4a) An Electric discharge machining operation is being performed on 2 work materials, Tungsten and Zinc. Determine amount of metal removed in the operation after 1 hour at a discharge amperage = 20 Amps for each of these metals. The melting temperatures of tungsten & zinc are 6170^0F & 420^0F respectively.

Ans:

Where, R_{MR} = Metal Removal Rate, mm^3/s or in^3/min

K = Constant of proportionality = 5.08 in U.S customary units & 664 in SI units

I = Discharge current, amps.

T_m = Melting temp^r of work metal, °c(°F).

Metal Removal Rate of EDM

For Tungsten $R_{MR} = \frac{KI}{T_m^{1.23}}$ ---- 2 Marks

$= \frac{5.08 \times 20}{6170^{1.23}}$ ---- 2 Marks

$= 0.00221\ in^3/s$ ---- 1 Mark

$= 0.1327\ in^3/hr$

For Zinc $R_{MR} = \frac{KI}{T_m^{1.23}} = \frac{5.08 \times 20}{420^{1.23}} = 0.0603\ in^3/s$ — 2+2

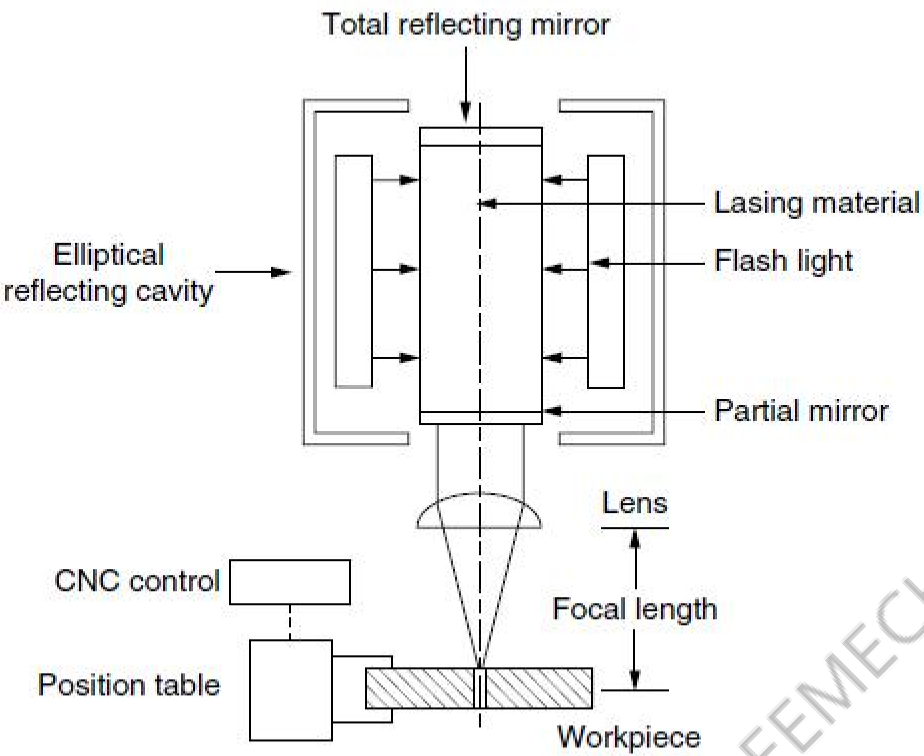
$= 3.62\ in^3/hr$ — 1M

4b) Industrialist needs the engraving of letters on a wood, plastics and rubber materials using LASER. Discuss suitable machining process.

Ans: The machining process which is used in industry for engraving the letters is LASER engraving.

A laser engraving machine is a piece of equipment that performs laser engraving, which is the process of engraving designs, letters or numbers on materials using a laser beam. These machines use automation to achieve precise cuts and engravings on various materials, including metal, wood, glass and plastic

Laser is the abbreviation of light amplification by stimulated emission of radiation. A highly collimated, monochromatic, and coherent light beam is generated and focused to a small spot. High power densities (10^6 W/mm^2) are then obtained. Laser engraving is a process that vaporizes materials into fumes to engrave permanent, deep marks. The laser beam acts as a chisel, incising marks by removing layers from the surface of the material. The laser hits localized areas with massive levels of energy to generate the high heat required for vaporization. The following figure shows the working of LASER.



Five Common Applications of Laser Engraving

- Barcode Creation.
- Decorative or Commemorative Annotations.
- Medical and Electronic Components.
- Signage.
- Awards and Trophies

Advantages of Laser Engraving:

- Versatile.
- Simple.
- High precision.
- Minimal maintenance.
- Minimal maintenance required

Section-3

5a) The components which are manufactured by Additive Manufacturing (AM) technology known to have various internal defects, such as porosity, internal cracks thermal stresses etc., which can significantly affect the mechanical properties and safety of final parts. Therefore inspection methods are very much important. List different inspection methods adopted in AM. Explain ultrasonic testing and write their advantages.

Ans:

Different inspection methods are

i) Magnetic particle testing

ii) Radiographic Testing
iii) Magnetic particle testing
iv) Ultrasonic testing
v) Electromagnetic Testing
vi) Tube Inspection With Remote Field Testing (RFT)
vii) Remote Visual Inspection (RVI)
viii) Liquid penetrant testing

ultrasonic testing

Ultrasonic testing remains the most popular nondestructive testing method after visual testing. In this method, a high-frequency sound wave generated by a transmitter travels through the object under test. The frequency of this wave is usually between 1 and 10 MHz. The wave distorts when encountering a change in the density of the material. This change in the transmitted wave is captured by a receiver. The equipment then measures and analyses the received wave to understand the nature and depth of the defect. The equipment can also calculate the thickness of the specimen by dividing the wave speed in the material by the time taken for travel. There are many types of ultrasonic testing available each with its own nuances and field of application. These are pulse-echo testing, immersion testing, guided wave testing and phased array ultrasonic testing to name a few. We can identify defects such as cracks, abrasions, thinning, pitting and corrosion using ultrasonic inspection.

Advantages of ultrasonic testing:

1. Quick 2.Clean 3. Reliable 4. Portable 5. Safe and easy to use 6. Highly accurate and sensitive 7. Ability to gauge dense materials 8. Detection of surface and subsurface defects 9. Identifications of minor defects not visible to the naked eye

5b) AM-produced parts are being used many applications. These parts are tested using Non-Destructive testing methods. Suggest the best Non-Destructive testing method used in this case. Present arguments to support your selection.

Ans:

Initial manufacturing process and repair also use NDT. Two of the most significant NDT methods used in aerospace are Magnetic Particle Inspection (MT) and Penetrant testing (PT).

Penetrant Testing –

penetrant inspection, or penetrant testing (PT) , is another method of NDT used in the aerospace industry.

One of the oldest approaches to detect surface flaws like cracks, porosity, gouges, and seams, inspectors add the dye to target areas on a surface.

By capillary action, the dye finds its way into openings, coating the flawed areas. After the excess dye is removed, an additive called the “developer” is introduced, and it draws the remaining dye out.

After a final cleaning step, the dye that penetrated through the developer exposes the critical cracks and porosity in the part when viewed under a black light.

While PT can be used in nearly any NDT application, compatibility of test materials must be considered for the specific industry.

With the inherent severity of chemical incompatibility in the aerospace industry, manufacturers developed classes of penetrants best suited for that industry.

The most common penetrant systems in aerospace are Type I (fluorescent), Methods A, B, and D (water washable, post emulsified – lipophilic, and post emulsified – hydrophilic, respectively).

Benefits of Penetrant testing

i)The method has high sensitivity to small surface discontinuities.

ii) The method has few material limitations, i.e. metallic and nonmetallic, magnetic and nonmagnetic, and conductive and non conductive materials may be inspected.

iii) Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.

iv) Parts with complex geometric shapes are routinely inspected.

v) Aerosol spray cans make penetrant materials very portable.

vi) Penetrant materials and associated equipment are relatively inexpensive.

The balance in the design of aerospace components comes with aiming to lighten the component mass while withstanding the high structural loads on the materials. This high load-to-material strength ratio makes the components susceptible to thermal and pressure cycle fatigue, as well as vibration, due to the wide ranges of operating conditions.

Additionally, corrosion from humidity in the ground air that condenses on the plane attacks the material as well. Over 80% of inspections are performed visually by trained inspectors. Inspectors use NDT for much of the remaining 20% they cannot access visually.

6a) Point out non-destructive testing (NDT) is important ? List the benefits and need of NDT over DT (Destructive testing).

Ans: The importance of non-destructive testing in ensuring that assets are properly maintained cannot be overstated.NDT is an important quality control and quality assurance management tool in industries it may assist in preventing failures that could hurt safety, reliability, and the environment. It is a critical procedure that supports all of their operations. Every equipment piece, product, and material has defined design criteria and expected life. However, because of its faults that may go unnoticed throughout production, fabrication, or service delivery, they may need to undergo substantial repair or be replaced; otherwise, unsafe circumstances or catastrophic failures may result from ignoring their unfit conditions for service.

Benefits of Non-Destructive Testing -

I) The benefits of non-destructive testing are manifold.

II) No damage to the part being tested is sustained and therefore it remains useful.

III) Non-destructive testing can be carried out at any time in the product's lifecycle: raw materials, semi-finished or finished components can be tested with equal measure of effectiveness.

IV) Non-destructive testing also offers very comprehensive testing and can be used to locate both surface and internal flaws.

V) Finally, non-destructive testing allows manufacturers and engineers to ensure worksites and materials are compliant with regulation designed to ensure their safety.

Non-Destructive Testing Needed Because-

Before non-destructive testing was conceived, destructive testing was used to ensure batches of components were manufactured to safety standards.

The logic was that destructive tests should provide an indication about whether a sample of parts was fit to endure the stresses placed on it during operation.

However, despite destructive testing taking place, several incidents occurred where components were destroyed during operation and led to loss of property and human life.

As a consequence, non-destructive testing methods were developed to eliminate such failures without damaging the product in use.

6b) Co-ordinate measuring machine and profile projector are necessity to reach higher standards in industries. Discuss the working principle of CMM.

Ans: Working Principle of CMMs:

Coordinate measuring machines (CMMs) refers to determine the 3D (x y and z) dimensions of objects with the help of probe contacts. The basic principle of CMM is putting the objects which need to be tested in the working range of the system.

It allows you to get the measurement of the object's coordinate either automatically (with the help of software) or with manual configuration. Thanks to software technology which helps in visualizing and analyzation of recorded data.

Then various mathematical calculation techniques are utilized for getting the shape, position tolerance, and other related features of the considered object.

Though advanced coordinate measurement machine provides various other features, however, the dimensional measurement is still the most fundamental application of CMMs. The block diagram of CMM as shown below.

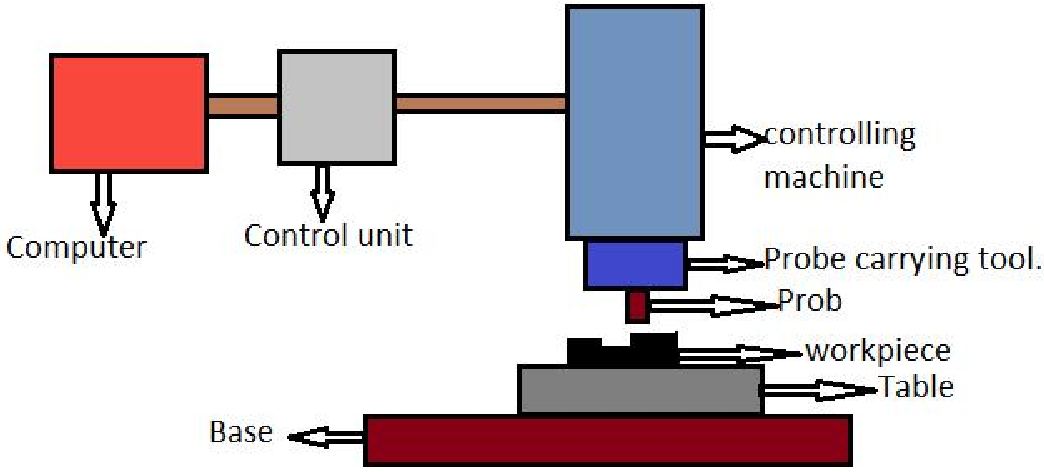


Fig: Coordinate Measuring Machine

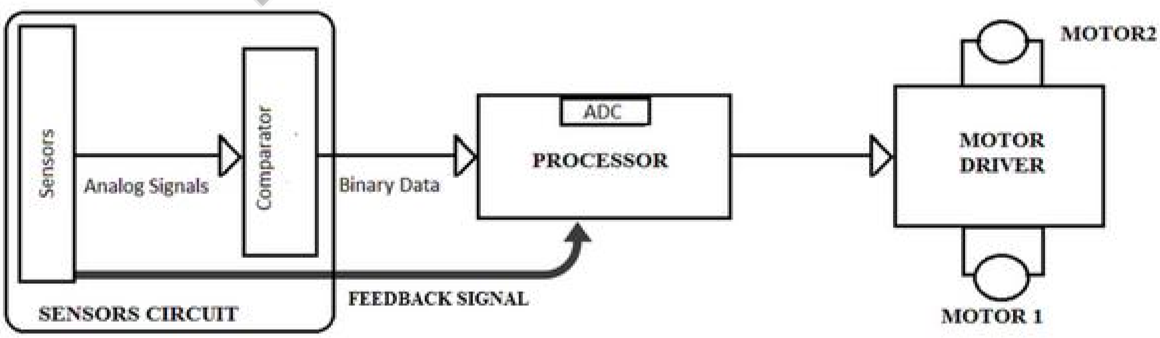
Section-4

7a) Driverless vehicles and navigation systems are improving day after day and are contributing to boost the AGV (Automated guided Vehicle) Market worldwide. Discuss the working principle of AGV.

Ans: Automated guided Vehicle

An AGV is an independently operated vehicle that moves material along defined paths

between defined delivery points or stations. Typically the paths are defined by either using wires embedded in the floor or reflecting paint strips on the floor. The difference of AGV from other electric vehicles is that its operation requires no human input, as it is controlled by a preset program and safety systems and, besides, the vehicle is equipped with additional mechanisms for loading/unloading without human assistance. AGV follows a predetermined path (See the Navigation Principles tab for details). The movement is initiated by a pre-programmed event (beginning of a shift, input of target cargo, operator's command, etc.) . A simple block diagram shows the working principle of AGV.



Working Principle

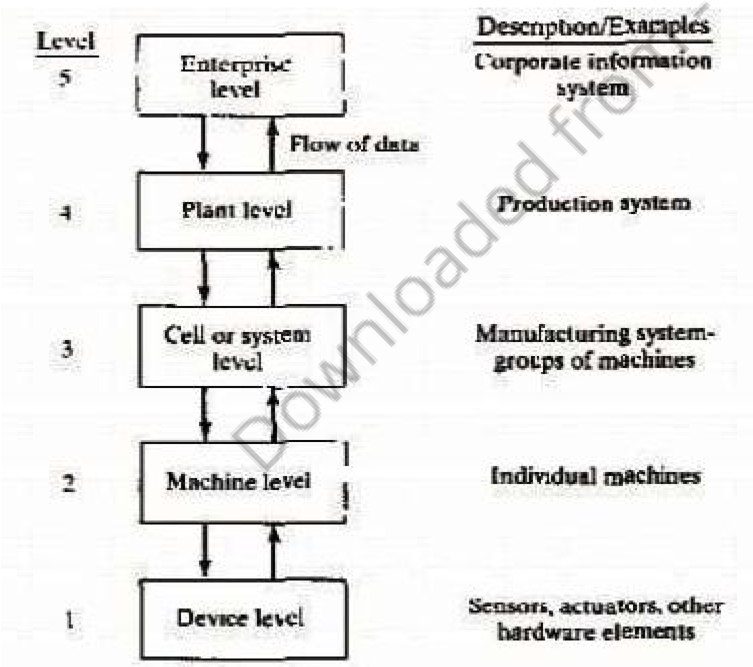
- The working sequence of AGV is as follows:

After receiving the cargo handling instructions, according to the pre-drawn operation map, the current coordinates and the forward direction of AGV. The central controller carries out vector calculation and route analysis, chooses the best driving route, automatically intelligently controls the AGV trolley's driving, turning and steering on the road, arrives at the accurate parking position of loading cargo, and loads the cargo. Then AGV starts to "run" to the target unloading point, stops after arriving at the exact location and completes the unloading, and reports its position and status to the control computer. Then AGV starts to run to the standby area until it receives new instructions and then does the next task. Mircolomay AGV aim to give full play to the maximum effect of AGV. As for consumer, you must have a clear understanding of the internal structure and principle of the product. When choosing an AGV with guaranteed quality. we should also have a thorough understanding and use according to the regulations, so as not to damage the safe operation of the AGV.

Nowadays, AGV(Automated Guided Vehicle) cart has been widely used in the industrial field. It not only solves the first important safety problem in industrial production, but also speeds up the production efficiency.

7b) Discuss the five levels of automation in advanced manufacturing.

Ans:



1. **Device level :**

This is the lowest level in our automation hierarchy. It includes the actuators, sensors, and other hardware components that comprise the machine level. The devices are combined into the individual control loops of the machine; for ex· ample, the feedback control loop for one axis of a CNC machine or one joint of an industrial robot.

2. **Machine level**

Hardware at the device level is assembled into individual machines. Examples include CNC machine tools and similar production equipment, industrial roo bOIS, powered conveyors, and automated guided vehicles. Control functions at this level include performing the sequence of steps in the program of instructions in the correct order and making sure that each step is properly executed.

3. Cell or system level

This is the manufacturing cell or system level, which operates under instructions from the plant level. A manufacturing cell or system is a group of machines or workstations connected and supported by a material handling system, computer. and other equipment appropriate to the manufacturing process. Production lines arc included in this level. functions include part dispatching and machine loading. coordination among machines and material handling system, and collecting and evaluating inspection data.

4. Plant level

This is the factory or production systems level. It receives instructions from *(the* corporate information system and translates them into operational plans for production. Likely functions include: order processing, process planning, inventory control, purchasing, material requirements planning, shop floor control, and quality control.

5. Enterprise level

This is the highest level consisting of the corporate information systern.It is concerned with all of the functions necessary to manage the company: marketing and sales, accounting, design, research, aggregate planning, and master production scheduling.

8a) Automated Storage and Retrieval Systems (ASRS or AS/RS) are used in applications where high volumes of inventory move in-and-out of manufacturing or distribution operations. Discuss the working principle of ASRS.

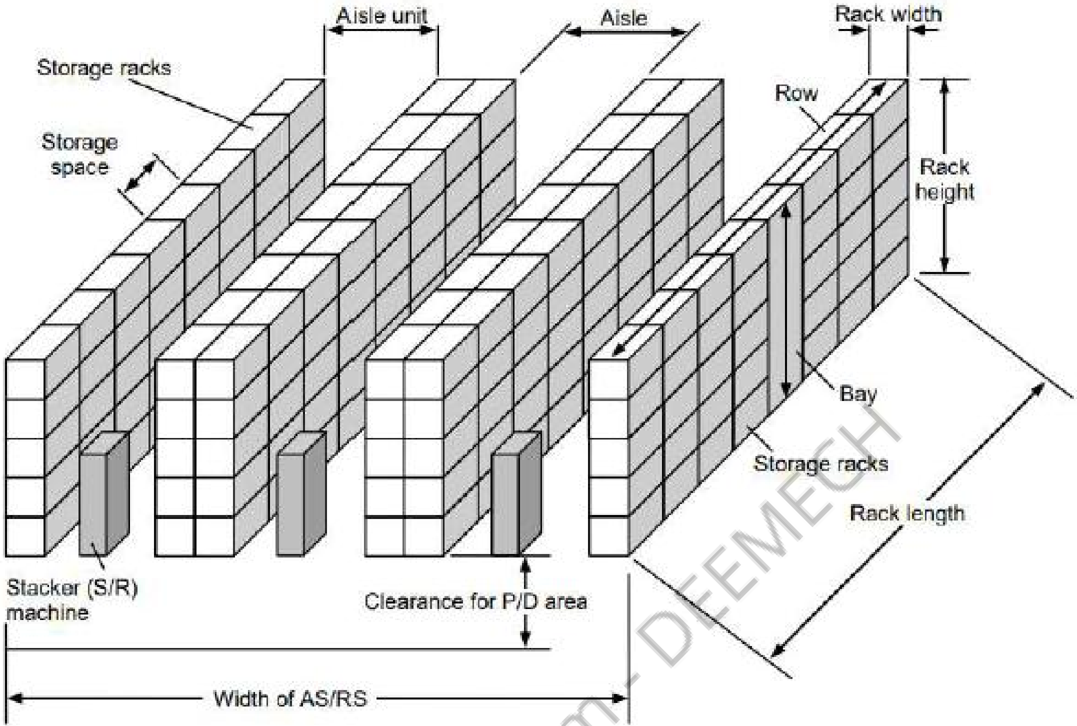
Ans: Automated Storage and Retrieval Systems work by using computer-controlled systems to automatically deposit and retrieve loads from a defined storage area. Automated storage and retrieval systems, sometimes known as ASRS or AS/RS, are made of a variation of computer-controlled systems that automatically place and retrieve loads from set storage locations in a facility with precision, accuracy and speed.

An Automated Storage and Retrieval System (AS/RS) is a combination of equipment and controls that handle, store and retrieve materials as needed with precision, accuracy and speed under a defined degree of automation. Systems vary from smaller automated systems to larger computer controlled storage/retrieval systems totally integrated into a manufacturing and/or distribution process.

Working of AS/RS:

An AS/RS consists of one or more storage aisles that are serviced by a storage/retrieval (S/R)

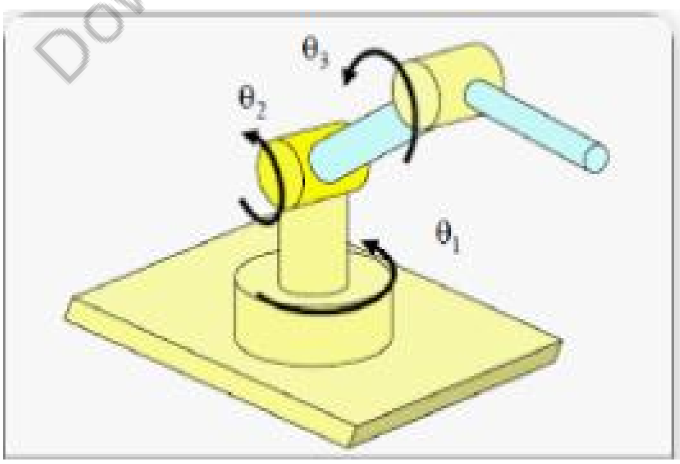
machine. The stored materials are held by storage racks of aisles. The S/R machines are used to deliver and retrieve materials in and out of inventory. There are one or more input/output stations in each AS/RS aisle for delivering the material into the storage system or moving it out of the system. In AS/RS terminology, the input/output stations are called pickup-and-deposit (P&D) stations. Generic structure of AS/RS as shown below.



8b) A company requires to setup an articulated robot and cartesian Robots. Discuss how both Robots works.

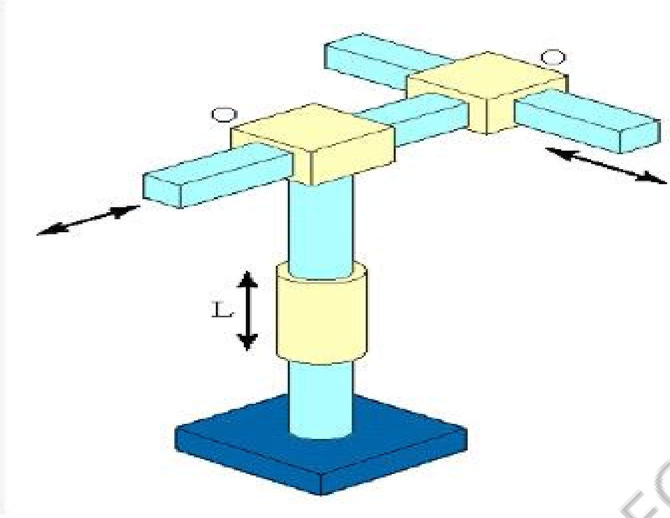
Ans:

Articulated/Revolute Type Configuration: Also called articulated manipulator that looks like an arm with at least three rotary joints. They are used in welding and painting; gantry and conveyor systems move parts in factories.



Cartesian Type Configuration (PPP),(X Y Z)

It is form by 3 prismatic joints, whose axes are coincident with the X, Y and Z planes. These robots move in three directions, in translation, at right angles to each other. Cartesian manipulator is useful for table-top assembly applications and, as gantry robots for transfer of material.



Section-5

9a) Discuss the working of ultrasonic machining process.

Ans: Ultrasonic machining is a mechanical type non-traditiona1 machining process. It is employed to machine hard and brittle materials (both electrically conductive and non-conductive material) having hardness usually greater than 40 HRC.

Working of USM

Ultrasonic machining is a non-conventiona1 machining process in which the removal of hard and brittle materials is done using an axially oscillating tool at ultrasonic frequencies [18—25 kilohertz (kHz)]. 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. There is no direct contact between tool and workpiece. There is gap between tool and workpiece of about 0.25 mm.

The impact force arising out of vibration of the tool and the abrasive particles are, therefore, hammered into the workpiece surface and actually causes thousands of microscopic abrasive grains to remove the work material by abrasion causing chipping of fine particles from it. The oscillating tool of desired shape, at amplitudes ranging from 10 to 50 pm, imposes a static pressure on the abrasive grains and feeds down as the material is removed to form the required tool shape. Fig. Shows the USM.

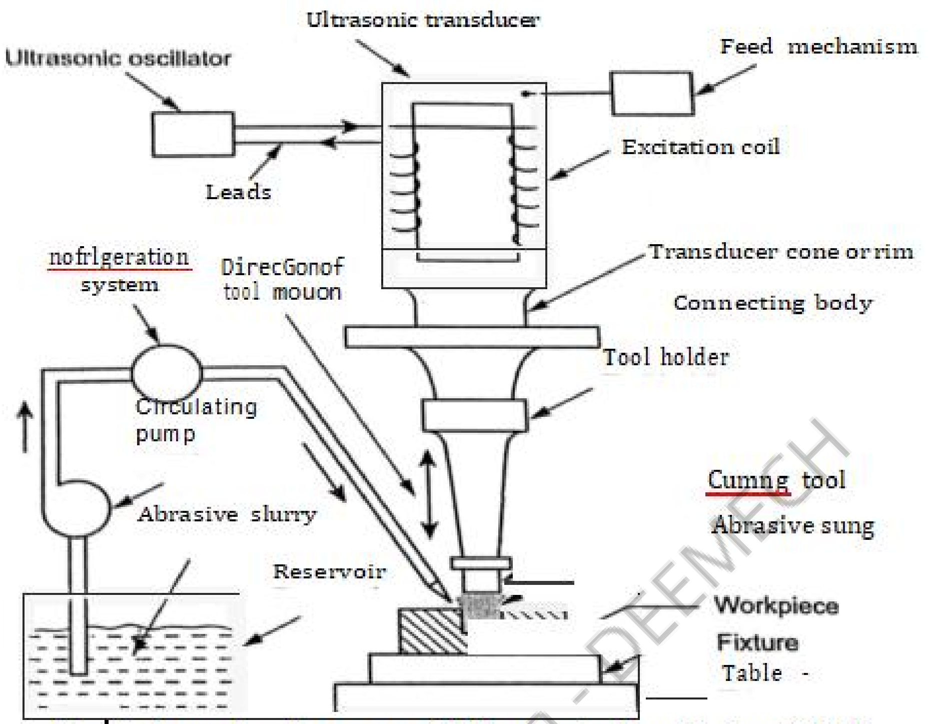


Fig. Schematic diagram of Ultrasonic Machining (USM)

9b) Testing methods use capillary forces to find surface cracks or pores & make them visible. Discuss suitable process and Justify.

Ans : Dye Penetrant Inspection

Principles

DPI is based upon capillary action, where low surface tension fluid penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed, a developer is applied. The developer helps to draw penetrant out of the flaw where an invisible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending upon the type of dye used - fluorescent or nonfluorescent (visible).

Inspection steps

1. **Pre-cleaning..**
   The test surface is cleaned to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications.

2. **Application of Penetrant..**
   The penetrant is then applied to the surface of the item being tested. The penetrant is

allowed "dwell time" to soak into any flaws (generally 5 to 30 minutes). The dwell time mainly depends upon the penetrant being used, material being tested and the size of flaws sought.

3. **Excess Penetrant Removal..**
   The excess penetrant is then removed from the surface. The removal method is controlled by the type of penetrant used.

4. **Application of Developer..**
   After excess penetrant has been removed a white developer is applied to the sample. Several developer types are available, including.. non-aqueous wet developer, dry powder, water suspendable, and water soluble.

5. **Inspection..**
   The inspector will use visible light with adequate intensity (100 foot-candles or 1100 lux is typical) for visible dye penetrant. Ultraviolet (UV-A) radiation of adequate intensity (1,000 micro-watts per centimeter squared is common), along with low ambient light levels (less than 2 foot-candles) for fluorescent penetrant examinations. Inspection of the test surface should take place after 10 to 30 minute development time, depends of product kind.

6. **Post Cleaning..**
   The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.

Justification

Dye Penetrant Inspection (DPI), also called Liquid Penetrant Inspection (LPI) or Penetrant Testing (PT), is one of the oldest and simplists NDT methods where its earliest versions using kerosene and oil mixture). Liquid penetrant inspection is used to detect any surface-connected discontinuities such as cracks from fatigue, quenching, and grinding, as well as fractures, porosity, incomplete fusion, and flaws in joints.

10a) EDM (Electrical discharge machining) has been used in a wide variety of industrial applications ranging from cavity sinking to deburring and ability to machine high strength alloys and hardened steel. Discuss the working of EDM. List the drawbacks.

Ans :

Working of Electrical Discharge Machining (EDM):

Electrical discharge machining works on the principle of metal removal by the combination of electrical and thermal energy. The electrical energy is utilized to create electric spark and heat is produced by erosion of metal.

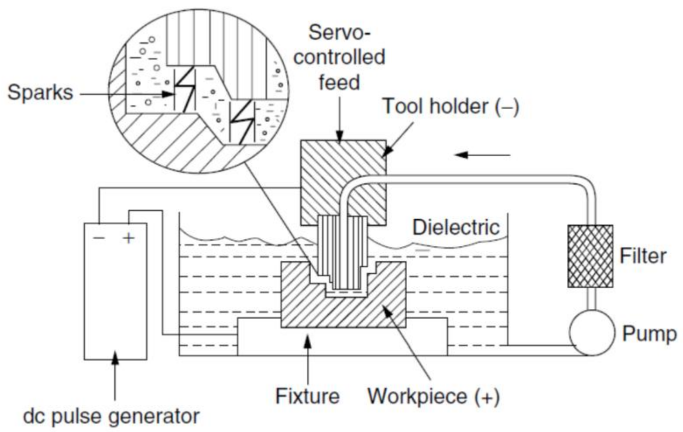


Figure: Working Principle of Electrical Discharge Machining (EDM)

In electro discharge machining, there is no physical contact between tool and workpiece. It is a non-traditional machining process. In this, the tool electrode is connected to the -ve terminal of the DC power supply and workpiece is connected to the +ve terminal of the DC power supply. So, tool acts as a cathode and workpiece acts as an anode.

There is a spark gap between the tool and workpiece is about 0.05 to 0.25 mm. In the flow of dielectric fluid. The dielectric fluid is works as an insulator and as a conductor. When the DC power supply, the tool electrode generated at the spark and due to this the spark hoes to the workpiece by dielectric fluid and machining is done.

In this process, work piece should be well electric conductive. Only electric conductive material can be machined by this method.

OR The working of EDM is as follow.

- First both work piece and tool are submerged into dielectric fluid. The dielectric fluid help to control the arc discharge. This also removes suspended particles of work piece material and tool from the work cavity.
- A servomechanism is used which maintains a very small gap between the work piece and the tool. This gap is desirable for proper arc formation. It is about the thickness of human hair.
- The tool is made as the opposite shape of work piece.
- A high frequency current supplied to electrode, which produces a spark between the tool and work piece. This spark generates high in work cavity.
- The metal removed from the work piece due to erosion and evaporate ion.
- The chips or suspended particle between tool and work piece should be removed to prevent them to form bridge that causes short circuit. This is done by continuous supply of dielectric fluid.
- The EDM produce a cavity slightly larger than the electrode because of overcut

Drawbacks

1. The metal removal rate is slow.
2. Only able to machine conductive materials.
3. Surface cracking may take place in some materials.
4. Reproduction of sharp corners is the limitation of the process

10b) Describe traditional and non-traditional machining processes. List the difference between traditional and non-traditional machining process.

Ans: Traditional Machining process - Traditional Machining process, also termed as conventional machining process which requires the presence of a tool that is harder than the workpiece to be machined.

Non-Traditional Machining - Non-traditional manufacturing processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes.

Differences between Conventional and Non conventional machining processes.

Sl No.	Conventional Process	Non Conventional Process
1.	The cutting tool and work piece are always in physical contact with relative motion with each other, which results in friction and tool wear.	There is no physical contact between the tool and work piece, In some non traditional process tool wear exists.
2.	Material removal rate is limited by mechanical properties of work material.	NTM can machine difficult to cut and hard to cut materials like titanium, ceramics, nimonics, SST,c omposites, semiconducting materials.
3.	Relative motion between the tool and work is typically rotary or reciprocating. Thus the shape of work is limited to circular or flat shapes. In spite of CNC systems, production of 3D surfaces is still a difficult task.	Many NTM are capable of producing complex 3D shapes and cavities.

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4.	Machining of small cavities , slits , blind holes or through holes are difficult	Machining of small cavities, slits and Production of non-circular, micro sized, large aspect ratio, shall entry angle holes are easy using NTM
5.	Use relative simple and inexpensive machinery and readily available cutting tools	Non traditional processes requires expensive tools and equipment as well as skilled labour, which increase the production cost significantly
6.	Capital cost and maintenance cost is low	Capital cost and maintenance cost is high
7.	Traditional processes are well established and physics of process is well understood	Mechanics of Material removal of Some of NTM process are still under research
8.	Conventional process mostly uses mechanical energy	Most NTM uses energy in direct form For example : laser, Electron beam in its direct forms are used in LBM and EBM respectively
9.	Surface finish and tolerances are limited by machining inaccuracies	High surface finish(up to 0.1 micron) and tolerances (25 Microns)can be achieved
10.	High metal removal rate.	Low material removal rate.

Makeup Examination – Sept. 2023
V Semester Diploma Examination

ADVANCED MANUFACTURING TECHNOLOGIES

Exam Date / Time: 22nd Sep. 2023 / 2.00 PM

Time: 3 Hours **Max.Marks:** 100

Instructions: (1) Answer one full question from each section.
(2) One full question carries 20 marks.

SECTION – I

1 (a) Back in the days, aircrafts were constructed using wood and fabrics. But the aircrafts that are made of wood and fabrics were subjected to rapid deterioration and high maintenance. Thus, the search for better materials began. Now, aluminium, steel, titanium and composite materials are preferred in the construction of aerospace structures. Why such materials are used in aerospace structures? Where else do you find the applications of these materials? **10 Marks**

1(b) Explain the most widely used non-traditional machining method which performs cutting, welding, drilling, surface texturing, wire stripping in manufacturing and can create fine features that are difficult or impossible to make using traditional machining equipment. **10 Marks**

2(a) Superalloys are the materials best suited for practical high temperature performance, these are materials that can survive hotter temperatures. Specifically, they are usually used for turbine blades. Why are Superalloys important and also, Special? **10 Marks**

2(b) In an aerospace application manufacturing of critical components of cryogenic engine is uphill task in conventional machining method. However, industries found the way by using Electron Beam Machining process. Illustrate the working of Electron Beam Machining. **10 Marks**

SECTION – II

3(a) Additive manufacturing (AM), also known as rapid prototyping or 3D printing, generally refers to techniques that produce three-dimensional parts by adding material gradually in a layer by layer fashion. In this sense, AM differs fundamentally from forming and subtractive techniques. There are different classes of materials used in additive manufacturing. Differentiate these different materials used in Additive manufacturing with respect to their Properties and Applications? **10 Marks**

3(b) The Fighter jet Aircraft ventilation distributor originally made by using composite of seven separate parts. The objective was to minimize the final delivery time by dramatically reducing manufacturing time through 3D printing, using sintering technology, also ensuring lower manufacturing costs. Illustrate how this Process can be achieved? **10 Marks**

4(a) Selective Laser Sintering (SLS) and 3D Printing (3DP) are two powerful and versatile AM techniques which are applicable to powder-based material systems. Differentiate and suggest the best technique among the two. Present arguments to support your selection. 10 Marks

4(b) Uniform wares explore the advantages of Additive Manufacturing (AM) technology, pushing the boundaries of design in an industry traditionally centred around heritage. What benefits exist in additive manufacturing? Differentiate the technologies available in additive manufacturing and list their applications. 10 Marks

SECTION – III

5(a) Like other conventional manufacturing, Additive Manufacturing (AM) components are also known to have various internal defects, such as balling, porosity, internal cracks and thermal/internal stress, which can significantly affect the quality, mechanical properties and safety of final parts. Therefore, inspection methods are important for reducing manufactured defects and improving the surface quality and mechanical properties of AM components. In this regard, discuss different inspection methods adopted in AM with their merits and demerits? 10 Marks

5(b) In most of the conventional methods, the tested materials may not be useful after testing, however, without destruction testing the properties of finished components are more economical. Why is Non-Destructive Testing (NDT) Important? What Tests are Available? What criterions are considered in selection of these NDT methods? 10 Marks

6(a) 3D printing is finally crossing that threshold from prototype to production. However, there are still a few challenges that hold AM back such as quality measures and quality control. These are essential for repeatability, consistency, scalability, and overall confidence in the process. Discuss the different Quality control methods adopted in AM with their merits and demerits? 10 Marks

6(b) AM-produced parts are being used by NASA in mission-critical situations and in the aviation and power industries where safety and reliability are of prime importance. These parts are tested using Non-Destructive testing methods. Suggest the best Non-Destructive testing method used in this case. Present arguments to support your selection. 10 **Marks**

SECTION – IV

7(a) Automation in manufacturing is the process of using production management software or robotic tools to operate a factory when making a physical product. Discuss the various levels of Automation in Advanced Manufacturing. 10 Marks

7(b) In manufacturing lead time, the highest time-consuming task is material handling. An automatic system may boost up the material movement and can reduce overall cost of the product. Explain the different types of automatic guided vehicles (AGV's) used in an Industry to transfer the material. 10 Marks

8(a) Industrial automation is the use of data-driven control systems, such as industrial computers, PLC controllers or robots, which reduces the need for human action by operating industrial processes or machinery. Does the convergence of these, Operation Technology (OT) and Information Technology (IT) is beneficial in advanced manufacturing? Justify your arguments. 10 Marks

8(b) Robots have existed for a few decades, and have been evolving with the advances in technology from a hardware and software standpoint. The evolution of these has produced robots that are superior to preceding generations due to their traits of improved perception, adaptability, mobility, and systems integration. Explain the functioning of advanced robots in Industry 4.0 Technologies. 10 Marks

SECTION – V

9(a) Electrochemical process is most commonly used method for mass production, and is able to cut extremely hard materials which are difficult to machine using conventional methods. Its use is limited to electrically conductive materials. Explain how this process works. 10 Marks

9(b) Electrical discharge machining (EDM) is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to machine by conventional machining processes. Discuss the process parameters required in an EDM process? Suggest, suitable process parameters that need to be considered for this case and justify. 10 Marks

10 (a) In an aerospace application, manufacturing the critical components of cryogenic engine is uphill task in conventional machining method. However, industries found the way by using Electron Beam Machining process. With a neat diagram explain the working of Electron Beam Machining.
10 Marks

10(b) An electric discharge machining operation is being performed on two work materials: tungsten and zinc. Determine the amount of metal removed in the operation after one hour at a discharge amperage = 20 amps for each of these metals. The melting temperature of tungsten and zinc are 6170°F and 420°F, respectively. 10 Marks

V Semester Diploma Examinations, Feb/March 2023

Advanced Manufacturing Technologies

Sub Code: 20ME53IT **MAX MARKS:100**

SCHEME OF VALUATION

SECTION-I

1(a).	Justification for the selection of better materials	5 Marks
	Applications of each materials	5 Marks.
1(b).	Identification of the process	1 Mark
	Laser beam machining-Figure.	5 Marks
	Working principle & process description	4 Marks
2(a).	Significance of super alloys for turbine blades.	3 Marks
	Importance of Each alloys in different applications	7 Marks
2(b).	Electron beam machining- Figure	5 Marks
	Working of EBM Process.	5 Marks

SECTION-II

3(a).	Listing the different classes of materials used in AM.	5 Marks
	Properties and Applications of materials (Any five)	5 Marks
3(b).	Justification for the objective	3 Marks
	Illustration of the sintering process	7 Marks
4(a).	Differences between SLS & 3D Printing	8 Marks
	Argument to support the selection	2 Marks
4(b).	Benefits of AM (Any 5)	5 Marks
	Listing of the additive technologies.	3 Marks
	Applications of each AM technology	2 Marks

SECTION-III

5(a).	Different Inspection Methods	5 Marks
	Merits and Demerits of each inspection Method	5 Marks
5(b).	Importance of NDT	2 Marks
	Listing the different NDTs	5 Marks
	Criteria for selection	3 Marks

6(a). Listing of different quality control methods	5 Marks
Merits and Demerits of each QC method	5 Marks
6(b). Selection of NDT for assigned situation	5 Marks
Argument to support for the selection	5 Marks

SECTION-IV

7(a). Levels of automation-Figure	5 Marks
Explanation of each level	5 Marks
7(b). Listing of different types AGV's	5 Marks
Explanation of each AGVs	5 Marks
8(a). Explanation of OT & IT	4Marks
Convergence of OT & IT	3 Marks
Benefits from Convergence	3 Marks
8(b). Significance of Industry 4.0	5 Marks
Function of different Robots	5 Marks

SECTION-V

9(a). Electro Chemical Process-Figure	5 Marks
Explanation of the process	5 Marks
9(b). Necessity of EDM	2 marks
Listing of different Process parameter	4 Marks
Justification of suitable parameters	4 Marks
10(a) Electron Beam Machining - Figure	5 Marks
Explanation of the Process	5 Marks
10(b) Formula to Calculate MRR	2 Marks
MRR of Tungsten	4 Marks
MRR of Zinc	4 Marks

MODEL ANSWERS

MAKEUP EXAMINATION SEPTEMBER 2023

V SEMESTER MECHANICAL ENGINEERING

Sub: Advanced Manufacturing Technologies - 20ME53IT Max Marks: 100

Note: The Model answers are only for reference, alternate answers can also be considered.

SECTION -1

1(a) Back in the days, aircraft were constructed using wood and fabrics. But aircraft that are made up of wood and fabric were subject to rapid deterioration and high maintenance. Thus, the search for better materials began. Now, aluminium, steel, titanium and composite materials are preferred in the construction of aerospace structures. Why such materials are used in Aerospace structures? Where else do you find the application of these materials?

The materials used in the manufacturing of aircraft have changed significantly from the construction of the first aircraft. With its objective of flying using air support while, resisting gravitational forces, the materials used for the construction of aircraft must have a small weight, high specific strength, heat resistant, fatigue load resistant, crack resistant and corrosion resistant. Back in the days, aircraft were constructed using wood and fabrics. But aircraft that are made up of wood and fabric were subject to rapid deterioration and high maintenance. Thus, the search for better materials began. Now, aluminum, steel, titanium and composite materials are preferred in the construction of aerospace structures.

Nowdays, the following materials are used in manufacturing of aircraft.

Aluminum: Aluminum is used due to its low density (2.7 g/cm3), high strength properties, good thermal and electric conductivity, technological effectiveness and high corrosion resistance. But the aluminum loses its strength at high temperatures, it is not used to the skin surface of an aircraft.

Applications:

- In aerospace applications.
- Automobiles
- Making windows.

- Marine applications
- Sports equipments
- **Steel**: Steel is an alloy of iron and carbon and can be three times stronger and heavier than aluminum. It is usually used in a landing gear due to its strength and hardness as well as in the skin surface of aircraft due to its high heat resistance.

Applications:

- For architecture applications.
- Oil and gas industries.
- For Cutting tools
- Water tanks.
- Medical Applications

Titanium:

Titanium and its alloys are commonly used in the construction of aircraft due to its high strength properties. High-temperature resistance and high corrosion resistance compared to steel and aluminum. Despite being expensive, titanium is used in aircraft construction due to its excellent material properties. It is used in the panel and swivels wing assemblies, hydraulic systems, and other parts.

Applications:

- Aircraft applications
- Military applications.
- Aerospace applications
- Jewelary application

Composite materials:

Composite materials are used in the production of aircraft due to their high tensile strength. High compression resistance, low weight and high resistance to corrosion. Composite materials are composed of a base material and resin that strengthens the material as a whole. Composite materials improve fuel efficiency and performance of the aircraft as well as lessen direct operating costs of aircraft. The most common composite material used is fiber glass that is made up of glass fibers as the base material and a resin matrix.

Applications:

- Military aircraft.
- Automotive.
- Electronics industries.
- Space systems.
- Medical equipments
- Construction.
- Corrosive Environments.
- Aerospace.

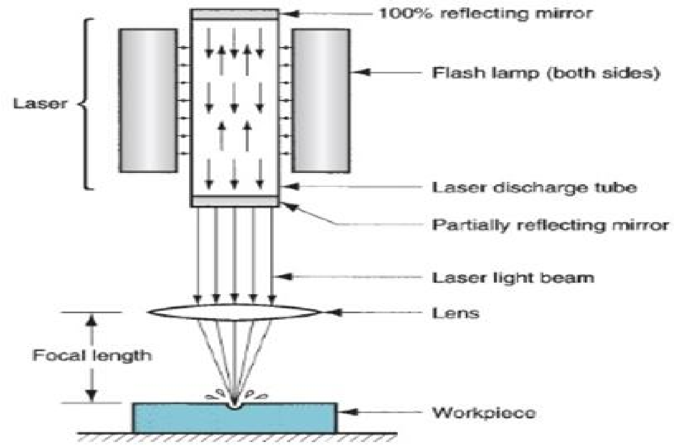
1(b)Explain the most widely used non-traditional machining method which performs cutting, welding, drilling, surface texturing, wire stripping in manufacturing and can create fine features that are difficult or impossible to make using traditional machining equipment.

Answer: Laser machining method.

Laser Beam Machining Working Principle

LASER stands for **L**ight **A**mplification of **S**timulated **E**mission by **R**adiation. Laser is an electromagnetic radiation which produces monochromatic light in the form of beam. The laser works on the principle of conversion of electrical energy into light energy then in the form of thermal energy.

In this process, the LASER beam is called monochromatic light. It 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 with flat reflecting ends which are placed in a flash lamp coil of about 1000W.



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

2(a) Super alloys are the materials best-suited for practical high temperature performance, there are materials that can survive hotter temperatures. Specifically, they are usually used for turbine blades. Why are Super alloys important and also, Special?

In the global energy production system scenario, gas turbine will play an important role. Substantial effort is to be given for increasing the efficiency and flexibility of gas turbines. The intense heat condition is basically faced by turbine blade; thus, it is one of the most important components of the industrial gas turbine. Materials technology is supporting these efforts by improving knowledge of materials and thermal barrier coating properties and influence of long service times. It is observed that in the gas turbine, the maximum possible energy is extracted by turbine blade from high temperature and high-pressure gas produced from the combustor. As it is exposed to intense heat conditions, blades fail due to fatigue, creep, erosion, corrosion, overheating, high vibration and resonance. This leads to, the need to develop or to select appropriate materials which can sustain in this severe condition. Hence, it can be concluded that the materials which have high strength, high melting point, good corrosion resistance and high fatigue limit are required for turbine blade. The most important requirement for the gas turbine blade is to have high creep resistance at a higher temperature. To cope with this, exotic materials like superalloys of nickel-based alloy, cobalt-based alloy or iron-based alloys are well suited. Examples of the use of superalloys in different applications are listed below:

1. **Medical Devices:** Nickel superalloys are used in the medical industry for surgical instruments, implants, and hospital equipment. These superalloys are being used as they are hygienic, corrosion-resistant, and have and can produce an excellent surface finish. By using hygienic and corrosion-resistant superalloys, safety can be improved.

2. Automotive Industry: Superalloys are used for turbochargers, in which their high-temperature performance proves advantageous. The benefit of using superalloys in this application is that the materials can endure the harsh conditions experienced in the turbocharger. The benefit of using superalloys in this application is that the materials can endure the harsh conditions experienced in the turbocharger.

3. Power Generation: The power generation or energy industry produces energy through nuclear power plants, fossil fuel power plants, wind turbines, solar panels, and hydroelectric dams. Superalloys are used in heat exchangers, gas boilers, steam turbines, gas turbines, and furnaces within the energy industry. The benefit of using superalloys is that they can withstand the hot corrosive environment that these components operate in.

4. Oil and Gas Industry: The oil and gas industry extracts oil and natural gas out of underground reserves either on land or at sea to produce oils and plastics and to be used as energy. Superalloys are used to manufacture casings and mandrels for drilling. Superalloys are required for this application due to the high pressure and severe corrosion experienced deep below the water's surface. The benefit of using superalloys for this application is that they can resist the corrosion usually caused by the local environment.

5. Chemical Processing: Superalloys are used for components in the processing machines of chemicals, including valves and instruments. Superalloys such as Hastelloy and Monel are being used in this industry for their corrosion-resistant properties. Using these materials reduces the corrosion experienced by the instruments used.

6. Military and Defense Industry: The military and defense industry operates hardware such as tanks, jets, and ships to provide national security. Superalloys are desirable for their temperature resistance and high strength, mainly in gas turbine engines used by tanks, jets, and ships. In addition, superalloys offer light weight and environmental resistance - both sought - after properties in this field of higher-performing equipment.

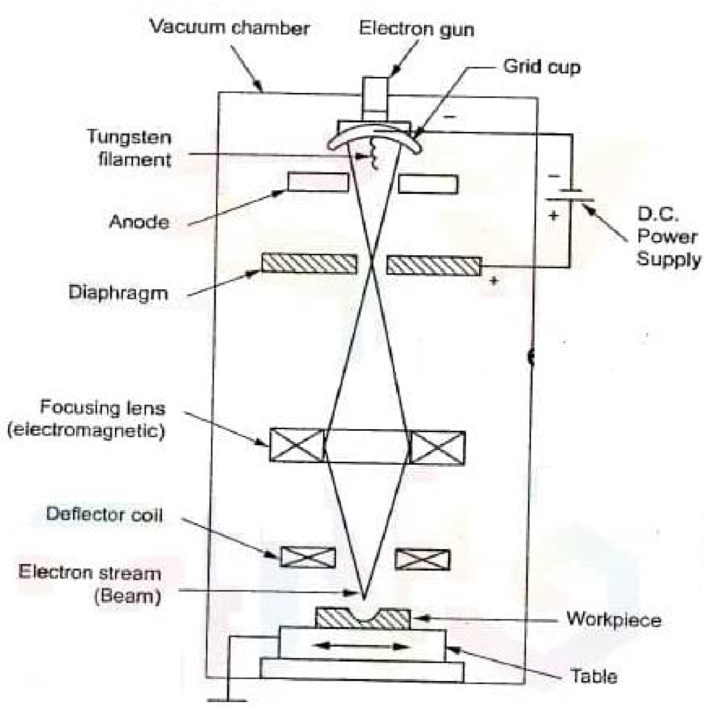
7. Aerospace Industry: The aerospace industry covers all goods manufactured to be used in airborne vehicles including commercial aircraft, drones, and satellites. Superalloys are used in the aerospace industry to build jet engines in which their high mechanical strength in elevated temperatures can be exploited. The use of high-strength-to-weight-ratio alloys improves the thrust-to-weight ratio performance of modern jet engines. Superalloys are used over composites in turbine applications due to the high temperatures the parts are exposed to.

2(b) In an aerospace application manufacturing of critical components of cryogenic engine is uphill task in conventional machining method. However, industries found the way by using Electron Beam Machining process. Illustrate the working of Electron Beam Machining.

.**Electron Beam Machining:** Electron Beam machining or EBM is a non-conventional machining process, Where the electrons are focused and concentrated on a small spot on the metal, the kinetic energy of the electrons is converted into heat energy which is sufficient to melt the workpiece, Known as Electron beam machining or EBM.

Working principle of EBM: EBM machining process works on the principle of the high-velocity beam of the electron is focused on the workpiece, the electrons strike on the workpiece and their kinetic energy is converted into heat energy. This results in the removal of material from the workpiece by vaporization and melting. EBM is particularly suitable for manufacturing complex and precise components in a vacuum environment. EBM is performed in a vacuum chamber with a vacuum level of approximately 10^{-5} to 10^{-6} mm of mercury. This vacuum environment serves several purposes:

1. To avoid collision of accelerated electrons with air molecules.
2. To protect the cathode from chemical contamination and heat losses.
3. To prevent the possibility of an arc discharge between the electrons.



Working of EBM Process: The EBM process involves several components, including an electron gun, diaphragm, focusing lens, deflector coil, tungsten filament, vacuum chamber, power source, and a movable work table.

Working Steps: 1. When a high voltage DC source is applied to the electron gun, the tungsten filament wire heats up, reaching temperatures up to 2500°C.

2. As a result of this high temperature, electrons are emitted from the tungsten filament. These electrons are directed by a grid cup to travel downwards and are attracted by the anode.

3. The electrons passing through the anode are accelerated to achieve high velocity, reaching up to half the velocity of light (approximately 1.6 x 10^8 m/s) by applying a voltage of 50 to 200 KV at the anode.

4. The high-velocity electron beam maintains its velocity as it travels through the vacuum.

5. After leaving the anode, the electron beam passes through a tungsten diaphragm and then through an electromagnetic focusing lens.

6. The focusing lens is used to concentrate the electron beam onto the desired spot of the workpiece.

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

8. Due to the high power density (approximately 6500 billion W/mm^2), it only takes a few microseconds to melt and vaporize the material.

9. The process is carried out in repeated pulses of short duration, with pulse frequencies ranging from 1 to 16000 Hz and durations ranging from 4 to 65000 microseconds.

10. By alternately focusing and turning off the electron beam, the cutting process can be continued as long as necessary.

11. The machine is equipped with a suitable viewing device that allows the operator to observe the progress of machining.

SECTION II

3(a). Additive manufacturing (AM), also known as rapid prototyping or 3D printing, generally refers to techniques that produce three dimensional parts by adding material gradually in a layer by layer fashion. In this sense, AM differs fundamentally from farming and subtractive techniques. There are different classes of materials used in additive manufacturing. Differentiate these different materials used in Additive manufacturing with respect to their Properties and Applications?

The following materials are used in additive manufacturing.

1. Ceramics
2. Plastics -i.Acrylanitride Butadiene Styrene (ABS),
   ii. Polylactide (PLA),
   iii.Polycarborate (PC)
   iv. Polyvinyl Chloride (PVC)
3. Polymers
4. Stainless steel
5. Titanium alloys
6. Aluminium based alloys
7. Nickle based alloys
8. Polymer based Composites
9. Metal based Composites

1. Ceramics:

Properties:

- These have superior unique set of physical and Mechanical Properties.
- High temperature resistance
- Superior Hardness
- High Stiffness
- Low coefficient of Friction
- Excellent Chemical Inertness.

Applications:

- These are used for cutting Tools and Engine Components
- Used for coating
- Used as thermal barriers
- Used for flooring and as a decorative materials
- Used in glass and optical fibres
- Used in bricks, lab equipments, membranes etc.
- Used in Communication equipments like TV and Radio components, Microphones.

2. Plastics:

✓ Acrylanitride Butadiene Styrene (ABS)
✓ Polylactide (PLA)
✓ Polycarborate (PC)
✓ Polyvinyl Chloride (PVC)

Properties: • They are light weight and chemically stable. • Low thermal conductivity. • They donot rust. • Poor dimensional stability.

Applications: • In electrical applications. • Manufacturing industries.• Health care application. •Textile applications. • Medical equipments. • Agricultural applications.

Polyethylene terephthalate (PET): Polyethylene terephthalate or PET is commonly seen in disposable plastic bottles. Due to higher chemical resistance and rigid compositions, PET is used in manufacturing plastic containers used in packaging food.

Properties are, • Good durability. • Recyclable material. • Good strength • temperature resistance.

Applications: •Food packaging industry. • Fruit container. • Synthetic clocks • Electronic applications.

3. Polymers:

Properties:

- Low density
- Low co-efficient of friction
- Good corrosion Resistance
- Good mouldability

- Excellent surface finish can be obtained
- Can be produced with close dimensional tolerances
- Economical
- Poor tensile Strength
- Low mechanical properties
- Poor temperature resistance
- Can be produced in different colours

Applications:

- It is used for floor coverings, garbage disposable bags and packaging.
- Automobiles parts, wind shields for fighter planes, pipes, tanks, packing materials, insulation, wood substitutes, adhesives, matrix for composites and elastomers.

4. Stainless Steel:

Properties:

- Corrosion Resistance
- High Tensile Strength
- Very durable
- Temperature resistance
- Easy formability and fabrication
- Low maintenance
- Attractive appearance

Applications:

- Utensils, Knives are made using less ductile grades of stainless steel.
- More ductile grades are used to make grills, cookers, saucers and sinks.
- Stainless steel can also be used to finish freezers, dishwaters, and refrigerators.

5. Titanium alloys:

Properties:

- High specific Strength
- High Temperature Resistance

- Good mechanical Properties
- Excellent corrosion resistance

Applications:

Titanium alloys are used in airframe structures and jet engine components because of their moderate weight and high structural properties.

It is used for aircraft, space craft and missile.

3(b). The fighter jet Aircraft ventilation distributor was originally made by using composite of seven separate parts. The objective was to minimize the final delivery time by dramatically reducing manufacturing time through 3D printing, using sintering technology, also ensuring lower manufacturing costs. Illustrate how this Process can be achieved?

The fighter jet Aircraft ventilation distributor was originally made by using composite of seven separate parts. The objective was to minimize the final delivery time by dramatically reducing manufacturing time through 3D printing, using sintering technology, also ensuring lower manufacturing costs.

Sintering Technique - Sintering is a process used in manufacturing to compact solid materials. The resulting product is a harder, stronger, more durable mass due to the high heat and pressure applied forcing the atoms of the material into tighter bonds with each other. Most manufacturing processes use a sintering furnace that can provide the necessary temperatures quickly and accurately. At its most effective, sintering materials reduces porousness while enhancing strength. Powder metallurgy is the specific study of the sintering process using powdered metals. **Sintering Process** – Raw materials are used to create the metal powders through an atomization process. In the sintered powder metal process, the metal particles are fused together through a thermal process. Powder metallurgy sintering process has the following steps.

- A mold is filled with a powdered metal material at room temperature or in a heated setting.

The shape of the sintered material in the mold is called the green body. Pressure is applied until the metal powder is compacted and shaped as desired.

- Amount of pressure depends on metal material and required density of final product. The formed metal is then removed from the mold and place in a sintering furnace.
- This sintering furnace will be set to a certain temperature required for material and desired density with a continuous thermal process and controlled atmospheric environment.
- Amount of time required for the material in the furnace depends on the material application.

Shrinkage may occur with the material during the sintering process. The metal is removed from the furnace and allowed to cool.

• In the sintering process particles can be combined to form larger solid materials with desired shapes. Sintering process allows for better control over material formation and enhanced mechanical properties.

The following mechanical properties will be enhanced using the sintering process.

- Thermal conductivity
- Electrical conductivity
- Strength of material
- Integrity of material
- Translucence nature of material

APPLICATIONS-

- Aerospace
- Dental equipment
- Battery manufacturing
- Automotive
- Research laboratories

4.a) Selective laser sintering (SLS) and 3D printing (3DP) are two powerful and versatile AM techniques which are applicable to powder-based material systems. Differentiate and suggest the best technique among the two. Present arguments to support your selection.

Selective Laser Sintering-

SLS (Selective laser sintering) is a powder bed fusion (PBF) 3D printing technology that make use of a relatively high-powered laser to sinter plastic particles into a final part.

3D Printing -

The manufacturing of solid objects by the deposition of layers of material (such as plastic) in accordance with specifications that are stored and displayed in electronic form as a digital model.

Different b/w SLS and 3D Printing-

- Selective laser sintering (SLS) 3D printing technology is different from traditional 3D printing because it uses lasers to heat powdered nylon material to create 3D models .
- Conversely , a normal 3D printing process utilizes the hot end to heat and extrude plastic filaments on a heated bed to build 3D models .

- Also, SLS 3D printing produces higher resolution and dimensionally accurate printed parts than regular 3D printing .

- Nylon material properties make SLS parts come out with high tensile strength and stiffness. More importantly, selective laser sintering does not need support structures as the unsintered powder bed surrounds and holds the parts during print building.
- The traditional manufacturing methods are known for the low volume production of plastic parts.
- So normal 3D printing process significantly improved the production of multiple components and heralded an increase in production volumes.
- However,the SLS machines saw the production of complex geometries . For example , SLS allows you to produce interlocking parts and can move . In short,an SLS machine enables you to print a highly complex desired three - dimensional shape.

4(b) Uniform wares explores the advantages of Additive Manufacturing (AM) technology, pushing the boundaries of design in an industry traditionally centred around heritage. What benefits exist in additive Manufacturing? Differentiate the technologies available in Additive Manufacturing and list their applications?

Following are the benefits of Additive Manufacturing:

1. It reduces the wastage to a great extent.
2. It reduces the amount of labour and efforts required to make a product.
3. Chances of errors are less.
4. The design can be directly made by commanding the system.
5. Complex structures can be easily made.
6. Cost in the long run reduces a lot.
7. Innovations are rapidly taking place.
8. The structure of the part remains same throughout.
9. Maintenance required is less.
10. Digital design integration.
11. Customization to individual
12. Easy to learn and use.

Additive manufacturing is different from traditional manufacturing as it allows a part to be built layer by layer, whereas traditional manufacturing (Metal cutting, casting, forging or Powder Metallurgy process) often requires a part to be made by joining separate components or by machining away unwanted material to produce the part.

Following are the different additive manufacturing technologies.

1. Liquid based additive manufacturing:

a. Melting: Fused Deposition Modeling (FDM)

b. Polymerization: i. Stereo Lithography (SL)

ii. Polyjet

2. Solid Base Additive Manufacturing:

Laminated Object Manufacturing.

3. Powder Base Additive Manufacturing:

a. Melting: i. Selective Laser Sintering (SLS)

ii.Electron Beam Melting (EBM)

iii. Laser Engineering Net Shaping(LENS)

b. Binding Additive Manufacturing

i.3D printing

ii.Prometal

Applications:

1. Liquid based additive manufacturing:

a: Melting: Fused Deposition Melting (FDM)

- Toys and small thermoplastic parts
- High resistance rapid prototypes
- Packaging
- Automotive parts
- Consumer goods
- Product Development tools
- Medical Devices

b. Polymerization- Stereo Lithography

- Investment casting patterns
- Rapid tooling Jigs and fixtures
- Moulds and Casting patterns

ii. Polyget

- Prototypes for investment casting
- Sophisticated prototype
- Multi material prototype.

2.Solid base additive manufacturing

a. Laminated Object Manufacturing (LOM)

- Investment Casting
- Injection tools

3.Powder base additive manufacturing

Melting: i. Selective Laser Sintering (SLS)

- Long lasting durable manufacturing aids, jigs and fixtures, and tooling.
- Mass customized consumer products.

ii. Electron Beam Melting (EBM)

- Medical and Areospace industries.
- To produce tubular implants and other medical implants.
- Orthopaedic devices.

iii) Laser Engineered Net Shaping (LENS)

- Mould and Die inserts.
- Fabricate titanium components for biological implants.
- Produce functionally gradient structures.

SECTION-III

5(a) Like other conventional manufacturing, Additive Manufacturing (AM) components are known to have various internal defects, such as balling, porosity, internal cracks and thermal/internal stress, which can significantly affect the quality, mechanical properties and safety of final parts. Therefore, inspection methods are important for reducing manufactured defects and improving the surface quality and mechanical properties of AM components. Discuss different inspection methods adopted in AM with their merits and demerits?

Main Inspection Methods are,

1.Ultrasonic testing

Advantages/Merits of Ultrasonic Testing.

- Portability
- Consistent
- Detects surface and subsurface defects
- Only limited access needed
- Instant results

Disadvantages/Demerits of Ultrasonic Testing.

- Training is more extensive than other methods
- More expensive than other methods
- Difficult to use on thin materials
- Part Geometry can cause complications
- Needs relatively smooth surface to couple transducer

- Must know velocity of part and have a reference to calibrate against for the equipment set-up

2. Radiographic Testing

Advantages:

- It has a very few material limitations.
- Detection of internal defects for thick materials (e.g. pipelines).
- Minimal or no part preparation is required.
- One of the major advantages of RT is its documentation capability.
- RT provides images of the object under inspection.
- The probability of misinterpretation of results is minimized since each image can be reviewed by multiple operators.

Disadvantages:

- The impact of radiation to health and environment can be considered as one of major disadvantages of radiographic testing, since a few seconds of being exposed to radiation can result in sever injuries.
- High degree of skill and experience is required for exposure and interpretation.
- The high voltage needed to create X-rays is dangerous for human health also.
- It is quite expensive method.
- Ineffective for planar defects and for surface defects.

3. Penetrant testing:

Advantages:

- The method has high sensitivity to small surface discontinuities.
- The method has few material limitations, i.e. metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected.
- Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.
- Parts with complex geometric shapes are routinely inspected.
- Aerosol spray cans make penetrant materials very portable.
- Penetrant materials and associated equipment are relatively inexpensive.

Disadvantages:

- Only surface breaking defects can be detected.
- Only materials with a relatively nonporous surface can be inspected.
- Precleaning is critical since contaminants can mask defects.
- The inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Multiple process operations must be performed and controlled.
- Post cleaning of acceptable parts or materials is required.
- Chemical handling and proper disposal is required.

4.Magnetic Particle Testing:

Advantages:

- Find flaws on the surface and near surfaces
- Fast examination method with an immediate result
- An easy method as compared to other NDT methods
- Portable and low-cost equipment.
- Defects are visible directly on the surface.
- Relatively safe method.
- Hot testing can be performed using dry particles.
- The shape and size of the cracks are indicated.
- Less training requirements.

Disadvantages:

- MPI is limited only for ferromagnetic materials like steels, cast irons, etc.
- Non-ferrous materials, cannot be inspected.
- The inspection is limited to small sections only.
- The examination of large parts may require the use of special equipment.
- Equipment must be calibrated, with no permanent record of the result.
- Post cleaning and demagnetization are normally required.
- Magnetic flux and indications must be aligned for proper results.
- Access may be a problem for the magnetizing equipment.
- Testing in two perpendicular directions required.

5. Visual testing:

Advantages:

- Inexpensive
- Little to no equipment needed
- Easy to train
- Portable
- Minimum Part Preparation

Disadvantages:

- Surface indications only
- Generally only able to detect large flaws
- Possible misinterpretation of flaws

5(.b) In most of the conventional methods, the tested materials may not be useful after testing, However without destruction testing the properties of finished components are economical. Why is Non-Destructive Testing (NDT) Important? What Tests are Available? What criterions are considered in selection of these NDT methods?

Non Destructive Testing (NDT) is a process of analysis techniques that allow inspectors to collect data about materials such as characteristic differences, welding defects, and discontinuities without damaging their basic properties. Non-Destructive Testing Needed Because Before non-destructive testing was conceived, destructive testing was used to ensure batches of components were manufactured to safety standards. The logic was that destructive tests should provide an indication about whether a sample of parts was fit to endure the stresses placed on it during operation. However, despite destructive testing taking place, several incidents occurred where components were destroyed during operation and led to loss of property and human life. As a consequence, non-destructive testing methods were developed to eliminate such failures without damaging the product in use.

Benefits of Non-Destructive Testing:

The benefits of non-destructive testing are manifold. No damage to the part being tested is sustained and therefore it remains useful. Non-destructive testing can be carried out at any time in the product's lifecycle: raw materials, semi finished or finished components can be tested with equal measure of effectiveness. Non-destructive testing also offers very comprehensive testing and can be used to locate both surface and internal flaws. Finally, non-destructive testing allows manufacturers and engineers to ensure worksites and materials are compliant with regulation designed to ensure their safety. Some Types of Tests are,

• Radiographic Testing:

This technique involves exposing a test object to penetrating radiation. Further, the radiation passes through the object being inspected and a recording medium is placed against the opposite side of that object. For thinner or less dense materials x-radiation and for thicker or denser materials, gamma radiation is generally used.

Ultrasonic Testing:

The method uses the same principle as that of naval SONAR and fish finders. Ultra-high frequency sound is introduced to the object. If the sound hits the very object with a different acoustic impedance, then some of the sounds will reflect back to the sending unit. And it can be presented on a visual display. The most common sound frequencies this technique uses are between 1.0 and 10.0 MHz. The compression (longitudinal) wave and the shear (transverse) wave are common ones used in industrial inspections.

Visual Testing:

The method consists of visual observation of the test object surface for evaluating the surface discontinuities. These inspections may comprise line-of-sight vision, direct viewing, enhanced using optical instruments, and computer-assisted viewing systems. In most industries, Visual Testing techniques are commonly used for inspection.

Magnetic Particle Testing:

The method uses one or more magnetic fields to locate surface and near-surface discontinuities in ferromagnetic materials. The MT techniques consist of Heads, Prods, Coils, Yokes, and Central Conductor.

Electromagnetic Testing:

Electromagnetic Testing consists of Remote Field Testing, Eddy Current Testing, and Alternating Current Field Measurement (ACFM). The electromagnetic test is used widely and is considered a stand-alone test method rather than an electromagnetic testing technique. All the techniques induct a magnetic field or an electric current into a conductive part. As a result, the effects are recorded and evaluated.

Penetrant Testing:

This examination consists of applying a dye penetrant on the examined surface. After penetration time, the developer is applied. Due to the absorption properties of the developer is highlight the discontinuities open to the surface.

6.a) 3D printing is finally crossing that threshold from prototype to production. However, there are still a few challenges that hold AM back such as quality measures and quality control. These are essential for repeatability, consistency, scalability, and overall confidence in the process. Discuss different Quality control methods adopted in AM with their merits and demerits?

Additive manufacturing is revolutionary in many ways. Few other fabrication methods have the design freedom and digital workflows that this collection of technologies offers. As a result, you can print complex and lightweight parts with optimal geometric features in trailblazing materials that outperform traditionally manufactured parts.

From a cost-effective perspective, the reduction of waste compared to subtractive processes can assure manufacturers significant savings in raw materials, not to mention the savings in time and labor.

And now, after many years of research, development, and innovation, 3D printing is finally crossing that threshold from prototype to production.

However, there are still a few challenges that hold AM back from complete adoption in the manufacturing industry. The biggest: standardized quality measures and quality control. These are essential for repeatability, consistency, scalability, and overall confidence in the process.

Traditional Tools Adapted for AM:

A widespread set of measurement options are available for quality inspections, from the traditional manual tools to digital industrial equipment. Starting from the basics, manual instruments like calipers and gauge kits, in comparison to other options, are affordable, straightforward, and widely accepted.

However, each of these tools deals with a specific geometrical feature (i.e., external length, diameter, corner angles). Simply put, not the most versatile options.

Coordinate Measuring Machine (CMM): The necessity to reach higher standards has lead industries to adopt CMMs (Coordinate Measurement Machines). These machines can replicate digital point clouds throughout their extremely precise contact probes with exact measurements of very intricate geometries like those of airfoils. Moreover, this enables direct interaction within CAD environments, which opens new possibilities for data analysis.

Digital tools can streamline tolerance verification processes by comparing the deviations of manufactured parts by aligning them with their respective nominal CAD design. Meanwhile, all that inspection data can be directly stored and processed in a centralized system. All in all, CMMs are marvelous; still, they have limitations too. Compared to other methods, CMMs inspection cycles are slow, they have low portability, and since they are contact based, they heavily rely on fixtures. Now, this allows us to appreciate light-based 3D scanners as valuable alternatives to CMMs.

Advantages:

- The hardware lasts for a long time.
- The software continuously gets better.
- Newer models are now resistant in less controlled environments.

Disadvantages:

- There is no standardization yet.
- CMM systems can be complicated to operate for some.

Profile Projector: A Profile Projector also called an Optical Comparator or a Shadowgraph Projector is a specialized measuring system that is broadly classified under the category Industrial Metrology Systems.

Advantages:

- Profile Projector can reveal imperfections such as burrs, scratches, indentations or undesirable chamfers which both micrometers or calipers can't reveal.
- They're able to measure in 2-D space. Unlike micrometers and Calipers, which measure one dimension at a time, where comparators measure length and width simultaneously.
- Optical comparators save time. Ease-of-use factors and ergonomic designs reduce the inspection time, retraining costs and operator fatigue, all while increasing throughput.
- Custom hard gages are subject to wear and need frequent recertification, which takes them out of service and adds an additional cost.
- Dimensioning techniques designed to give more leeway to parts in relation to their true functional purpose, such as profile tolerance and true-position tolerance with bonuses, reduce the reject rate of good parts that might have passed had their tolerances been assigned differently.

Disadvantage:

The limitation of using profile projector as a fixed device forms a disadvantage of it, while instruments such micrometer or calipers can be used to reach for measuring far and joint accessible components and it is large and bulky and usually require a cart to transport from place to place, also the device requires power for operation.

6(.b) AM-produced parts are being used by NASA in mission-critical situations and in the aviation and power industries where safety and reliability are of prime importance. These parts are tested using Non-Destructive testing methods. Suggest the best Non-Destructive testing method used in this case. Present arguments to support your selection.

The balance in the design of aerospace components comes with aiming to lighten the component mass while withstanding the high structural loads on the materials. This high load-to-material strength ratio makes the components susceptible to thermal and pressure cycle fatigue, as well as vibration, due to the wide ranges of operating conditions. Additionally, corrosion from humidity in the ground air that condenses on the plane attacks the material as well. Over 80% of inspections are performed visually by trained inspectors. Inspectors use NDT for much of the remaining 20% they cannot access visually. Initial manufacturing process and repair also use NDT.

Two of the most significant NDT methods used in aerospace are Magnetic Particle Inspection (MT) and Penetrant testing (PT).

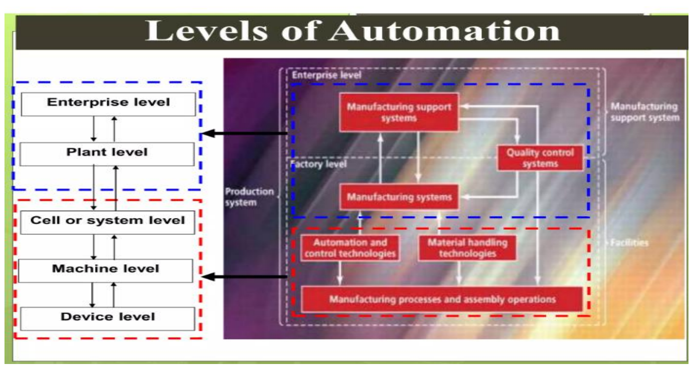
Penetrant Testing: Penetrant inspection, or penetrant testing (PT), is another method of NDT used in the aerospace industry. One of the oldest approaches to detect surface flaws like cracks, porosity, gouges, and seams, inspectors add the dye to target areas on a surface. By capillary action, the dye finds its way into openings, coating the flawed areas. After the excess dye is removed, an additive called the “developer” is introduced, and it draws the remaining dye out. After a final cleaning step, the dye that penetrated through the developer exposes the critical cracks and porosity in the part when viewed under a black light. While PT can be used in nearly any NDT application, compatibility of test materials must be considered for the specific industry. With the inherent severity of chemical incompatibility in the aerospace industry, manufacturers developed classes of penetrants best suited for that industry. The most common penetrant systems in aerospace are Type I (fluorescent), Methods A, B, and D (water washable, post emulsified – lipophilic, and post emulsified – hydrophilic, respectively).

Benefits of Penetrant testing:

- The method has high sensitivity to small surface discontinuities.
- The method has few material limitations, i.e. metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected.
- Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.• Parts with complex geometric shapes are routinely inspected.
- Aerosol spray cans make penetrant materials very portable.
- Penetrant materials and associated equipment are relatively inexpensive.

SECTION- IV

7.a) Automation in manufacturing is the process of using production management software or robotic tools to operate a factory when making a physical product. Discuss the various levels of Automation in Advanced Manufacturing.



1.Device level - This is the lowest level in our automation hierarchy. It includes the actuators, sensors, and other hardware components that comprise the machine level. The devices are combined into the individual control loops of the machine; for ex· ample, the feedback control loop for one axis of a CNC machine or one joint of an industrial robot.

2.**Machine level** – Hardware at the device level is assembled into individual machines.

Examples include CNC machine tools and similar production equipment, industrial robots, powered conveyors, and automated guided vehicles. Control functions at this level include performing the sequence of steps in the program of instructions in the correct order and making sure that each step is properly executed.

3.Cell or system level- This is the manufacturing cell or system level, which operates under instructions from the plant level. A manufacturing cell or system is a group of machines or workstations connected and supported by a material handling system, computer. and other equipment appropriate to the manufacturing process. Production lines are included in this level. Functions include part dispatching and machine loading. Coordination among machines and material handling system, and collecting and evaluating inspection data.

4. Plant level – This is the factory or production systems level. It receives instructions from (he corporate information system and translates them into operational plans for production. Likely functions include: order processing, process planning, inventory control, purchasing, material requirements planning, shop floor control, and quality control.

5. Enterprise level- This is the highest level, consisting of the corporate information system. It is concerned with all of the functions necessary to manage the company: marketing and sales, accounting, design, research, aggregate planning, and master production scheduling.

7(b).In manufacturing lead time, highest time consuming task is material handling. An automatic system may boost up the material movement and can reduce overall cost of the product. Explain the different types of automated guided vehicles (AGVs) used in industry to transfer the material.

There are several types of automated guided vehicles. Many AGVs are similar to other human-operated vehicles but are designed to operate without direct human intervention or guidance.

i. **Automated Guided Carts:**

An automatic guided cart (AGC) is the most basic type of AGV with minimal features. Navigation systems can range from systems as simple as magnetic tape to complex, sensor-based navigation systems that use AI to navigate their environment. They can transport a variety of materials, from small parts to loaded pallets, and are often used in sorting, storage, and cross-docking applications.

ii. **Forklift AGVs:**

Fork vehicles, or forklift automatic guided vehicles, are another commonly used type of AGV. They're designed to perform the same functions a human-operated forklift performs (transporting pallets), but without the need for a human operator.

iii. Towing AGVs:

Towing vehicles, or tugger automatic guided vehicles, pull one or more non-powered, load-carrying vehicles behind them in a train-like formation. Sometimes called driverless trains, powered towing vehicles travel on wheels. Tugger automatic guided vehicles are often used for transporting heavy loads over longer distances. They may have several drop-off and pick-up stops along a defined path through a warehouse or factory.

iv. Unit Load Handlers:

Unit load handlers carry discrete loads such as individual objects, or a single unit such as a pallet or tote that contains multiple items.

v. Heavy Burden Carriers:

For the heaviest loads, heavy burden carriers are a type of AGV used in applications such as large assembly, casting and coil and plate transport. Some heavy burden carriers have self-loadingcapabilities and may have standard, pivot or omni-directional steering.

vi. Autonomous Mobile Robots:

Autonomous mobile robots (AMRs) are typically more technologically advanced than other types of AGVs. While many AGVs use fixed navigation systems, such as wires or magnetic tape, many AMRs are equipped with intelligent navigation capabilities such as sensors and camera systems that enable them to detect and navigate around obstacles. Thanks to more sophisticated technology, AMRs can dynamically navigate a warehouse or other facility and plan the most efficient paths.

8(a). Industrial automation is the use of data-driven control systems, such as industrial computers, PLC controllers or robots, which reduces the need for human action by operating industrial processes or machinery. Does the convergence of these, Operation Technology (OT) and Information Technology (IT) is beneficial in advanced manufacturing? Justify your arguments.

Information Technology (IT): Information Technology (IT) is the development, management, and application of computer equipment, networks, software, and systems. IT is crucial to modern business operations because it enables people and machines to communicate and exchange information.

Information technology (IT) is the use of computers to create, process, store, retrieve, and exchange all kinds of data and information. IT forms part of information and communications technology (ICT).

Operation Technology (OT): Operational technology (OT) uses hardware and software to manage industrial equipment and systems. OT controls high-tech specialist systems, like those found in the energy, industrial, manufacturing, oil and gas, robotics, telecommunications, waste control, and water control industries.

Convergence of IT & OT: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.

Here are some industries that benefit from the convergence OT and IT:

- **Manufacturing:** IT/OT convergence enables organizations to be more cost-and resource-efficient by using sales and inventory data to drive manufacturing operations, optimizing equipment and power use while minimizing maintenance and unsold inventory.
- **Military and law enforcement:** IT/OT convergence can aid in the coordination and rapid deployment of resources, while providing more insight into the condition and maintenance of critical equipment.
- **Utility and energy companies**: Modern IT enables OT teams to access operational data remotely, helping industries such as oil, gas and electricity to optimize industrial equipment inspections, make damage assessments and handle inventory monitoring and distribution.

8(b). Robots have existed for a few decades, and have been evolving with the advances in technology from a hardware and software standpoint. The evolution of these has produced robots that are superior to proceeding generations due to their traits of improved perception, adoptability, mobility and systems integration. Explain the functioning of advanced robots in industry 4.0 technologies.

The manufacturing industry has come a long way from the days of manual labor to the era of automation. With the emergence of Industry 4.0, the focus has shifted toward achieving an interconnected, digitized, automated manufacturing ecosystem.

Industry 4.0 aims to create a smart factory where machines, devices, and products communicate, increasing efficiency and productivity. However, achieving these objectives requires the integration of advanced technologies such as artificial intelligence, big data analytics, and robotics.

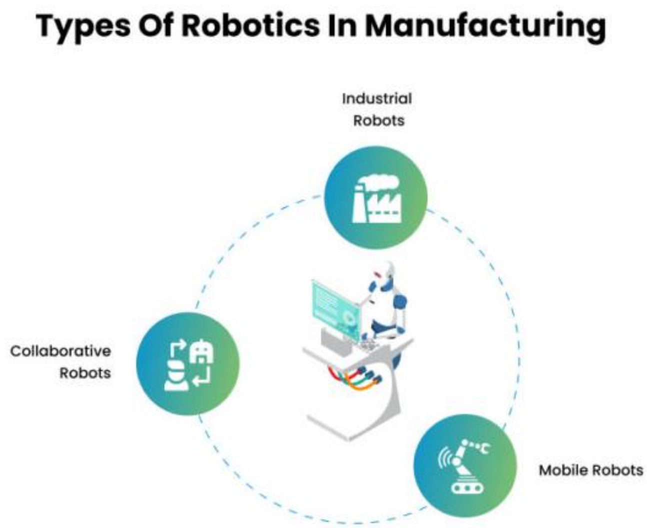
In recent years, robotics has emerged as a crucial technology in implementing Industry 4.0 objectives. With the advancement in robotics technology, it has become possible to automate even complex and repetitive tasks, increasing productivity and efficiency in manufacturing processes. Robotics can bring about a paradigm shift in manufacturing, leading to a more efficient, cost-effective, and sustainable industry.

Different types of robotics are utilized in Advanced 4.0 technologies, each with unique features and capabilities. These are –

Industrial Robots: Industrial robots are the most common type of robots used in manufacturing. Industrial robots are highly precise, can work long hours without breaks, and perform tasks such as welding, painting, and assembly.

Collaborative Robots: Robots designed to work alongside human operators are called collaborative robots. These robots are equipped with sensors that allow them to detect the presence of humans and adjust their movements accordingly. Collaborative robots are ideal for tasks that require human-robot interaction, such as packaging and material handling.

Mobile Robots: These robots are designed to move around a factory floor or warehouse. They are equipped with sensors and cameras to navigate and avoid obstacles. Mobile robots are ideal for material handling, transportation, and inventory management.



SECTION - V

9(a) Electro Chemical Process is most commonly used method for mass production, and is able to cut extremely odd materials. Which are difficult to machine using conventional methods. Its use is limited to electrically conductive materials. Explain how this process works.

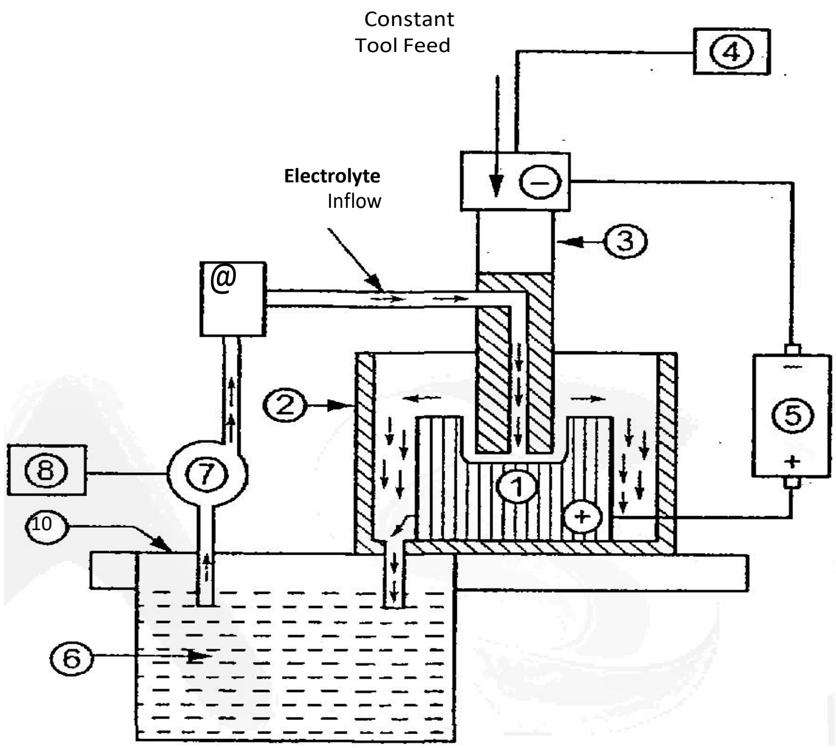
Electro-Chemical Machining (ECM) is one of the recent and most useful machining processes. In this process, electrolysis method is used to remove the metal from the work piece. It is best suited for the metals and alloys which are difficult to be machined by mechanical machining processes.

Principle:

This process is based on the principle of Faraday's laws of electrolysis which may be stated as follows

1. The first law states that the amount of any material dissolved or deposited, is proportional to the quantity of electricity passed.
2. The second law proposes that the amount of change produced in the material is proportional to its electrochemical equivalent of the material.

Basically in electroplating, the metal is deposited on the work piece, while in ECM, the objective is to remove the metal from the work piece. So, the reverse of electroplating is applied in ECM process. Therefore, the work piece is connected to positive terminal (anode) and the tool is connected to negative terminal (cathode). When the current is passed, the work piece loses metal and the dissolved metal is carried out by circulating an electrolyte between the work and tool.



1. Workpiece, 2. Tank, 3. Tool (cathode), 4. Servomotor for controlled tool feed, 5. D.C. Power supply, 6. Electrolyte, 7. Pump, 8. Motor for pump, 9. Filter, 10. Reservoir

CONSTRUCTION AND WORKING OF ECM PROCESS

Construction

- The schematic arrangement of ECM process is shown in fig.
- It consists of work piece, tool, servomotor for controlled tool feed, D.C power supply, electrolyte, pump, motor for pump, filter for incoming electrolyte and reservoir for electrolyte.
- A shaped tool (electrode) is used in this process, which is connected to negative terminal (cathode) and the workpiece is connected to positive terminal (anode).
- The tools used in this process should be made up of the materials which have enough thermal and electrical conductivity, high chemical resistance to electrolyte and adequate stiffness and machinability.
- The widely used tool materials are stainless steel, titanium, brass and copper.
- The tool is of hollow tabular type as shown in figure. and an electrolyte is circulated between the work and tool.
- Most widely used electrolyte in this process i's sodium nitrate solution. Sodium chloride solution in water is a good alternative but it is more corrosive than the former. Some other chemical used in this process are sodium hydroxide, Sodium sulphate, sodium flouride, potassium nitrate, potassium chloride.
- Servomotor is used for controlling the tool feed and the filter is used to remove the dust particles from the electrolytic fluid.

Working

- The tool and work piece are held close to each other with a very small gap (0.05 to 0.5 mm) between them by using servo motor.
- The electrolyte from the reservoir is pumped at high pressure and flows through the gap between the work piece and tool at a velocity of 30 to 60 m/s.
- A mild D.C. voltage about 5 to 30 Volts is applied between the tool and work piece.
- Due to the applied voltage, the current flows through the electrolyte with positively charged ions and negatively charged ions. The positive ions move towards the tool (cathode) while negative ions move towards work piece (anode)
- The electrochemical reaction takes place due to this flow of ions and it causes the removal of metal from the work piece in the form of sludge.

9(b) Electrical discharge machining (EDM) is a well-established machining option for manufacturing geometrically complex or hard material parts that are extremely difficult-to machine by conventional machining processes. Discuss the process parameters required in an EDM process? Suggest a suitable process parameter that needs to be considered for this case and justify.

EDM or electrical discharge machining is a manufacturing process by which heated electrodes are utilized to shape a workpiece by melting away excess materials. There are two kinds of EDM machines: wired and sinker. This article will go over the differences between the two machines and their applications. Electrical Discharge Machining is also known as Spark Machining or Spark Eroding process. MRR (Material Removal Rate): Out of all the non-traditional machining methods, the Electric Discharge Machining will remove more material. In this sense, the MRR is higher for EDM. Working Principle of Electrical Discharge Machining Process: The workpiece is fixed in the dielectric container using a fixture. The tool is fed up by the Servo Feed Unit which can move downward in a vertical direction. The power supply is given to the electrical discharge machining process i.e. Positive terminal is given to the workpiece and a Negative terminal is given to the tool. The tool and workpiece are separated using dielectric fluid and an optimum gap is maintained between them. As stated above, that at normal conditions, the dielectric fluid acts as an insulator. In this sense, no electrical conductivity is taking place. But, by an increase of high pressure, the dielectric fluid ionizes into Negative and Positive Ions. The positive ions are attracted to negative ions and negative ions are attracted to positive ions and thereby the heat is generated. When positive and negative ions collide with each other then the spark is generated between the tool and workpiece which can remove the material from the surface of the workpiece. When there is no spark in the container, then the dielectric fluid again turns as an insulator The same procedure is repeated to remove the material from the surface of the workpiece. This is a detailed explanation of the Electrical Discharge Machining process along with the basic terms and PROCESS PARAMETERS-

• **Peak voltage** represents the amplitude of a waveform. It shows how large the magnitude of a waveform gets from the 0 horizontal axis line to the peak of the waveform. You can see in this example above that the peak voltage of the waveform is 10V.

• **The peak current** is the maximum amount of current which output is capable of sourcing for brief periods of time. When a power supply or an electrical device is first turned on, high initial current flows into the load, starting at zero and rising until it reaches a peak value, known as the peak current.

• **Pulse duration** is the period of time the current is allowed to flow per cycle during the micro-EDM process. The discharge energy is really controlled by the peak current and the length of the pulse on-time. It is the 'work' part of the spark cycle, when the current flows and work is done only during this time.

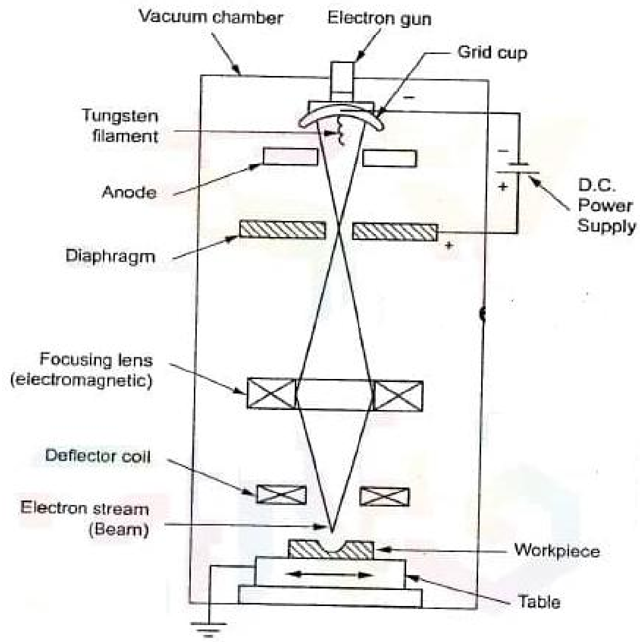
• **Polarity** is when an entity contains two distinct and opposite poles that can either attract or repel each other. The term is commonly used in electricity, magnetism, chemistry and electronic signaling to describe the flow of electrons.

10 (a) In an aerospace application, manufacturing the critical components of cryogenic engine is uphill task in conventional machining method. However, industries found the way by using Electron Beam Machining process. Illustrate the working of Electron Beam Machining.

. **Electron Beam Machining:** Electron Beam machining or EBM is a non-conventional machining process, Where the electrons are focused and concentrated on a small spot on the metal, the kinetic energy of the electrons is converted into heat energy which is sufficient to melt the workpiece, Known as Electron beam machining or EBM.

Working principle of EBM: EBM machining process works on the principle of the high-velocity beam of the electron is focused on the workpiece, the electrons strike on the workpiece and their kinetic energy is converted into heat energy. This results in the removal of material from the workpiece by vaporization and melting. EBM is particularly suitable for manufacturing complex and precise components in a vacuum environment. EBM is performed in a vacuum chamber with a vacuum level of approximately 10^{-5} to 10^{-6} mm of mercury. This vacuum environment serves several purposes:

1. To avoid collision of accelerated electrons with air molecules.
2. To protect the cathode from chemical contamination and heat losses.
3. To prevent the possibility of an arc discharge between the electrons.



Working of EBM Process: The EBM process involves several components, including an electron gun, diaphragm, focusing lens, deflector coil, tungsten filament, vacuum chamber, power source, and a movable work table.

Working Steps: 1. When a high voltage DC source is applied to the electron gun, the tungsten filament wire heats up, reaching temperatures up to 2500°C.

2. As a result of this high temperature, electrons are emitted from the tungsten filament. These electrons are directed by a grid cup to travel downwards and are attracted by the anode.

3. The electrons passing through the anode are accelerated to achieve high velocity, reaching up to half the velocity of light (approximately 1.6 x 10^8 m/s) by applying a voltage of 50 to 200 KV at the anode.

4. The high-velocity electron beam maintains its velocity as it travels through the vacuum.

5. After leaving the anode, the electron beam passes through a tungsten diaphragm and then through an electromagnetic focusing lens.

6. The focusing lens is used to concentrate the electron beam onto the desired spot of the workpiece.

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

8. Due to the high power density (approximately 6500 billion W/mm2), it only takes a few microseconds to melt and vaporize the material.

9. The process is carried out in repeated pulses of short duration, with pulse frequencies ranging from 1 to 16000 Hz and durations ranging from 4 to 65000 microseconds.

10. By alternately focusing and turning off the electron beam, the cutting process can be continued as long as necessary.

11. The machine is equipped with a suitable viewing device that allows the operator to observe the progress of machining.

10 (b). An electric discharge machining operation is being performed on two work materials: tungsten and zinc. Determine the amount of metal removed in the operation after 1 hour at a discharge amperage = 20 amps for each of these metals. The melting temperatures of tungsten and zinc are 6170°F and 420°F, respectively.

Solution: MRR = Metal Removal Rate, mm^3 /s ,

K = Constant of proportionality whose value = 664 in SI units (5.08 in U.S. customary units),

I = Discharge current, amps

Tm = Melting temperature of work metal, 0C (0 F).

To determine the amount of metal removed in an electric discharge machining operation, we need to calculate the volume of material removed for both tungsten and zinc.

The formula for calculating the volume of material removed is: $MRR=KI/Tm^{1.23}$

Volume of material removed:

(a) For Tungsten:

Discharge amperage (I) = 20 amps

Time of operation (T) = 1 hour = 3600 seconds

Melting temperature of tungsten(TM) = 6170°F

Using the formula: $MRR= K*I/ Tm^{1.23} = 5.08\times20/(6170)^{1.23}$

$= 101.6/45925.16$

$= 0.0022\ mm^3/s.$

MRR= Time of Operation * MRR per Second = 3600 * 0.0022

$= 7.92\ mm^3.$

Therefore, the amount of tungsten removed in one hour of operation is approximately 7.92 mm^3.

(b) **For Zinc:** Discharge amperage (I) = 20 amps

Time of operation (T) = 1 hour = 3600 seconds

Melting temperature of zinc (TM) = 420°F

Using the formula: $MRR = K*I/ Tm^{1.23} = 5.08 \times 20/(420)^{1.23}$

$= 101.6/1685 = 0.06\ mm^3/s$

MMR= Time of Operation * MRR per Second = 3600 * 0.06

$= 216\ mm^3$

Therefore, the amount of zinc removed in one hour of operation is approximately 216 mm^3.

CERTIFICATE

I hereby certified that the model answers prepared by me for the subject **20ME53IT: ADVANCED MANUFACTURING TECHNOLOGIES** are taken from the prescribed sources. Model answers and scheme of valuation prepared by me are correct and relevant to the topics in the question paper.

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