UNIT-IV
CHEMICAL AND ELECTRO-CHEMICAL ENERGY BASED PROCESSES
PART - A (2 MARKS)

1. **What is meant by maskant?**

   The chemical machining process is the one type of Unconventional Machining Process, in this the areas of the work piece which are not being machined are covered with a resistant, called a resist or maskant.

2. **Mention the applications of ECH.**

   It is used for,

   - Machining complicated profiles
   - Drilling small deep holes
   - Machining of hard materials
   - Machining of irregular shapes

3. **Elaborate the functions of electrolyte in ECM.**

   - It carries the current between the tool and work piece
   - It cools the cutting zone
   - It removes the products of machining from the cutting zone

4. **Give the applications of electro chemical grinding.** It is best suited for,

   - Very precision grinding of hard metals like TnC tool tips, HSS tools etc.
   - Cutting thin sections of hard materials without any danger or distortion

5. **What are the different techniques of applying maskants to the substrate in Chemical machining process?**

   The following are the techniques of applying the maskants to the substrate in CHM process,

   - Scribed and Peeled maskants
   - Photoresists maskants

6. **Why is surface finish obtained in ECH process superior to conventional honing process?**

   - MRR is faster with reduced tool wear, it is about 10 times faster than conventional honing and about 4 times faster than internal grinding.
   - Burr free and stress free components are produced

7. **Write the principle of Electro chemical machining.**

   ECM is based on the principle of Faraday's laws of Electrolysis and reverse electroplating. In this process, 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.

8. **What are the materials used for tools in Electro Chemical Machining?**

   Most commonly used tool materials are copper, brass, titanium, copper-tungsten and stainless steel when the electrolyte is made of sodium or potassium. The other materials which can be used as tool materials are Aluminium, graphite, bronze, platinum, and tungsten carbide.

9. **What are the process parameters of Electro Chemical Machining?**

   - Current density.
   - Gap between tool and work piece.
   - Type of electrolyte used.
   - Tool feed rate.

10. **List few commonly used ECM electrolytes.**

    The commonly used ECM electrolytes are 20% of NaCI solution in water, Mixture of brine and H_2SO_4, Potassium salts and strong alkaline solutions are used as electrolyte in ECM process.

11. **What is the function of electrolyte used in ECM Process?**

    - It carries the current between the tool and the work piece.

- It cools the cutting zone which becomes hot due to the flow of high current.
- It removes products of machining from the cutting zone.

12. Mention the applications of ECM process.

- Machining complicated profiles.
- Drilling small deep holes.
- Machining of hard materials and heat resistant materials.
- Machining of cavities and holes or irregular shapes.

13. List the preferred characteristics of ECM electrolytes.

- It should be good conductor of electricity.
- It should have non-corrosive property.
- It should have low viscosity and high specific heat.
- It should be non-toxicity and chemical stability.

14. Write the difference between chemical machining and Electro chemical machining.

Chemical machining: The material is removed from the work piece through a controlled etching or chemical attack of the work piece material.

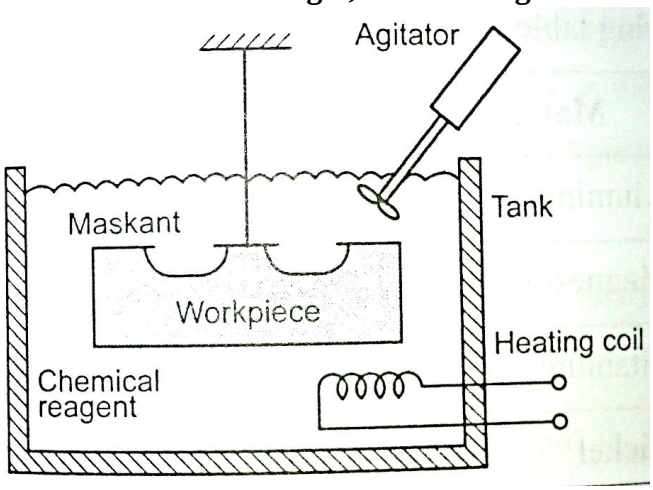
Electro chemical machining: Material is removed by ion displacement of the work piece material in contact with the chemical solution.

15. Why the life of Electro Chemical Grinding (ECG) wheel is much higher than conventional grinding wheel?

The work is machined by the combined action of Electro chemical effect and conventional grinding operation. The major portion of the metal is removed by electro chemical effect. So, the life of electro chemical grinding wheel is much higher than conventional grinding wheel.

PART –B (16 MARKS)

1. Explain the principle, construction and working of Chemical machining (CHM) with a neat sketch. Also, State some of the advantages, disadvantage and its application.



Principle:

In chemical machining process, the material is removed from the workpiece through controlled etching of the workpiece material in contact with a chemical solution.

Construction and Working:

- In this process, the metal is removed from the workpiece through controlled etching or chemical attack of the workpiece.
- Material can be removed from selected area of a workpiece or from the entire surface of the workpiece, according to requirement.
- If selective machining is desired, the areas of the workpiece which are not to be machined are covered with a resistant material called a resist or maskant.

- The workpiece to be machined first cleaned in trichloroethylene vapour or in a solution of mild alkaline at 85 – 90 ^{o}C, followed by washing in a clean water. This removes dust and oil from the workpiece.
- After cleaning, the workpiece is dried and coated with the maskant material.
- The workpiece is then immersed in a chemical reagent as shown in figure. So, chemical reaction takes place and the metal is removed from the workpiece. The metal is removed by the chemical conversion of the metal into metallic salt.
- The time of immersion of the workpiece depends upon the amount of material removed by chemical action.
- The chemical etching agent depends upon work material. Caustic soda is used as etching reagent for aluminium, solution of hydrochloric and nitric acids for steel and iron chloride for stainless steels.
- In order to obtain a uniform depth of metal removal, temperature control and stirring of chemical reagent is important.
- After machining, the workpiece should be washed thoroughly to prevent reaction with any chemical etching reagent residues.

Advantages:

- Burr free components are produced.
- Most difficult to machine materials can be processed.
- High surface finish is obtained.
- Any metal can be machined.

Disadvantages:

- Since the process is slow, MRR is low.
- Manufacturing cost is high.
- Workpiece thickness, that can be machined, is limited.
- Large floor area is needed.

Applications:

- Chemical machining process is applied in great number of usages where the depth of metal removal is critical to a few microns and the tolerances are close.
- The major application of chemical machining is in the manufacturing of burr free components.

2. Explain the principle, construction and working of Electro-chemical machining (ECM) with a neat sketch. Also, State some of the advantages, disadvantage and its application.

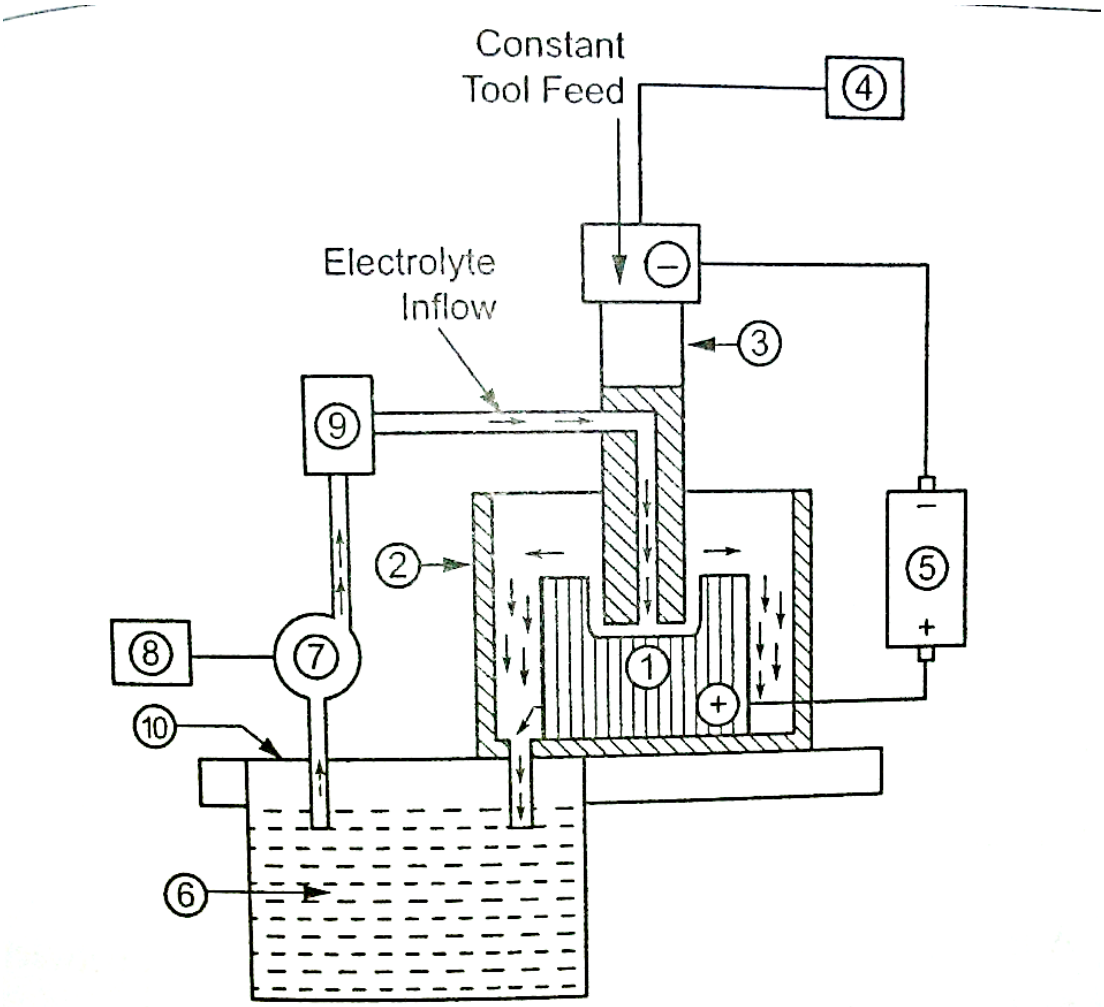
Principle:

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 workpiece, while in ECM, the objective is to remove the metal from the workpiece. So, the reverse of electroplating is applied in ECM process. Therefore, the workpiece is connected to positive terminal (anode) and the tool is connected to negative terminal (cathode). When the current is passed, the workpiece 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:

- The schematic arrangement of ECM process is shown in figure.
- It consists of workpiece, tank, tool, servo motor for controlled tool feed, D.C. poer 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 tubular type as shown in figure and an electrolyte is circulated between the work and tool.
- Most widely used electrolyte in this process is sodium nitrate. Sodium chloride solution in water is a good alternative but it is more corrosive than the former. Some other chemicals used in this process are sodium hydroxide, sodium sulphate, sodium fluoride, potassium nitrate, and 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 workpiece are held close to each other with a very small gap (0.05-0.5 mm) between them by using servomotor.
- The electrolyte from the reservoir is pumped at high pressure and flows through the gap between the workpiece and tool at a velocity of 30-60 m/s.
- A mild D.C. voltage about 5 to 30 V is applied between the tool and workpiece.
- 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 the workpiece (anode).
- The electrochemical reaction takes place due to this flow of ions and it causes the removal of metal from the workpiece in the form of sludge.

Advantages:

- Wear and tear of tool is negligible.
- Machining is done at low voltage.
- The machined work surface is free of stresses.
- No cutting forces are involved in this process.

Disadvantages:

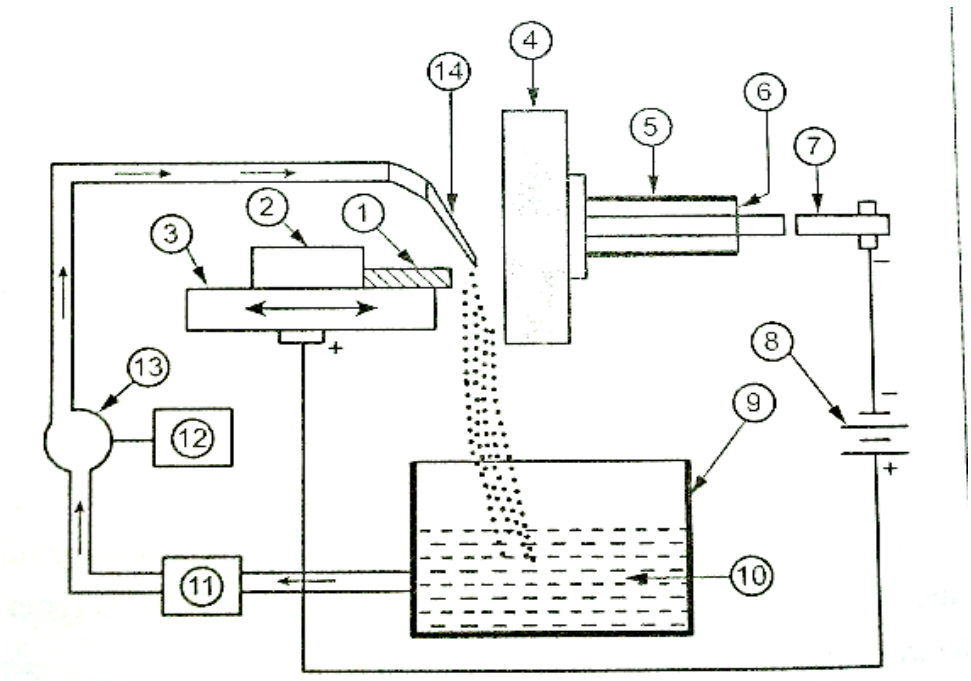
- Non-conducting materials cannot be machined.
- Machining process is comparatively slow.
- Initial investment is quite high.
- More space is required.

Applications:

It is used for

- Machining complicated profiles such as jet engine blades, turbine wheels, etc.,
- Drilling small deep holes, such as nozzles.
- Machining of cavities and holes of irregular shapes.
- Machining of blind holes and pockets such as in forging dies.

3. Explain the principle, construction and working of Electro-chemical grinding (ECG) with a neat sketch. Also, State some of the advantages, disadvantage and its application.



1. Workpiece, 2. Fixture, 3. Work table, 4. Grinding wheel,
5. Insulation, 6. Sleeve, 7. Spindle, 8. D.C. power source,
9. Tank for electrolyte, 10. Electrolyte, 11. Filter,
12. Motor for pump, 13. Pump, 14. Nozzle.

Principle:

In electrochemical grinding method, the work is machined by the combined section of electrochemical effect and conventional grinding operation. But the major portion of the metal (about 90%) is removed by electrochemical effect.

Construction:

- The schematic arrangement of ECG process is shown in figure.
- It consists of workpiece, work table, grinding wheel, spindle, D.C. power supply, electrolyte, pump, motor for pump, nozzle, filter for incoming electrolyte, and reservoir for electrolyte.
- The grinding wheel is mounted on a spindle, which rotates inside suitable bearing.
- The workpiece is held on the machine table in suitable fixtures. The table can be moved forward and backward to feed the work or to withdraw it.
- The grinding wheel and spindle are separated from the machine by using an insulating sleeve as shown in figure.
- Sodium nitrate, sodium chloride and potassium nitrate with a concentration of 0.150 – 0.300 kg/lit of water are usually used as electrolyte.
- The electrolyte from the reservoir is pumped and passed through nozzle in the gap between the wheel and workpiece.
- A constant gap of 0.025 mm is maintained between the grinding wheel and workpiece.
- The grinding wheel is made up of fine diamond particles. These particles are slightly projecting out from the surface and come in contact with work surface with very little pressure.
- The grinding wheel runs at a speed of 900 – 1800 m/min.
- The workpiece is connected to positive terminal (anode) of battery and grinding wheel is connected to negative terminal (cathode).

Working:

- A mild D.C. voltage of about 3-30V is applied between the grinding wheel and workpiece.
- 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 grinding wheel (cathode) while the negative ions move towards the workpiece (anode).
- The electrochemical reaction takes place due to this flow of ions and it causes the removal of metal from the workpiece.
- It can be seen that workpiece is fed against the rotation of grinding wheel and the metal is removed from the workpiece surface by the simultaneous abrasive action and electrolytic reaction. In fact, 10% of the workpiece metal is removed by abrasive cutting, and 90% by electrolytic reaction.
- Grinding wheel wear is negligible because the major part of the cutting action is electrolytic, and little dressing of grinding wheel is needed.
- The short-circuit between the wheel and work is prevented due to point contact made by the fine diamond points.

Advantages:

- Good surface finish is obtained.
- Work material is not subjected to any structural changes.
- Intricate parts can be machined without any distortion.
- Burr free and stress free components are produced.

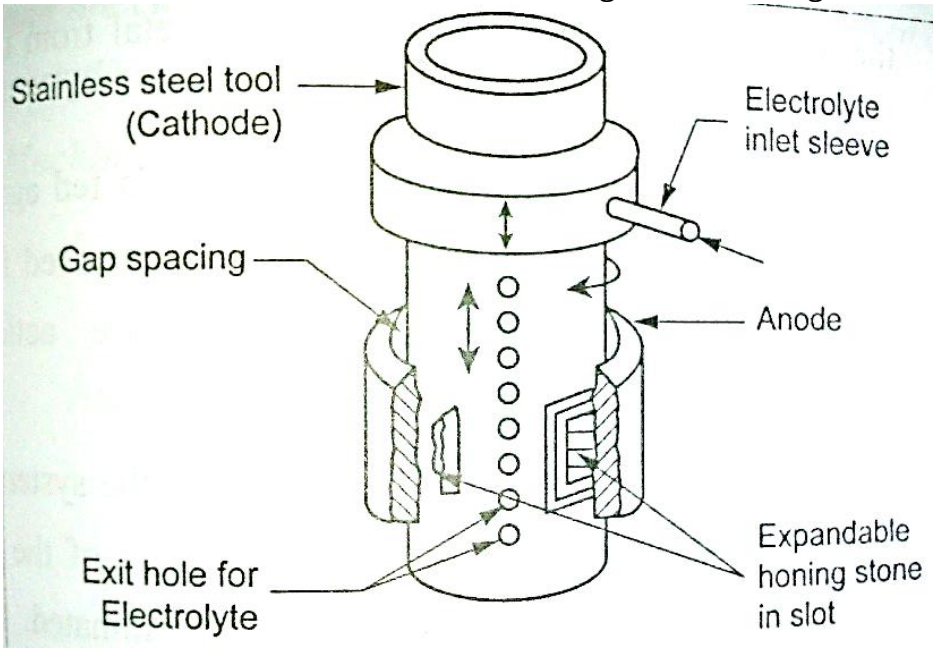
Disadvantages:

- Initial cost is high.
- Power consumption is high.
- Non-conducting materials cannot be machined.
- Maintenance cost is high.

Application:

- It is best suited for very precision grinding of hard metals like tungsten carbide tool tips, high speed steel tools.
- For cutting thin sections of hard materials without any damage or distortion.

4. Explain the principle, construction and working of Electro-chemical honing (ECH) with a neat sketch. Also, State some of the advantages, disadvantage and its application.



Principle:

Electrochemical honing is similar to Electrochemical grinding i.e., the work is machined by the combined action of electrochemical effect and conventional grinding operation. ECH, however, uses rotating and reciprocating, non-conducting bonded honing stones instead of a conducting grinding wheel. Most of the metal is removed by electrochemical effect.

Construction:

- The schematic arrangement of Electrochemical honing machine is shown in figure.
- The workpiece is connected to positive terminal (anode) of battery and tool is connected to negative terminal (cathode).
- The gap between the tool and the workpiece is usually maintained between 0.075 – 0.125 mm at the start of the cycle. It increases by the amount of stock removal per cycle up to 0.50 mm.
- Electrolyte is passed between the tool and workpiece through several rows of small holes in the tool body as shown in figure.
- Electrolyte is supplied about ½ lit/min under a pressure of upto 1.05 N/mm2 depending upon the workpiece size.
- Bonded-abrasive honing stones are inserted in slots in the tool and these stones are fed out with equal pressure in all directions, so that, their cutting faces are in constant contact with the cylinder surface.

Working:

- A mild D.C voltage of about 25 V is applied between the honing tool and workpiece.
- 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 honing tool (cathode) while the negative ions move towards the workpiece (anode).

- The electrochemical reaction takes place due to this flow of the ions and it causes the removal of metal from the workpiece.
- It can be seen that workpiece (cylinder) is fed against the rotation of honing tool and the metal is removed from the workpiece by the simultaneous abrasive action and electrolytic reaction.
- Automatic gauging devices designed into the system which initiates a signal and when the cylinder is of the desired diameter size, the cycle is automatically terminated.
- It is mostly used for internal cylindrical grinding, with a size tolerance of 0.012 mm on diameter and 0.005 mm on roundness.

Advantages:

- Metal removal rate is faster with reduced tool wear, it is about 10 times faster than conventional honing and about 4 times faster than internal grinding.
- Burr free and stress free components are produced.
- Less pressure is required between honing stones and workpiece.
- It is used for machining burred edges.
- Noise and distortion are reduced when honing thin walled tubes.

5. i) Explain the process parameters of ECG process.

The following process parameters are involved in the effectiveness of electro-chemical grinding process.

1. Current density

The metal is removed from the workpiece based on the current density. It is of the order 100 – 200 A/cm2. The power supply is D.C voltage of 3 – 30 V.

It is clear that the material removal rate increases with current density which leads to better surface finish.

2. Electrolyte

The surface finish, precision and MRR are influenced by the composition of the electrolyte. Sodium nitrate, sodium chloride and potassium nitrate with a concentration of 0.150 – 0.300 kg/lit of water are usually used as electrolyte. It is passed through nozzle in the gap (0.25mm) between the wheel and workpiece. Electrolyte is maintained at a temperature between $15^{o}C$-$30^{o}C$.

3. Feed rate

If the applied feed rate is very slow, it results in poor surface finish and tolerance. If the feed rate is very fast, the abrasive particles will be forced into the workpiece, resulting in excessive wheel wear. The maximum depth of cut for grinding wheel is 2.5 mm.

4. Grinding wheel speed

The grinding wheel runs at a speed of 900 – 1800 m/min. higher speed of wheel leads to wear and tear. Accuracy of wheel running and wheel pressure also influences the effectiveness of electro grinding process.

ii) List out its advantages, disadvantages and application of ECG process.

Advantages:

- Since the tool wear is negligible, the life of the grinding wheel is increased. This factor is most valid in the grinding of hard metals such as tungsten carbide, where, costly diamond grinding wheels are used. In ordinary grinding there are high wear rates on these expensive diamond wheels.
- Work is free of surface cracks and distortion because heat is not generated in the process.
- As compared to conventional grinding, a very little cutting force is applied to the workpiece.

- Good surface finish is obtained.
- Work material is not subjected to any structural changes.
- Intricate parts can be machined without any distortion.
- The surface finish produced by this process is varied form 0.2 – 0.4 μm.
- Accuracy of the order of 0.01 mm can be achieved by proper selection of wheel grit size and abrasive particles.
- Burr free and stress free components are produced.
- The wheel bond wears very slowly. So, the grinding wheel need not be dressed frequently.

Disadvantages:

- Initial cost is high.
- Power consumption is high.
- Metal removal rate is lower than conventional grinding.
- Non-conducting materials cannot be machined.
- Preventive measure are needed against corrosion by the electrolyte.
- Maintenance cost is high.
- Since the tolerances achieved are slightly low, the workpiece need final abrasive machining.

Application:

- It is best suited for very precision grinding of hard metals like tungsten carbide tool tips, high speed steel tools.
- For cutting thin sections of hard materials without any damage or distortion.

6. i) Discuss the masking techniques for different production level.

The usual methods of masking are:

1. Scribed and Peeled maskants.
2. Photoresists maskants.

1. Scribed and Peeled maskants:

In this method, a maskant (like paint) is applied to the entire surface of the workpiece by dip, spray, brush or stencil. After the maskant hardens, it is removed from those surfaces where metal removal is desired. The maskant is removed by scribing with knife and peeling away the desired surfaces. Templates can be used to assist in scribing. This method is used when critical dimensional tolerance are not required.

2. Photoresists maskants:

- it is an excellent method of masking, especially for complex work. This method is used for thin sections and components requiring closed dimensional tolerances.
- The workpiece to be machined is thoroughly cleaned and decreased by acids or alkalis. The cleaned metal is dried and photoresist material is applied to the workpiece by dipping, spraying, brushing or roller coating.
- The coating is then dried and hardened by heating in an oven upto about 125^{o}C.
- The design of the part to be machined is prepared at a magnification of upto 100X. The master drawing is photographed and reduced to the size of the finished part.
- The negative of photograph is placed over the dried photoresist coated surface of the workpiece and exposed to UV light, which hardens the exposed areas.
- After exposure, the workpiece is then developed by immersing it into a tank which contains an organic solvent bath solution. The unexposed portions are dissolved out during the developing process, while the exposed portions remains on the workpiece.

- Finally the treated workpiece is dipped into the etching solution. After 5-15 min, the unwanted metal is removed from the workpiece and the finished part is washed thoroughly to eliminate all chemical residues.

ii) What is meant by 'etching factor'? List down all the disadvantages of ECM process.

Etching Factor:

The chemical machining proceeds on all exposed surfaces to the etching medium, under cuts are always associated with this processing operation. This undesired cutting is known as "etching factor" restricts not only the size of mask but also on depth of cutting and accuracy is lost when machining to higher depth.

Disadvantages:

- Non-conducting materials cannot be machined.
- Consumption of power is nearly 100 times more than in turning or milling the steel.
- Machining process is comparatively slow.
- Initial investment is quite high.
- More space is required.
- To vary the tool feed rate and supply of electrolyte, constant monitoring is needed.
- Difficulty in designing a proper tooling system.

7. i) Differentiate ECM process and EDM process.

ELECTRO DISCHARGE MACHINING (EDM)	ELECTRO CHEMICAL MACHINING (ECM)
1. Electrical energy is use to cut material to final shape. (SPARK EROSION PROCESS).	1. Electrical energy is use to cut material to final shape (No spark)
2. When a difference of potential is applied between two conductors immersed in a dielectric fluid. Fluid will ionize, if the potential diff. reaches a high enough value and a spark will occur.	2. In this process an electrolytic cell is formed by the anode (work piece) and cathode (tool) in the midst of a flowing electrolyte.
3. If both the electrodes are of same material then +ve one (anode, work piece) will have more erosion.	3. Due to electrolytic process at the cathode, -ve ions are released which combine with the metal ion of anode to form insoluble metal hydroxides.
4. A gap of 0.01 to 0.05 mm is maintained, it governs the MRR	4. Thus the metal is mainly removed in the form of slugs and precipitates
5. Current vary from 0.5 to 400 amp	5. This process is reverse of electro plating but the metal is pumped in the flowing electrolyte before it gets stuck on the tool surface
6. Voltage 40-300 V DC	6. Gap 0.01-0.7 mm
7. Fluid is pumped with a pressure of 2 kg/cm^2.	7. voltage D.C. supply(5-30 volts)
	8. current of order 50-40000 amp
	9. Fluid pressure =14 kg/cm^2

ii) What are the requirements of tool materials for ECM process? List the commonly used tool materials.

- Since the tool has no contact with the workpiece, there is no tool wear. So any material that is good conductor of electricity can be used as tool material.
- The general requirements of tool material in ECM process are
  - It must be a conductor of electricity.
  - It must be chemically inert to the electrolyte.
  - It must be easily machinable.
  - It must be rigid enough to take up the load due to fluid pressure.
- Most commonly used tool materials are copper, brass, titanium, copper-tungsten, and stainless steel, when the electrolyte is made of sodium or potassium. The other materials which can be used as tool materials are aluminium, graphite, bronze, platinum and tungsten carbide.
- Tool material properties:

Properties	Material			
	Copper	Brass	Stainless Steel	Copper-tungsten
Electrical resistivity	1.00	4.00	53.00	8.00
Stiffness	1.60	1.00	1.90	2.20
Machinability	6.00	8.00	2.50	1.80
Thermal Conductivity	25.00	7.50	1.00	10.00

8. Briefly explain the following terms of WEDM process.

a. Electro-chemical deburring

In electrochemical deburring (ECDB), the anodic part to be deburred is placed in a fixture, which positions the cathodic electrode in close proximity to the burrs. The electrolyte is then directed, under pressure, to the gap between the cathodic deburring tool and the burr. On the application of the machining current, the burr dissolves forming a controlled radius. Since the gap between the burr and the electrode is minimal, burrs are removed at high current densities. ECDB, therefore, changes the dimensions of the part by removing burrs leaving a controlled radius. Figure 4.31 shows a typical EC hole deburring arrangement. ECDB can be applied to gears, spline shafts, milled components, drilled holes, and punched blanks. The process is particularly efficient for hydraulic system components such as spools, and sleeves of fluid distributors.

b. **Electro-chemical honing**

Refer Question No.4

c. Chemical Machining

Refer Question No.1

d. Maskants and etchants used in CHM

Refer Question No.10 (i)

9. i) Explain the characteristics of ECM process.

1. Metal removal technique	Based on Faraday's law of electrolysis and reverse electroplating
2. Work material	Difficult to machine materials (conducting materials)
3. Tool material	Copper, brass or steel
4. Voltage	5-30 V
5. Current	50-40,000 A
6. MRR	27 cubic mm/ s
7. Electrolyte	20%NaCl solution in water, mixture of brine and H2SO4

8. Surface finish	0.2 to 0.8 micro metre
9. Tolerance	0.005 mm
10.Specifi power consumption	7 W/ cubic mm/ min

ii) List out its advantages, disadvantages and application of ECM process.

Advantages:

- The MRR by this process is quite high for high strength-temperature resistant (HSTR) materials compared to conventional machining processes.
- Wear and tear of tool is negligible.
- Machining is done at low voltage.
- Intricate and complex shapes can be machined easily through this process.
- The machined work surface is free of stresses.
- No cutting forces are involved in this process.
- High surface finish, of the order of 0.2 – 0.8 microns, can be obtained.
- Very thin sections such as sheet metal can be easily machined without any damage.
- It is an accurate process and close tolerance of the order 0.005 mm can be easily obtained.
- No burrs are produced and this process can be easily automated.
- Toughness and brittleness of material has no effect on the machining process.

Disadvantages:

- Non-conducting materials cannot be machined.
- Consumption of power is nearly 100 times more than in turning or milling the steel.
- Machining process is comparatively slow.
- Initial investment is quite high.
- More space is required.
- To vary the tool feed rate and supply of electrolyte, constant monitoring is needed.
- Difficulty in designing a proper tooling system.

Applications:

It is used for

- Machining complicated profiles such as jet engine blades, turbine wheels, etc.,
- Drilling small deep holes, such as nozzles.
- Machining of cavities and holes of irregular shapes.
- Machining of blind holes and pockets such as in forging dies.
- Machining of hard materials and heat resistant materials.

10. i) Explain the maskants and etchants used in CHM process.

Maskants:

1. Scribed and Peeled maskants:

In this method, a maskant (like paint) is applied to the entire surface of the workpiece by dip, spray, brush or stencil. After the maskant hardens, it is removed from those surfaces where metal removal is desired. The maskant is removed by scribing with knife and peeling away the desired surfaces. Templates can be used to assist in scribing. This method is used when critical dimensional tolerance are not required.

2. Photoresists maskants:

- it is an excellent method of masking, especially for complex work. This method is used for thin sections and components requiring closed dimensional tolerances.
- The workpiece to be machined is thoroughly cleaned and decreased by acids or alkalis. The cleaned metal is dried and photoresist material is applied to the workpiece by dipping, spraying, brushing or roller coating.
- The coating is then dried and hardened by heating in an oven upto about 125^{o}C.

- The design of the part to be machined is prepared at a magnification of upto 100X. The master drawing is photographed and reduced to the size of the finished part.
- The negative of photograph is placed over the dried photoresist coated surface of the workpiece and exposed to UV light, which hardens the exposed areas.
- After exposure, the workpiece is then developed by immersing it into a tank which contains an organic solvent bath solution. The unexposed portions are dissolved out during the developing process, while the exposed portions remains on the workpiece.
- Finally the treated workpiece is dipped into the etching solution. After 5-15 min, the unwanted metal is removed from the workpiece and the finished part is washed thoroughly to eliminate all chemical residues.

The following table shows the various maskants for various materials:

S.No.	Material	Maskants
1.	Aluminium	Butyl rubber, Neoprene rubber
2.	Magnesium	Polymers
3.	Titanium	Translucent chlorinated polymers
4.	Nickel	Neoprene
5.	Ferrous Metals	PVC, polyethylene

Etchants:

The etchant is nothing but chemical reagent which is used to remove the metal from the workpiece. The metal is removed by the chemical conversion of the metal into metallic salt. The chemical etching reagent depends upon work material.

The following table shows the etchant for different materials.

S.No.	Material	Etchant
1.	Aluminium	Caustic soda
2.	Steel	Hydrochloric acid or Nitric acid
3.	Stainless Steel	Iron chloride
4.	Magnesium	Nitric acid
5.	Titanium	Nitric acid

ii) List out its advantages, disadvantages and application of CHM process.

Advantages:

- Burr free components are produced.
- Most difficult to machine materials can be processed.
- High surface finish is obtained.
- Any metal can be machined.
- Stress free components are produced**.**
- Since the process is comparatively simple, there is no need of highly skilled labors.
- Both faces of the workpiece can be machined simultaneously.
- Hard and brittle materials can be machined.
- Tooling cost is very low.

- Complex contours can be easily machined.

Disadvantages:

- Since the process is slow, MRR is low.
- Manufacturing cost is high.
- Workpiece thickness, that can be machined, is limited.
- Large floor area is needed.
- It is not possible to produce sharp corners.

Applications:

- Chemical machining process is applied in great number of usages where the depth of metal removal is critical to a few microns and the tolerances are close.
- The major application of chemical machining is in the manufacturing of burr free components.