ST.ANNE'S COLLEGE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE, New Delhi. Affiliated to Anna University, Chennai)
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ANGUCHETTYPALAYAM, PANRUTI – 607 106.

DEPARTMENT OF MECHANICAL ENGINEERING

CME 387 - NON TRADITIONAL MACHINING PROCESS

REGULATION - R-2021

THIRD YEAR - SIXTH SEMESTER

PREPARED BY

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CME 387 NON-TRADITIONAL MACHINING PROCESSES L T P C 3 0 0 3

COURSE OBJECTIVES

1. To classify non-traditional machining processes and describe mechanical energy based non-traditional machining processes
2. To differentiate chemical and electro chemical energy-based processes.
3. To describe thermo-electric energy-based processes.
4. To explain nano finishing processes.
5. To introduce hybrid non-traditional machining processes and differentiate hybrid non-traditional machining processes.

UNIT – I INTRODUCTION AND MECHANICAL ENERGY BASED PROCESSES 9

Introduction - Need for non-traditional machining processes - Classification of non-traditional machining processes - Applications, advantages and limitations of non-traditional machining processes - Abrasive jet machining, Abrasive water jet machining, Ultrasonic machining their principles, equipment, effect of process parameters, applications, advantages and limitations.

UNIT- II CHEMICAL AND ELECTRO CHEMICAL ENERGY BASED PROCESSES 9

Principles, equipments, effect of process parameters, applications, advantages and limitations of Chemical machining, Electro-chemical machining, Electro-chemical honing, Electro-chemical grinding, Electro chemical deburring.

UNIT - III THERMO-ELECTRIC ENERGY BASED PROCESSES 9

Principles, equipments, effect of process parameters, applications, advantages and limitations of Electric discharge machining, Wire electric discharge machining, Laser beam machining, Plasma arc machining, Electron beam machining, Ion beam machining.

UNIT – IV NANO FINISHING PROCESSES 9

Principles, equipments, effect of process parameters, applications, advantages and limitations of Abrasive flow machining – Chemo mechanical polishing, Magnetic abrasive finishing, Magnetorheological finishing, Magneto rheological abrasive flow finishing.

UNIT – V HYBRID NON-TRADITIONAL MACHINING PROCESSES 9

Introduction - Various hybrid non-traditional machining processes, their working principles, equipments, effect of process parameters, applications, advantages and limitations. Selection and comparison of different non- traditional machining processes.

TOTAL: 45 PERIODS

TEXT BOOK:

1. Adithan. M., "Unconventional Machining Processes", Atlantic, New Delhi, India, 2009. ISBN 13: 9788126910458
2. Anand Pandey, "Modern Machining Processes", Ane Books Pvt. Ltd., New Delhi, India, 2019.

REFERENCES:

1. Benedict, G.F., "Non-traditional Manufacturing Processes", Marcel Dekker Inc., New York 1987. ISBN-13: 978-0824773526.
2. Carl Sommer, "Non-Traditional Machining Handbook", Advance Publishing., United States, 2000, ISBN-13: 978-1575373256.
3. Golam Kibria, Bhattacharyya B. and Paulo Davim J., "Non-traditional Micromachining Processes: Fundamentals and Applications", Springer International Publishing., Switzerland, 2017, ISBN:978-3-319-52008-7
4. Jagadeesha T., "Non-Traditional Machining Processes", I.K. International Publishing House Pvt. Ltd., New Delhi, India, 2017, ISBN-13: 978-9385909122.
5. Kapil Gupta, Neelesh K. Jain and Laubscher R.F., "Hybrid Machining Processes: Perspectives on Machining and Finishing", 1st edition, Springer International Publishing., Switzerland, 2016, ISBN-13: 978-3319259208

UNIT I

INTRODUCTION AND MECHANICAL ENERGY BASED PROCESSES

Part-A (2 Mark questions)

1. Define non- traditional machining processes (or) Unconventional machining process.(Non/Dec 2021)

Non-traditional manufacturing processes are 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.

2. What is meant by conventional machining processes?

In conventional machining processes, metal is removed by using some of the tool which is harder than the work piece and is subjected to wear. In this process, tool and the work piece in direct contact with each other.

3. What are difference between non-traditional machining process and traditional machining process? (Nov/Dec-2016) (Or) Difference between conventional and unconventional machining processes. (May/June-2021)

- ✓ Traditional machining process, there is a direct contact between the tool and the work piece. Large cutting forces are involved and material is removed in the form of chips.
- ✓ But in non-traditional machining process, there is a no direct contact between the tool and the work piece. In other words tool cannot touch the work piece. So it's called non- traditional machining process.

4. State the industrial needs/necessity of Unconventional machining process.(May/June-2010, 2015,2016,2014, 2021, Nov/Dec -2013,2014,2016,2021)

Non-traditional machining processes, also called advanced manufacturing processes, are employed where traditional machining processes are not feasible, satisfactory or economical due to special reasons as outlined below.

- ✓ Work piece material is too hard, strong, or tough.
- ✓ Work piece is too flexible to resist cutting forces or too difficult to clamp.
- ✓ Part shape is very complex with internal or external profiles or small holes.

5. Merits (advantages) of unconventional machining process.(Apr/May-2011),(May/June-13,16)

A harder and difficult to machining material such as carbides, stainless steel and many other high strength temperature resistance alloys find wide applications in aerospace and nuclear industries.

6. **What is the importance of unconventional machining? (May / June 2006) (Nov/Dec 2023)**

   In several industries, hard and brittle materials like tungsten carbide, high speed steels, stainless steels, ceramics etc., find a variety of applications.

- ✓ For example, tungsten carbide is used for making cutting tools while high speed steel is used for making gear cutters, drills, taps, milling cutters etc.

7. **List down various mechanical energy based Unconventional machining processes (Nov/Dec-2004& Apr/May-2010,2021)**

- ✓ Abrasive Jet Machining (AJM), Ultrasonic Machining (USM), Water Jet Machining (WJM)
- ✓ Abrasive Water Jet Machining (AWJM)

8. **What are the different machining characteristics with respect to which the non-traditional machining processes can be analysed? (Nov/Dec-2008)**

   The machining characteristics of different non-conventional processes can be analysed with respect to

- ✓ Physical parameters
- ✓ Shapes to be machined
- ✓ Process capability or machining characteristics
- ✓ Economic consideration

9. **What are the machining characteristics with respect to which the non- traditional machining process can be analysed? (Nov/Dec 2008) (Apr/ May 2011)**

Parameters	USM, AJM	CHM	EDM, EDM	LBM	PAM
Type of energy required	Mechanical	Chemical	Electrical	Thermal	Thermal
Mechanism of Material Removal	Erosion	Ablative action, Ion Displacement	Vaporisation	fusion	fusion
Source of Energy	Pressure	Etchant (Chemicals)	High Voltage	Amplified Light	Ionised Material
Energy Transfer Medium	High Velocity Particles	Environment, Electrolyte	Electron	Radiation	Hot Gases

10. Distinguish traditional and non-traditional machining processes. (Apr/May-15, Nov/Dec-16, Nov/Dec 2019)

Conventional	**Non-conventional**
Tool must be harder than work piece	Tool need not be harder than work piece
Generally, macroscopic chip formation by sheer deformation	Material removal may occur with chip formation or even no chip formation may take place
Material removal takes place due to application of cutting force	They used a different energy domain to provide machining
There must be a physical tool	There not be a physical tool person

11. Mention thermal energy based unconventional processes. (May/June-2012)(May/June-2013)

Thermal based processes:

- ✓ Laser beam machining
- ✓ Plasma arc machining
- ✓ Ion beam machining
- ✓ Electron beam machining

12. Why unconventional mechanical machining process is not so effective on soft materials like aluminium? (Apr/May-2008, Nov/Dec 2019)

- ✓ Unconventional machining process is not so effective on soft material like aluminium because accuracy cannot be maintained due to more metal removal rate.

13. How non- traditional machining Process is classified? (Nov/Dec 2005,Nov/Dec-2013)

- ✓ Thermal energy methods
- ✓ Electrical energy methods
- ✓ Electro chemical energy methods
- ✓ Chemical energy methods
- ✓ Mechanical energy methods

14. List out the limitations of traditional machining processes. (Nov/Dec 2014, Nov/Dec-2015, May 2019)

- ✓ Large amounts of energy
- ✓ Unwanted distortion

- ✓ Residual stresses
- ✓ Burrs

15. List the unconventional machining based on chemical energy? (Nov/Dec-2015) (May/June-16)

- ✓ Chemical machining
- ✓ Electro Chemical grinding
- ✓ Electro Chemical honing.

16. What are thermal energy methods of unconventional machining? (May/ June-2012,May/Jun-2013)

In these methods, heat energy is concentrated on a small area of the work piece to melt and vaporise to tiny bits of work material. The required shape is obtained by the continued repetition of this process.

Examples: LBM, PAM, EBM, IBM.

17. List the unconventional machining process which uses mechanical energy. (Nov/Dec 2004) (Apr/May 2010)

- ✓ Ultrasonic machining (USM)
- ✓ Abrasive jet machining(AJM)
- ✓ Water jet machining(WJM)

18. What are the characteristics of UCMP? (Nov/Dec 2004) (Nov/ Dec 2007)

- ✓ The UCMP do not employ a conventional or traditional tool for metal removal, instead, they directly utilize some form of energy for metal machinery.
- ✓ The tool material need not be harder than the work piece material
- ✓ The machined surface do not have any residual stresses.

19. What are the desirable properties of carrier gas in AJM? (Nov/Dec 2004) (Apr/May 2018)

- ✓ It should be cheap.
- ✓ It should be non-toxic.
- ✓ It should be easily available.
- ✓ It should dry quickly.
- ✓ N_2, CO_2, He, etc., are normally used as carrier gas.

20. What are the different types abrasives used in AJM?(Apr/May-2010)(Nov/Dec-16)

Aluminium oxides, silicon carbides, Crushed glass, Sodium bicarbonate and Dolomite.

21. What are the desirable properties of carrier gas in AJM?(Nov/Dec-2004)(May/June2012,May 2019)

- ✓ It should be cheap and easily available.
- ✓ It should be non-toxic.
- ✓ Generally used carrier gases are: Air, N_2, CO_2, He, etc.,

22. Why abrasive jet machining is not recommended to machine ductile materials? (Apr/May-2011) (Nov/Dec 2014)

Abrasive jet machining process is not suitable for machining ductile materials, because there is always danger of abrasive particle getting embedded in the work piece.

23. Mention the Process parameters affecting the MRR in AJM? (Nov/Dec 2013) (Nov/Dec 2018) (or) What are the process parameters affecting the material removal rate in AJM? (Nov/Dec 2019)

- ✓ Gas Pressure.
- ✓ Velocity of Particles.
- ✓ Abrasive mass flow rate.
- ✓ Mixing ratio.
- ✓ Nozzle Tip Distance.

24. What is the principle of WJM? (Nov / Dec 2005) (Apr/May 2018)

The water travelling through a nozzle of reduced cross sectional area causes the water particles to rapidly accelerate. This accelerated stream leaving the nozzle impacts on the material to be cut.

25. List out the parameters which improve the material removal rate in water jet machining. (Apr/May 2010, Nov/Dec 2007, 2021)

- ✓ Material removal rate
- ✓ Geometry and surface finish of work material
- ✓ Wear rate of the nozzle

26. What are the applications of WJM? (Nov/Dec-16, Apr/May-2015,May/June-16)

- ✓ Aero space
- ✓ Automobile
- ✓ Paper pulp industries

27. What is ultrasonic machining? (Or) State the working principle of USM. (Apr/May-2015,18)(May/June-16)

- ✓ USM is a device is used to remove unwanted material from the work piece using of ultrasonic waves.

- ✓ USM is a mechanical material removal process in which the material is removed by repetitive impact of abrasive particles carried in liquid medium on to the work surface, by a shaped tool, vibrating at ultrasonic frequency.

28. Outline the properties of tools used in USM process. (Apr/May-2023)

- ➢ Made from hard, wear-resistant materials like tungsten carbide or diamond for durability and longevity.
- ➢ Designed to vibrate at resonance frequency for efficient material removal, held securely in a tool holder for precise control during machining.

29. What are the characteristics of a good suspension media of the USM Process? (Apr/May2008),(Apr/May2005)(May/June2013)(Nov/Dec 2014)

The process parameters which govern the ultrasonic machining process have been identified and the same are listed below along with material parameters

- ✓ Amplitude of vibration – 15 – 50 μm
- ✓ Frequency of vibration (f) – 19 – 25 kHz
- ✓ Feed force (F) – related to tool dimensions
- ✓ Feed pressure (p)
- ✓ Abrasive size – 15 μm – 150 μm
- ✓ Abrasive material – Al2O3 - SiC- B4C – silicon carbide - Diamond

30. What are the Disadvantages of USM? Or State the demerits of the ultrasonic machining. (Nov/Dec 2021)

- ✓ Tool wear
- ✓ Frequent turning is required
- ✓ Low material removal rate.
- ✓ Not economical for soft materials.
- ✓ Not suitable for heavy stock removal.

31. Name the different abrasive used in abrasive jet machining process. (Nov/Dec 2019)

- ✓ Aluminium oxide
- ✓ Silicon carbide
- ✓ Glass power
- ✓ Dolomite
- ✓ Specially prepared sodium bicarbonate.

PART –B & C (13- and 15-Marks Questions)

Introduction

- An unconventional machining process is a very special type of machining process because in this process there is no direct contact between the tool and the workpiece.
- In an unconventional machining process, a form of energy (such as mechanical energy, electrical energy, chemical energy, etc.) is used to remove unwanted material from a given workpiece.
- For supporting the workpiece in these types of machining processes always fixtures are used.
- It is also called a non-traditional machining process or non-conventional machining process.

1. **What is the need for development of unconventional machining processes? Explain with examples. (Apr/May-2010 & May/June-2007)(Nov/Dec 2013), what are the basic limitations of unconventional manufacturing processes? Justify the need of unconventional manufacturing process in today's industries. (May/June 2014,Nov/Dec-2015, Nov/Dec 2019)**

   Conventional machining sufficed the requirement of the industries over the decades. But new exotic work materials as well as innovative geometric design of products and components were putting lot of pressure on capabilities of conventional machining processes to manufacture the components with desired tolerances economically.

   This led to the development and establishment of unconventional machining processes in the industry as efficient and economic alternatives to conventional ones.

   With development in the unconventional machining processes, currently there are often the first choice and not an alternative to conventional processes for certain technical requirements. The following examples are provided where unconventional machining processes are preferred over the conventional machining process:

- ✓ Intricate shaped blind hole – e.g. square hole of 15 mmx15 mm with a depth of 30mm
- ✓ Difficult to machine material – e.g. same example as above in Inconel, Ti- alloys or carbides.
- ✓ Low Stress Grinding – Electrochemical Grinding is preferred as compared to conventional grinding
- ✓ Deep hole with small hole diameter – e.g. φ 1.5 mm hole with l/d =20
- ✓ Machining of composites.
- ✓ Machining of thin materials.
- ✓ For good accuracy.
- ✓ For excellent surface finish.

2. Differentiate between conventional and unconventional machining processes. Discuss the reasons for the development of unconventional machining methods. (Nov/Dec2014) (May/June-16) Nov/Dec 2023

Conventional	**Non-conventional**
Tool must be harder than work piece	Tool need not be harder than work piece
Generally, macroscopic chip formation by sheer deformation	Material removal may occur with chip formation or even no chip formation may take place
Material removal takes place due to application of cutting force	They used a different energy domain to provide machining
There must be a physical tool	There not be a physical tool person

Conventional machining sufficed the requirement of the industries over the decades. But new exotic work materials as well as innovative geometric design of products and components were putting lot of pressure on capabilities of conventional machining processes to manufacture the components with desired tolerances economically.

This led to the development and establishment of NTM processes in the industry as efficient and economic alternatives to conventional ones.

With development in the NTM processes, currently there are often the first choice and not an alternative to conventional processes for certain technical requirements.

The following examples are provided where NTM processes are preferred over the conventional machining process:

- ✓ Intricate shaped blind hole – e.g. square hole of 15 mmx15 mm with a depth of 30 mm.
- ✓ Difficult to machine material – e.g. same example as above in Ti-alloys or carbides.
- ✓ Low Stress Grinding – Electrochemical Grinding is preferred as compared to conventional grinding
- ✓ Deep hole with small hole diameter – e.g. φ 1.5 mm hole with l/d = 20 Machining of composites.

3. **How are the Unconventional machining process classified? (May/June-2012) Nov/Dec 2023**

- ✓ The non-conventional manufacturing processes are not affected by hardness, toughness or brittleness of material and can produce any intricate shape on any work piece material by suitable control over the various physical parameters of the processes.
- ✓ The non-conventional manufacturing processes may be classified on the basis of type of energy.
- ✓ They are mechanical, electrical, chemical, thermal or magnetic, apply to the work piece directly and have the desired shape transformation or material removal from the work surface by using different scientific mechanism.
- ✓ Thus, these non-conventional processes can be classified into various groups according to the basic requirements which are as follows

A) Type of energy required

- ✓ Mechanical
- ✓ Electrical
- ✓ Chemical
- ✓ Thermal
- ✓ Electro-Chemical

B) Basic mechanism involved in the processes

- ✓ Erosion
- ✓ Ionic dissolution
- ✓ Vaporization
- ✓ Shear
- ✓ Fusion
- ✓ Ablative action

C) Source of immediate energy required for material removal

- ✓ Hydrostatic pressure
- ✓ High current density
- ✓ High voltage
- ✓ Ionized material
- ✓ High current
- ✓ Chemically reactive agent
- ✓ Amplified light

D) Medium for transfer of those energies

- ✓ High velocity particles
- ✓ High velocity liquid
- ✓ Electrolyte
- ✓ Electron
- ✓ Hot gases
- ✓ Radiation
- ✓ Environment

i) Mechanical energy methods

In mechanical energy methods, the material is removed by mechanical erosion of the work piece material. Examples

- ✓ Ultrasonic Machining(USM)
- ✓ Abrasive Jet Machining(AJM)
- ✓ Water Jet Machining(WJM)

ii) Electrical energy methods

In these methods, electrical energy is directly used to cut the material to get the final shape and size. Examples

- ✓ Electro Discharge Machining (EDM)
- ✓ Wire Cut Electrical Discharge Machining(WCEDM)

iii) Chemical energy methods

These methods involve controlled etching of the work piece material in contact with a chemical solution. Example

- ✓ Chemical machining (CHM)

iv) Thermal energy methods:

In these methods, heat energy is concentrated on a small area of the work piece to melt and vaporize the tiny bits of work material. The required shape is obtained by the continued repetition of this process. Examples:

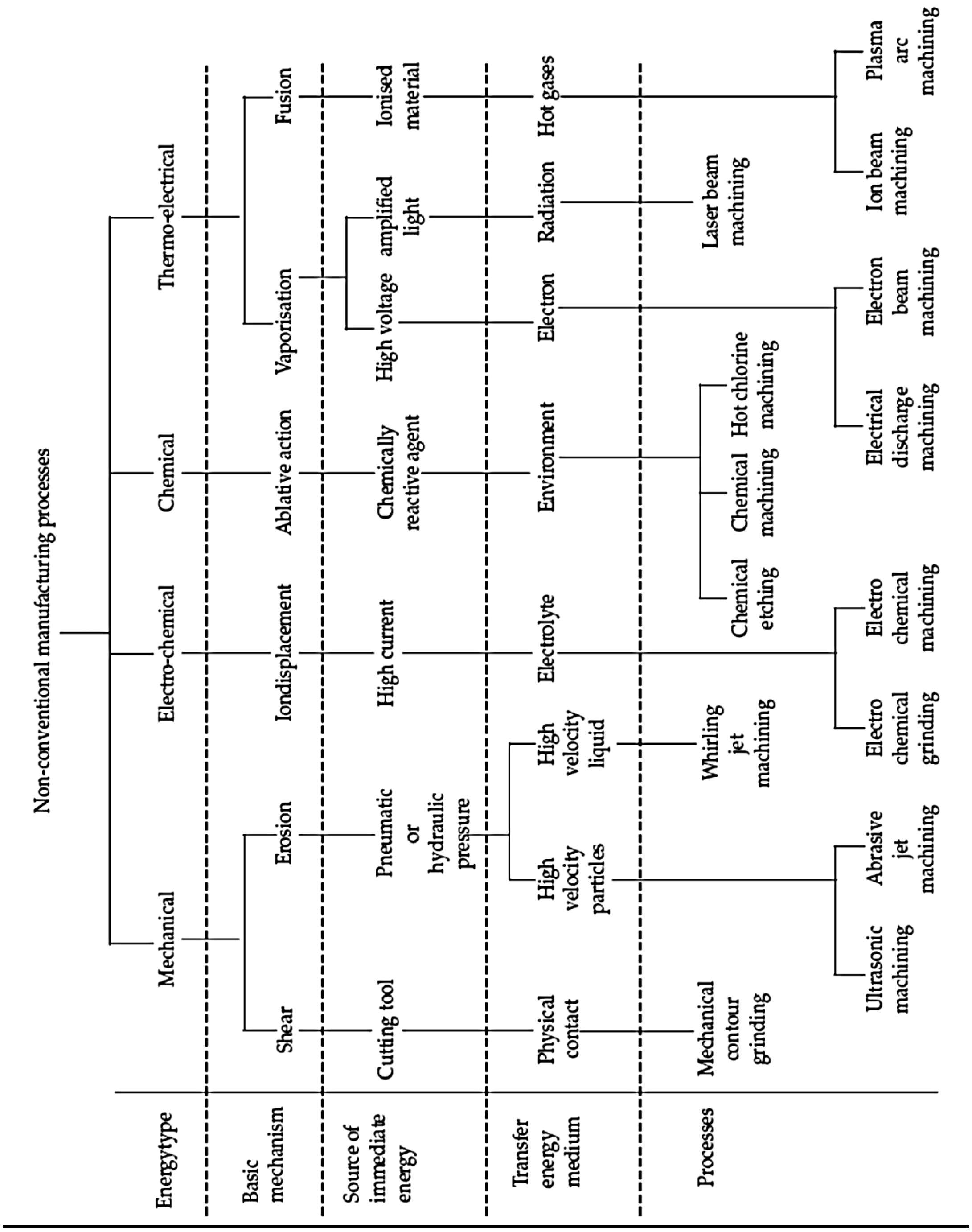
- ✓ Laser Beam Machining(LBM)
- ✓ Plasma Arc Machining(PAM)
- ✓ Electron Beam Machining(EBM)
- ✓ Ion Beam Machining (IBM)

v) Electro chemical energy methods

In these methods, material is removed by ion displacement of the work piece material in contact with a chemical solution. Examples

- ✓ Electro Chemical Machining (ECM)
- ✓ Electro Chemical Grinding(ECG)
- ✓ Electro Chemical Honing(ECH)
- ✓ Electro Chemical Deburring(ECD)

All methods are not suitable for all materials. Depending on the material to be machined, following methods can be used as shown in the table.



Applications, advantages and limitations of non-traditional machining processes

Applications

- Machining complex-shaped holes and cavities in molds and pieces;
- Various hard and brittle materials, such as hard alloy and hardened steel, are machinable.
- Processing fine deep holes, curved holes, deep grooves, narrow slits, and thin slices, among other things
- Cutting and measuring instruments like cutting tools, sample plates, and thread ring gauges are all machinable.

Advantages

- It has good accuracy.
- It provides a good surface.
- Complex shapes can be made easily.
- It has longer tool life.
- The rate of metal removal is high.

Disadvantage of unconventional machining process

- The cost of this process is high.
- It requires skilled operators.
- Its setup is difficult.

Abrasive Jet Machining (AJM)

4. Describe the Principle and Equipment for AJM.(May/June-11, 16)(Nov/Dec-13,15,16) (Nov/Dec-2004)

Explain the principle of AJM. Mention some of the specification. (April/May 2008)

Explain with neat sketch the working principle and parametral influence of abrasive jet machining.(Nov/Dec 2021)

Write its advantages and disadvantages. (April/May 2010) (April/May 2015. May 2019) (April/May 2012) (May/June 2008, 2014, 2021)

Abrasive Jet Machining (AJM)

Principle of AJM

- ✓ In abrasive jet machining process, a high speed stream of abrasive particles mixed with high pressure air or gas are injected through a nozzle on the workpiece to be machined.

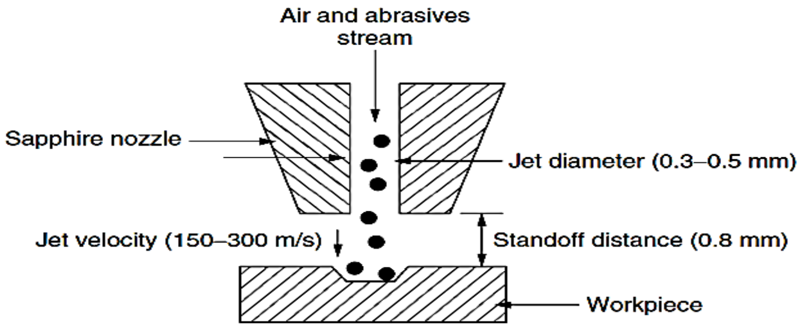


Fig: 2.1 Principle of AJM

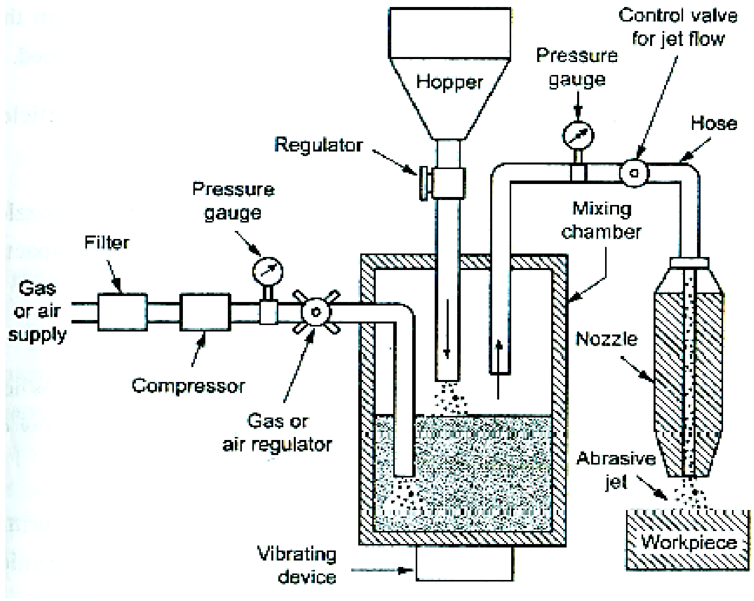


Fig: 2.2Equipment of AJM Process

Construction and Working of AJM

Construction:

The schematic arrangement of abrasive jet machine is shown in Fig.2.2.

- ✓ It consists of mixing chamber, nozzle, pressure gauge, hopper, filter, compressor, vibrating device, regulator, etc.

Abrasive jet:

- ✓ It is a mixture of a gas (or air) and abrasive particles. Gas used is carbon-di-oxide or nitrogen or compressed air. The selection of abrasive particles depends on the hardness and Metal Removal Rate (MRR) of the workpiece. Most commonly, aluminium oxide or silicon carbide particles are used.
- ✓ The various abrasive particles used in this process are aluminum oxide, silicon carbide, glass powder, dolomite and specially prepared sodium bicarbonate.

- Aluminum oxide (Al_2O_3) is a general purpose abrasive and it is used in sizes of 10, 25 and 50 micron Silicon carbide (Sir) is used for faster cutting on extremely hard materials.
- It is used in sizes of 25 and 50 microns. Dolomite of 200 grit size is found suitable for light cleaning and etching Glass powder of diameter 0.30 to 0.60 mm arc used for light polishing and deburring.

Mixing chamber:

- It is used to mix the gas and abrasive particles.

Filter:

- It filters the gas before entering the compressor and mixing chamber.

Compressor:

- Is a device is used to increase gas or air pressure.
- The gases generally used in this process are nitrogen, carbon dioxide or compressed air.

Hopper:

- Hopper is used for feeding the abrasive powder.

Pressure gauges and flow regulators:

- They are used to control the pressure and regulate the flow rate of abrasive jet.

Vibrator:

- It is provided below the mixing chamber. It controls the abrasive powder feed rate in the mixing chamber.

Nozzle:

- It forces the abrasive jet over the workpiece. Nozzle is made of hard and resistant material like tungsten carbide.
- As the nozzle is subjected to a great degree of abrasion wear, it is made up of hard materials such as tungsten carbide, synthetic sapphire (ceramic), etc., to reduce the wear rate.
- Nozzles made of tungsten carbide have an average life of 12 to 20 hours whereas synthetic sapphire nozzles have an average .life of 300 hours. Nozzle tip clearance from work is kept at a distance of 0.25 to 0.75 mm.
- The abrasive powder feed rate is controlled by the amplitude of the vibration of mixing chamber. A pressure regulator controls the gas or air flow and pressure. To control the size and shapeof the cut, either the workpiece or the nozzle is moved by a well-designed mechanism such as cam mechanism, pantograph mechanism, etc.

Working:

- Dry air or gas (N, or CO2) is entered into the compressor through a filter where the pressure of air or gas is increased. The pressure of the air varies from 2 kg / cm2 to 8 kg / cm2.

- ✓ Compressed air or high pressure gas is supplied to the mixing chamber through a pipe line. This pipe line carries a pressure gauge and a regulator to control the air or gas flow and its pressure.
- ✓ The fine abrasive particles arc collected in the hopper and fed into the mixing chamber. A regulator is incorporated in the line to control the flow of abrasive particles.
- ✓ The mixture of pressurized air and abrasive panicles from the mixing chamber flows into the nozzle at a considerable speed.
- ✓ Nozzle is used to increase the speed of the abrasive particles and it is increased upto 300 in / s.
- ✓ This high speed stream of abrasive particles from the nozzle, impact the workpiece to be machined. Due to repeated impacts, small chips of material get loosened and a fresh surface is exposed.
- ✓ A vibrator is fixed at the bottom of the mixing chamber. When it vibrates, the amplitude of the vibrations controls the flow of abrasive particles.
- ✓ This process is widely used for machining hard and brittle materials. Non-metallic materials (germanium, glass, ceramics and mica) of thin sections. This process is capable of performing drilling, cutting. Deburring, etching and cleaning the surfaces.
- ✓ Abrasive Jet Machining (AJM) process differs from sand blasting process. AJM is basically meant for metal removal with the use of small abrasive particles, whereas the sand blasting process is a surface cleaning process which does not involve any metal cutting.

Advantages of AJM

- ✓ Very thin and brittle materials can be cut without any risk of breaking.
- ✓ There is no direct contact between the tool and workpiece.
- ✓ Low initial investment.
- ✓ Good surface finish.
- ✓ It can be used to cut intricate hole shapes in hard and brittle materials.

Disadvantages of AJM

- ✓ Material removal rate is slow.
- ✓ Soft material cannot be machined.
- ✓ Machining accuracy is poor.
- ✓ Nozzle wear rate is high.
- ✓ The abrasive powder used in this process cannot be reused.

Applications of AJM

- ✓ Machining of hard and brittle materials like quartz. Ceramics, glass, sapphire. etc.

- ✓ Fine drilling and micro welding.
- ✓ Machining of semi-conductors.

<u>Water Jet Machining (WJM)</u>

5. Explain the principle of working and equipment of water jet machining with a neat diagram. (May/June-2012,2021) (Nov/Dec-2008,2014,2015,2018)

Introduction

- ✓ The key element in water jet machining (WJM) is a water jet, which travels at velocities as high as 900 m/s (approximately Mach 3).
- ✓ When the stream strikes a workpiece surface, the erosive force of water removes the material rapidly. The water, in this case, acts like a saw and cuts a narrow groove in the workpiece material.

Construction and working

The machining system

- ✓ Figure 2.19 shows the WJM system and the main parts of which it is composed.

Hydraulic pump

- ✓ The hydraulic pump is powered from a 30-kilowatt (kW) electric motor and supplies oil at pressures as high as 117bars in order to drive a reciprocating plunger pump termed an intensifier.
- ✓ The hydraulic pump offers complete flexibility for water jet cutting and cleaning applications. It also supports single or multiple cutting stations for increased machining productivity.

Intensifier

- ✓ The intensifier accepts the water at low pressure (typically 4 bar) and expels it, through an accumulator, at higher pressures of 3800 bar.
- ✓ The intensifier converts the energy from the low-pressure hydraulic fluid into ultrahigh-pressure water.
- ✓ The hydraulic system provides fluid power to a reciprocating piston in the intensifier centre section. A limit switch, located at each end of the piston travel, signals the electronic controls to shift the directional control valve and reverses the piston direction.
- ✓ The intensifier assembly, with a plunger on each side of the piston, generates pressure in both directions.

- ✓ As one side of the intensifier is in the inlet stroke, the opposite side is generating ultrahigh-pressure output.
- ✓ During the plunger inlet stroke, filtered water enters the high-pressure cylinder through the check value assembly. After the plunger reverses direction, the water is compressed and exits at ultrahigh pressure.

Accumulator

- ✓ The accumulator maintains the continuous flow of the high-pressure water and eliminates pressure fluctuations.
- ✓ It relies on the compressibility of water (12 percent at 3800 bar) in order to maintain a uniform discharge pressure and water jet velocity, when the intensifier piston changes its direction.

High-pressure tubing

- ✓ High-pressure tubing transports pressurized water to the cutting head. Typical tube diameters are 6 to 14 mm.
- ✓ The equipment allows for flexible movement of the cutting head. The cutting action is controlled either manually or through a remote-control valve specially designed for this purpose.

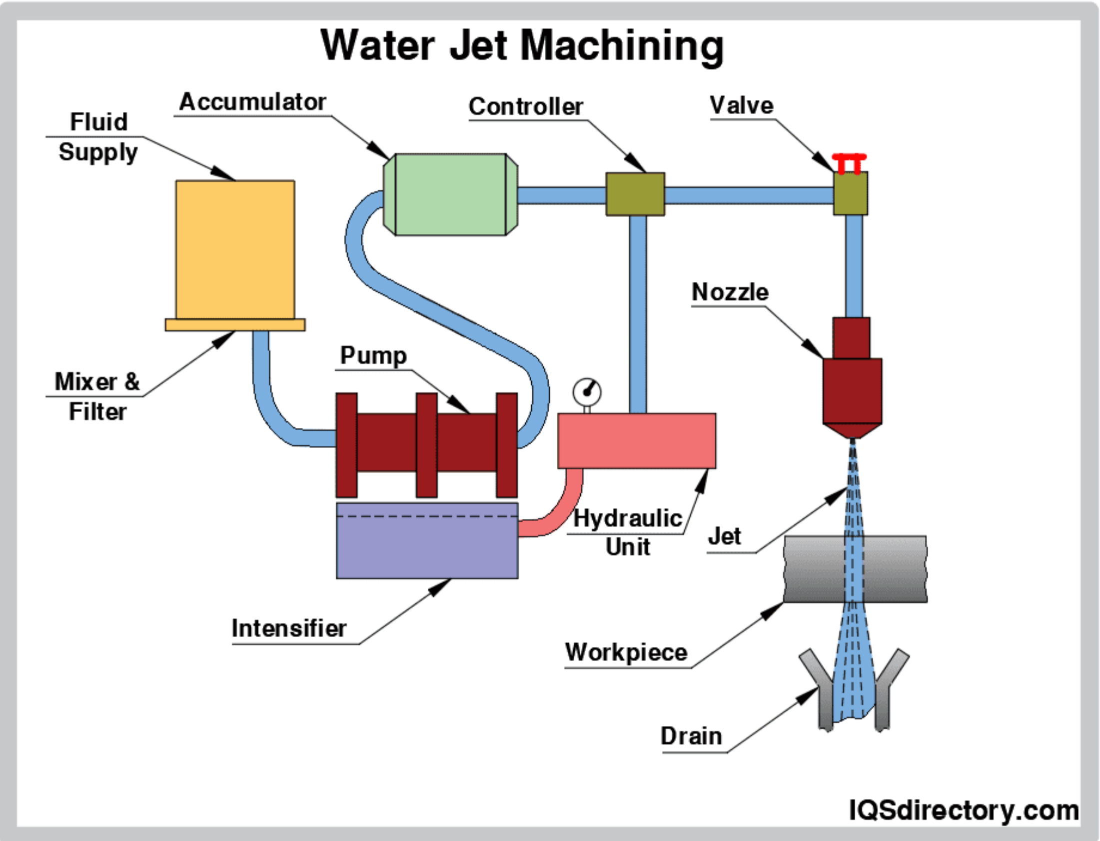


Fig: 2.6(a) Equipment of WJM / AWJM

Fig:2.6(b) Equipment of WJM / AWJM

Jet cutting nozzle

- ✓ The nozzle provides a coherent water Jet stream for optimum cutting of low-density, soft material that is consider machinable by conventional methods.
- ✓ Nozzles are normally made from synthetic sapphire. About 200 h of operation are expected from a nozzle, which becomes damaged by particles of dirt and the accumulation of mineral deposits on the orifice due to erosive water hardness.
- ✓ A longer nozzle life can be obtained through multistage filtration, which removes undesired solids of size greater than 0.45 μm.
- ✓ The compact design of the water jet cutting head promotes integration with motion control systems ranging from two-axis (XY) tables to sophisticated multi axis robotic installations.

Catcher

- ✓ The catcher acts as a reservoir for collecting the machining debris entrained in the water jet.
- ✓ Moreover, it reduces the noise levels [105 decibels (dB)] associated with the reduction in the velocity of the water jet from Mach 3 to subsonic levels.

Working of Water Jet Machining (WJM):

- ✓ Water from the reservoir is pumped to the intensifier using a hydraulic pump.
- ✓ The intensifier increases the pressure of the water to the required level. Usually, the water is pressurized to 200 to 400 MPa.
- ✓ Pressurized water is then sent to the accumulator. The accumulator temporarily stores the pressurized water.
- ✓ Pressurized water then enters the nozzle by passing through the control valve and flow regulator.
- ✓ Control valve controls the direction of water and limits the pressure of water under permissible limits

Advantages

- ✓ In WJM process, water is used as energy transfer medium. It is cheap, non-toxic and easy to dispose.
- ✓ Low operating cost.
- ✓ Low maintenance cost.
- ✓ The work area remains clean and dust free.

- ✓ Very less amount of heat is generated during cutting operation. So, there is no thermal damage to the work.
- ✓ Easily automated.

Disadvantages

- ✓ Initial cost of this process is high.
- ✓ It is difficult to machine and material.
- ✓ Noise operation.

Applications

- ✓ This process is very convenient for cutting relatively soft and non-metallic materials like paper boards, plastic, wood, rubber, leather, fiber glass, etc.
- ✓ It can be used to cut intricate contours.

<u>Ultra-Sonic Machining (USM)</u>

6. Explain the working principle and equipment of Ultra Sonic Machining with a neat sketch. Mention its applications, advantages and limitations. (May/June-2016) (Nov/Dec 2013) (May/June 2014) (Nov/Dec -14,15,16) (Nov/Dec 2019) (Apr/May-2023)

- ✓ Ultrasonic machining is one kind of grinding method.
- ✓ It is also known as ultrasonic grinding or impact grinding.
- ✓ The term ultrasonic refers to waves of high frequency.
- ✓ Human ear can hear the sound waves between 20 Hz to 20 kHz.
- ✓ This range is known as audible range.
- ✓ The sound waves which have frequencies less than the audible range are called infrasonic waves.
- ✓ The sound waves having frequencies above the audible range are known as ultrasonic waves.
- ✓ The ultrasonic machining process is suitable only for hard and brittle materials like carbides, glass, ceramics, silicon, precious stones. Germanium, titanium, tungsten, tool steels, die steels, etc.

Principle of USM

- ✓ In this machining method, a slurry of small abrasive particles are forced against the work piece by means of a vibrating tool and it causes the removal of metal from the work piece in the form of extremely small chips as shown in fig. 2.14.

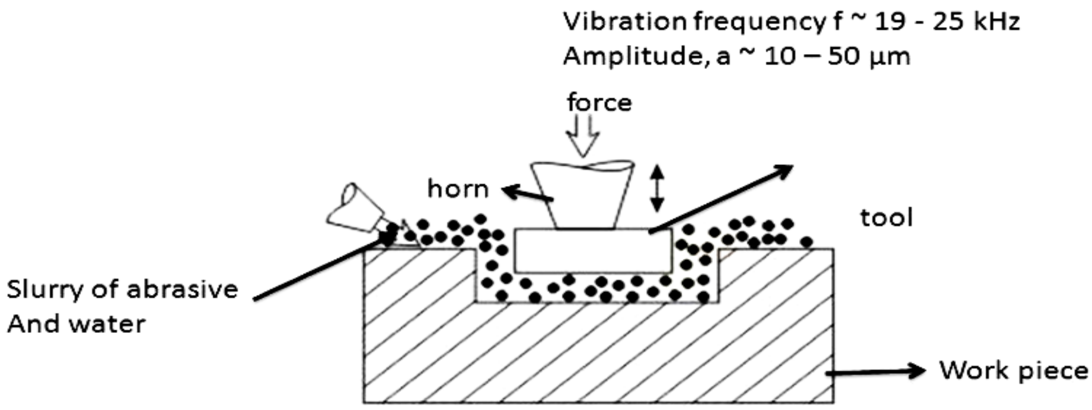


Fig: 2.14 Principle of USM process.

Construction of USM:

The general arrangement of ultrasonic machining is shown in Fig.2.12.

- ✓ It consists of abrasive slurry, workpiece, fixture, table, cutting tool, circulating pump reservoir, ultrasonic oscillator, leads, excitation coil, feed mechanism, ultrasonic transducer, transducer cone, connecting body and tool holder.
- ✓ The ultrasonic oscillator and amplifier also known as the generator is used to convert the applied electrical energy at low frequency to high frequency.
- ✓ The transducer is made up of magneto strictive material and it consists of a stack of nickel laminations that are wound with a coil.
- ✓ The function of the transducer is to convert electrical energy into mechanical energy.
- ✓ Generally tough and ductile tool material is used in this process. Low-carbon steels and stainless steels are commonly used as tool materials.
- ✓ The tool is brazed, soldered or fastened mechanically to the transducer through a tool holder. Generally tool holder is of cylindrical or conical in shape.
- ✓ The materials used for tool holders are titanium alloys. Monel, aluminium, stainless steel, etc.
- ✓ An abrasive slurry, usually a mixture of abrasive grains and water of definite proportion (20 — 30 percent), is made to flow under pressure through the gap between tool and workpiece.
- ✓ The gap between the tool and workpiece is of the order 0.02 to 0.1 mm.
- ✓ The most commonly used abrasives are boron carbide (B4C), silicon carbide (SiC), aluminium oxide (Al203), and diamond. Boron carbide is most commonly used abrasive slurry.
- ✓ Since it has the fastest cutting abrasive property.

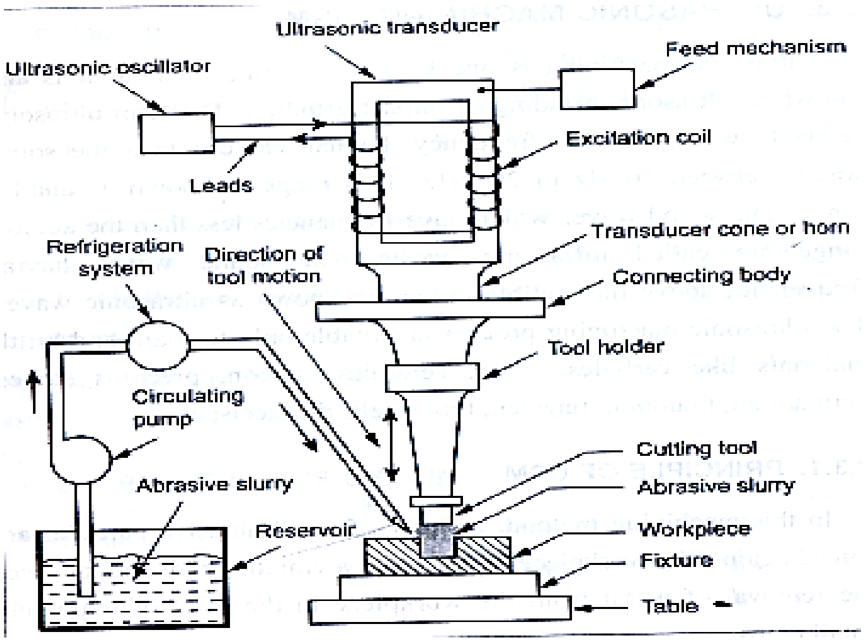


Fig: 2.15 Ultra Sonic Machining

Working of USM:

- ✓ Electric power is given to ultrasonic oscillator and this oscillator converts the electrical energy at low frequency to high frequency (20 kHz).
- ✓ High frequency power (20 kHz) from oscillator is supplied to the transducer.
- ✓ The function of the transducer is to convert the electrical energy into mechanical vibrations.
- ✓ The transducer is made up of magneto strictive material, which is excited by flowing high frequency electric current and these results in the generation of mechanical vibrations.
- ✓ The vibrations are generated in the transducer of the order of 20 kHz to 30 kHz and hence ultrasonic waves are produced.
- ✓ These vibrations are then transmitted to the cutting tool through transducer cone, connecting body and tool holder.
- ✓ This makes the tool to vibrate in a longitudinal direction as shown in Fig.2.I2.
- ✓ Abrasive slurry is pumped from the reservoir and it is made to flow under pressure through the gap between tool and work piece.
- ✓ In abrasive slurry, when the cutting tool vibrates at high frequency, it leads in the removal of metal from the workpiece.
- ✓ The impact force arises out from the vibration of tool end and the flow of slurry through the workpiece — tool gap causes thousands of microscopic grains to remove the workpiece material by abrasion.
- ✓ A refrigerated cooling system is used to cool the abrasive slurry to a temperature of 5 to 6°C.
- ✓ The ultrasonic machining process is a copying process in which the shape of the cutting tool is same as that of the cavity produced.

Applications

- ✓ Most successful USM application is machining of cavities (or holes) in electrically non-conductive ceramics.
- ✓ For this purpose hypodermic needles have been used as tools. USM has also been employed for multistep processing for fabricating silicon nitride ($Si_3 N_4$) turbine blades.
- ✓ In machining, wire drawing, punching or blanking of small dies
- ✓ Drilling small holes in helicopter power transmission shafts and gears.

Advantages of USM:

- ✓ In USM process, there are no physical, chemical or thermal changes. The microstructures reveal that there are also no structural changes as the stresses induced are too less.
- ✓ The cutting forces being low, work piece is unstressed, undistorted and free from heat effects.
- ✓ The process is free from burrs and distortions.
- ✓ The process is suitable for any materials, irrespective of electrical conductivity
- ✓ The process is very much suitable for machining brittle materials
- ✓ The process offers good surface finish and structural integrity.

Disadvantages / Limitations of USM:

- ✓ Soft materials like lead and plastics are not suitable for machining by the USM process, since they tend to absorb the abrasive particles rather than to chip under their impact.
- ✓ The USM process consumes higher power and has lower material-removal rates compared to traditional fabrication processes.
- ✓ The tool wear rate in USM process is fast.
- ✓ The areas of machining and higher depths are the constraints in USM.
- ✓ Due to this, the bottom surfaces of blind holes tend to become slightly concave.

UNIT II

Part-A

1. **State the principle of chemical machining process**

   In chemical machining process, material is removed from the work piece through a controlled etching or chemical attack of the work piece material.

2. **What are the parameters that affect the MRR in chemical machining? (May/June-2012)**

- Feed rate.
- Voltage.
- Concentration of the electrolyte.
- Temperature of the electrolyte.
- Current density.
- Velocity of the electrolyte.

3. **State the advantages of chemical machining. (May/June-2007)**

- ✓ Burr free components are produced.
- ✓ High surface finish is obtained.
- ✓ Any metal can be machined
- ✓ Tooling cost is very low

4. **What is meant by etch factor? (Apr/May-2008) ? (Nov/Dec2022)**

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

5. **Define electro chemical machining (ECM)? (Nov/Dec2004) Nov/Dec 2023**

   It is the controlled removal of metals by the anodic dissolution in an electrolytic medium, where the work piece (anode) and the tool (cathode) are connected to the electrolytic circuit, which is kept, immersed in the electrolyte medium.

6. **Write the Faraday's first law of electrolysis?**

   The amount of any material dissolved or deposited is proportional to the quantity of electrolyte passed.

7. **Write the Faraday's second law of electrolysis? (May/June-2021)**

   The amount of different substances dissolved or deposited by the same quantity of electricity are proportional to their chemical equivalent weight.

8. **What are the materials used to make the tool electrode in ECM? (Apr/May-2005)**

Copper and copper alloys, titanium, aluminum, brass, bronze, carbon, Monel and reinforced plastic

9. **Write the difference between Chemical Machining and Electro Chemical Machining. (Apr/May-2011)**

Chemical machining	**Electro Chemical machining**
The material is removed from the work piece through a controlled etching or chemical attack of the work piece material	Material is removed by ion displacement of the of work piece material in contact with the chemical solution

10. **What are the main functions of electrolysis in the ECM? (May/June-2006 & Nov/Dec-2006) (May/June 2014) (Nov/Dec 2014)**

- ✓ For completing the electric circuit between the tool and the work piece and to allow the reaction to proceed efficiently.
- ✓ To remove the products of machining from the cutting region.
- ✓ To carry away the heat generated during the chemical reaction.
- ✓ To avoid ion concentration at the work piece- tool gap.

11. **What are the properties expected from the electrolysis used in the ECM? (Nov/Dec-13)(May/June-16)**

- ✓ High thermal conductivity.
- ✓ Low viscosity and high specific heat.
- ✓ Should chemically stable even at high temperature.
- ✓ Should be non-toxic and non-corrosive.

12. **What are the electrolytes commonly used in ECM? (Apr/May-2005, May/June-2007)**

15 -20 % NaCl in water, sodium nitrate, potassium nitrate, sodium sulphate, sodium chromate and potassium chloride.

13. **What are the different types ECM operations? (May/June-2021)**

i) Electro Chemical Machining (ECM)
ii) Electro Chemical Grinding (ECG)
iii) Electroplating
iv) Electro Chemical Honing (ECH)

14. **What are the process parameters of ECM? (Apr/May-2005)(Or)List the factors that affect MRR in ECM? (Nov/Dec-16)**

- ➢ Current density

- Gap between tool and work piece
- Type of electrolyte use
- Tool feed rate.

15. What is the self-adjusting feature in ECM? (Apr/May-2008)

In steady state or equilibrium condition with a constant feed, the gap remains constant. Whatever the initial gap is given, it tends to a unit gap. I.e. equilibrium is reached.

In a constant feed rate ECM system, the machine process is inherently self-regulated since the metal removed rate tends to approach the feed rate.

16. Please identify the principle of ECM. How does it differ from electroplating? (Nov/Dec-2008, May/June-16, Apr/May-2010)

- When a D.C potential is applied across two electrodes separated by a small gap and an electrolyte is pumped through the small gap.
- The constituents of the anode work piece material goes into the solution and not plated on the cathode tool. Electroplating is the reverse of ECM where the cathode is plated by the depleted metal from the anode. (or)
- In electroplating the main attention is paid to the deposition process i.e. to the reaction occurring at the cathode whereas in ECM the anodic dissolution process is most important.

17. What are the advantages of ECM? (Nov/Dec-13)(May/June-16) (Apr/May-2023)

- ECM is simple, fast and versatile method.
- Surface finish can be extremely good.
- Fairly good tolerance can be obtained.

18. What are the limitations of ECM? (Nov/Dec-2007)(Nov/Dec-2013)(May/June-16)

- Large power consumption and the related problems.
- Sharp internal corners cannot be answered.
- Maintenances of higher tolerances require complicated contours.

19. What are the applications of ECM? (Nov/Dec2006)

ECM is used for sinking, profiling and contouring, multi hole drilling, trepanning, broaching, honing, steel mill applications, surfacing, sawing, contour machining of hand to hand machine materials.

20. Define masking in electro chemical machining. (Nov/Dec 2021)

What is meant by maskant in CHM/ECM? (Apr/May-15)

In the chemical machining process, the areas of the work piece which are not to be machined are covered with a resistant material is called masking, a applied masking material is called resistant or maskant.

21. List out the types of etchants used in chemical machining. (or) What are the etchants in chemical machining process? (Nov/Dec-15,2021)

S. No	Material	Etchant
1.	Aluminum	Caustic Soda
2.	Steel	Nitric Acid
3.	Stainless Steel	Iron Chloride
4.	Titanium	Nitric Acid

22. List the commonly used maskant in Chemical Machining Process. (May/June2013)

S. NO	Material	Maskant
1	Aluminium	Butyl rubber, Neoprene rubber
2	Magnesium	Polymers
3	Titanium	Translucent chlorinate polymers
4	Nickel	Neoprene

23. What are the important functions of abrasive particles used in ECG?

It acts as an insulator to maintain a small gap between the wheel and work piece. They are electrolysis products from the working area. To cut chips, the wheel should contact the work piece particularly in the event of power failure.

- ✓ To grind end mill cutters more precisely.

24. Why the life of Electro Chemical Grinding (ECG) wheel is much higher than Conventional grinding wheel? (Apr/May-2011) (Nov/Dec 2022)

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

25. List the applications of Electro Chemical Honing (ECH). (Apr/May-2010, Apr/May-2015)

- ➢ Salvaging out of tolerance part and reconditioning worn surface.
- ➢ Very precision grinding of hard metal like tungsten carbide tool tip, High speed tool steel.
- ➢ Cutting the thin section of hare material without any damaging.

26. Write the formula for finding the MRR in ECG process. (May/June2013)

The metal removable rate (MRR) =E I /F A ρ

Where:

E=Equivalent weight of substance dissolved.

I= Current flow through the electrolyte (amp)

F= Faraday's constant (Coulombs)

ρ= Density of work material kg/m^3

27. How does electrochemical deburring take for electrochemical grinding? Nov/Dec 2023

Electrochemical deburring is primarily used for removing burrs from the edges of workpieces, while electrochemical grinding involves material removal through abrasion and grinding using an electrochemical process. The former focuses on burr elimination, while the latter is a more versatile process for precision material removal in grinding applications.

Part-B & C (13 and 15 Mark Questions)

1. **Explain the principle of working, equipment, Applications, Advantages and drawbacks of chemical machining and chemical milling (May/June-13, 16)(Nov/Dec-13, 15 Apr/May-15) (Apr/May-2023)**

INTRODUCTION:

- ✓ Chemical machining is a well-known non-traditional machining process.
- ✓ It is controlled chemical dissolution of the machined work piece material by contact with a strong acidic or alkaline chemical reagent.
- ✓ Special coatings called maskant protect areas from which the metal is not to be removed.
- ✓ The process is used to produce pockets and contours and to remove materials from parts having a high strength-to-weight ratio.
- ✓ Moreover, the machining method is widely used to produce micro-components for various industrial applications such as micro electro mechanical systems (MEMS) and semiconductor industries.

Steps in chemical machining:

Chemical machining process has several steps for producing machine parts. They are:

i) Work piece preparation:

- ✓ The work piece material has to be cleaned in the beginning of chemical machining process.
- ✓ The cleaning operation is carried out to remove the oil, grease, dust, rust or any substance from the surface of material.
- ✓ A good cleaning process produces a good adhesion of the masking material. There are two cleaning methods; mechanical and chemical methods.
- ✓ The most widely used cleaning process is chemical method due to less damages occurred comparing to mechanical one.
- ✓ Ultrasonic cleaning machine is applied with using special cleaning solution and heating is beneficial during the cleaning process.

ii) Coating with masking material:

- ✓ The next step is the coating cleaned workpiece material with masking material.
- ✓ The selected masking material should be readily strippable mask, which is chemically impregnable and adherent enough to stand chemical abrasion during etching.

iii) Scribing of the mask:

- ✓ This step is guided by templates to expose the areas that receive chemical machining process.
- ✓ The selection of mask depends on the size of the workpiece material, the number of parts to be produced, and the desired detail geometry.

- ✓ Silk-screen masks are preferred for shallow cuts requiring close dimensional tolerances.

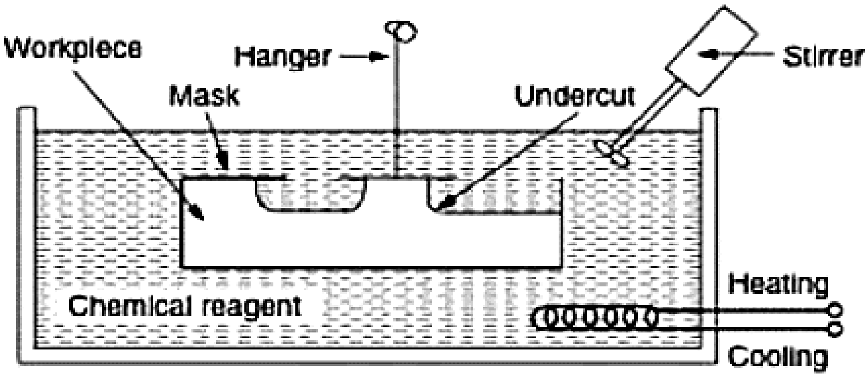


Fig 4.1 Typical chemical machining set-up

iv) Etching

- ✓ This step is the most important stage to produce the required component from the sheet material.
- ✓ This stage is carried out by immerse type etching machine (Fig 4.1).
- ✓ The work piece material is immersed into selected etchant and the uncovered areas were machined.
- ✓ This process is generally carried out in elevated temperatures which are depended on the etched material.
- ✓ Then the etched work piece is rinsed to clean etchant from machined surface.

v) Cleaning masking material:

- ✓ Final step is to remove masking material from etched part.
- ✓ The inspections of the dimensions and surface quality are completed before packaging the finished part.

Table.4.1 Different Work Piece Materials and Etchants

Material	**Chemical etchant**
Aluminum and alloys	$FeCl_3$
Copper and alloys	$FeCl_3$,$CuCl_2$,Alkaline etchants
Steel	$FeCl_3$
Nickel	$FeCl_3$
Titanium	HF
Magnesium	HNO_3

Glass	$HF+HNO_3$
Silicon	HNO_3+HF+H_2O

Advantages of chemical machining:

- ✓ Easy weight reduction
- ✓ No effect of workpiece materials properties such as hardness
- ✓ Simultaneous material removal operation
- ✓ No burr formation
- ✓ No stress introduction to the workpiece
- ✓ Low capital cost of equipment
- ✓ Easy and quick design changes
- ✓ Requirement of less skilled worker
- ✓ Low tooling costs
- ✓ The good surface quality
- ✓ Using decorative part production
- ✓ Low scrap rates (3%).

Disadvantages of chemical machining:

- ✓ Difficult to get sharp corner
- ✓ Difficult to chemically machine thick material (limit is depended on workpiece material, but the thickness should be around maximum 10 mm)
- ✓ Scribing accuracy is very limited, causes less dimensional accuracy
- ✓ Etchants are very dangerous for workers
- ✓ Etchant disposals are very expensive

Electro-Chemical Machining

2. Explain the principle of working, equipment's, Applications, Advantages and drawbacks of Electro chemical machining (May/June-14,16, 21)(Nov/Dec-16) (Apr/May-2015) (Nov/Dec 2021)

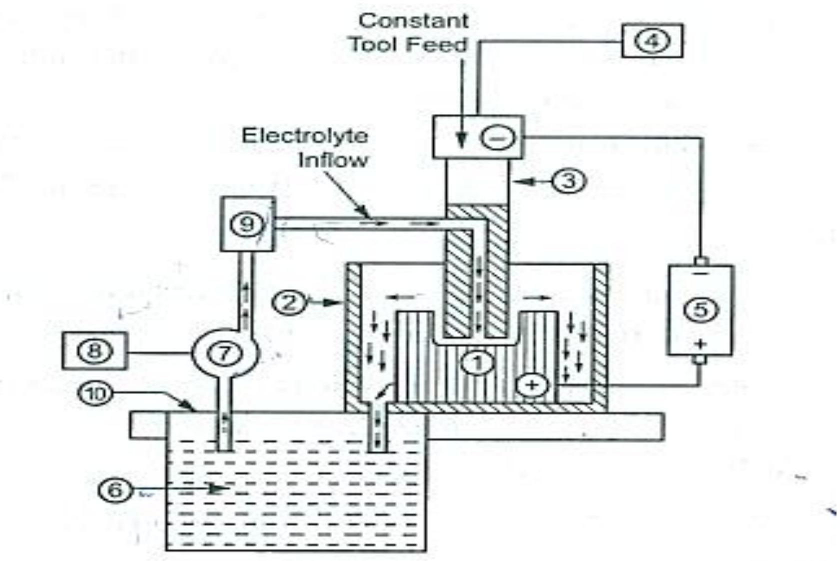
Electro-chemical machining:

Introduction

- ✓ 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.

Construction of ECM Process

- ✓ 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 work piece 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 mach inability.
- ✓ The widely used tool materials are stainless steel, titanium, brass and copper.
- ✓ The tool is of hollow tabular type and an electrolyte is circulated between the work and tool.
- ✓ Most widely used electrolyte in this process is sodium nitrate solution.
- ✓ 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.



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

Fig.4.5 Electrochemical Machining

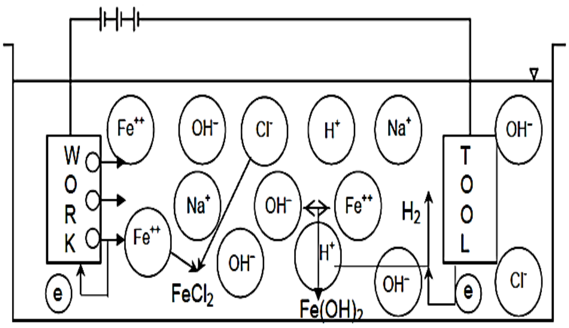
Working of ECM Process

- ✓ The tool and work piece are held close to each other with a very small gap (0.05 to 0.5mm) 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.

$$NaCl \leftrightarrow Na^{+} + Cl^{-}$$

$$H_2O\ H \leftrightarrow^{+} + (OH)^{-}$$

$$2H^{+} + 2e^{-} = H_2\uparrow \text{ at cathode}$$



Advantages

- ✓ Tool wear is negligible.
- ✓ Machining done at low voltage.
- ✓ Machined surface is free from stresses.
- ✓ Very thin sections can be machined.
- ✓ No burrs formed.
- ✓ Machining rate is not affected by material hardness and strength.

Disadvantages

- ✓ Non-conducting materials cannot be machined.
- ✓ Higher power consumption.
- ✓ Slow machining rate.

- ✓ More space required.
- ✓ Design of proper tooling is difficult.
- ✓ Not environmentally friendly (sludge and other waste).

Applications

- ✓ ECM can machine any electrically conductive work material irrespective of their hardness, strength or even thermal properties.
- ✓ Moreover as ECM leads to atomic level dissolution, the surface finish is excellent with almost stress free machined surface and without any thermal damage.
- ✓ ECM is used for
- ❖ Die sinking
- ❖ Profiling and contouring
- ❖ Trepanning
- ❖ Grinding
- ❖ Drilling
- ❖ Micro-machining

<u>Electro Chemical Grinding (ECG)</u>

3. Explain the principle, working, equipment's and Applications of Electro Chemical Grinding (May/June-10, 12, 15, 16, 21), (Nov/Dec-13, 15, 16) (Nov/Dec 2021) (Apr/May-2023)

Introduction

The materials which cannot be easily shaped due to their extreme hardness or high tensile strength can be ground by using Electro-chemical grinding process.

Examples: Cemented carbides, hardened steel etc.,

Principle

- ✓ In Electrochemical grinding method, the work is machined by the combined action of electrochemical effect and conventional grinding operation.
- ✓ But the major portion of the metal (about 90%) is removed by electrochemical effect.
- ✓ Electro Chemical Grinding is combination of conventional grinding and Electro Chemical Machining.
- ✓ Extremely difficult to machine material like cemented carbides, tool steel can be ground by ECG.

Construction of ECG process:

- ✓ It consists of workpiece, work table, grinding wheel, spindle, D.C power source, 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 bearings.
- ✓ The work piece 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 Fig.4.9.
- ✓ Sodium nitrate, sodium chloride and potassium nitrate with a concentration of 0.150 to 0.300 kg/ litre 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.

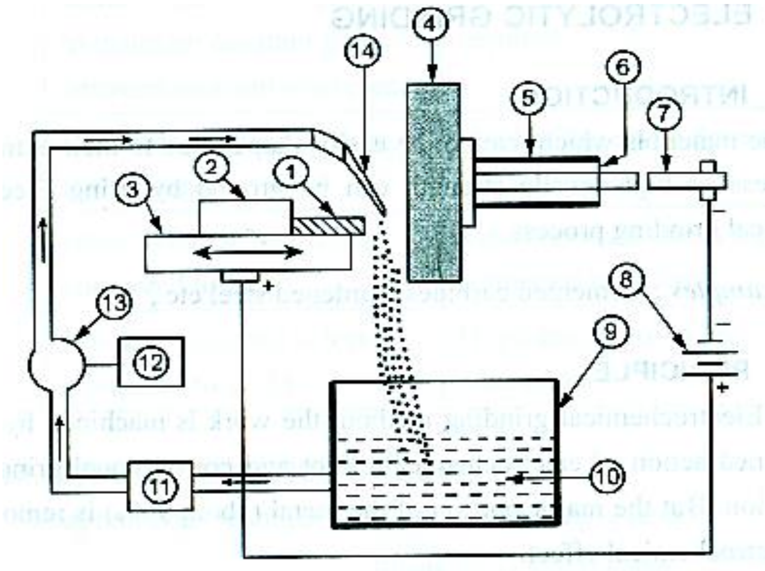


Fig.4.9 Electro Chemical Grinding (ECG)

- ✓ The grinding wheel is made 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 to 1800 m/min.
- ✓ The work piece is connected to positive terminal (anode) of battery and grinding wheel is connected to negative terminal (cathode).

Working of ECG Process:

- ✓ A mild D.C voltage of about 3 to 30 V is applied between the grinding wheel 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 grinding wheel (cathode) while the negative ions move towards the 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.
- ✓ It can be seen that the work piece 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 work piece 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.
- ✓ Short-circuit between the wheel and work is prevented due to point contact made by the fine diamond points.

Advantages of ECG

- ✓ 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 arc 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 work piece.
- ✓ Good surface finish is obtained.

Disadvantages

- ✓ Initial cost is high.
- ✓ Power consumption is high.
- ✓ Metal removal rate is lower than conventional grinding.
- ✓ Non-conducting materials cannot be machined.
- ✓ Preventive measures are needed against corrosion by the electrolyte.

Applications

It is best suited for,

- ❖ Very precision grinding of hard metals like tungsten carbide tool tips, high speed steel tools.
- ❖ Cutting thin sections of hard materials without any damage or distortion.

Electro Chemical Honing (ECH)

4. Explain Electro chemical Honing process with neat sketch? (May/June-16) (Nov/Dec-14,15)

INTRODUCTION

- ✓ 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 of Electro Chemical Honing Process

- ✓ The schematic arrangement of Electro-Chemical honing machine is shown in Fig.4.7.
- ✓ The work piece is connected to positive terminal (anode) of battery and tool is connected to negative terminal (Cathode).
- ✓ The gap between the tool and the work piece is usually maintained between .075 to 0.125 mm at the start of the cycle. It increases by the amount of stock removal per cycle upto 030 mm.
- ✓ Electrolyte is passed between the tool and work piece through several rows of small holes in the tool body.

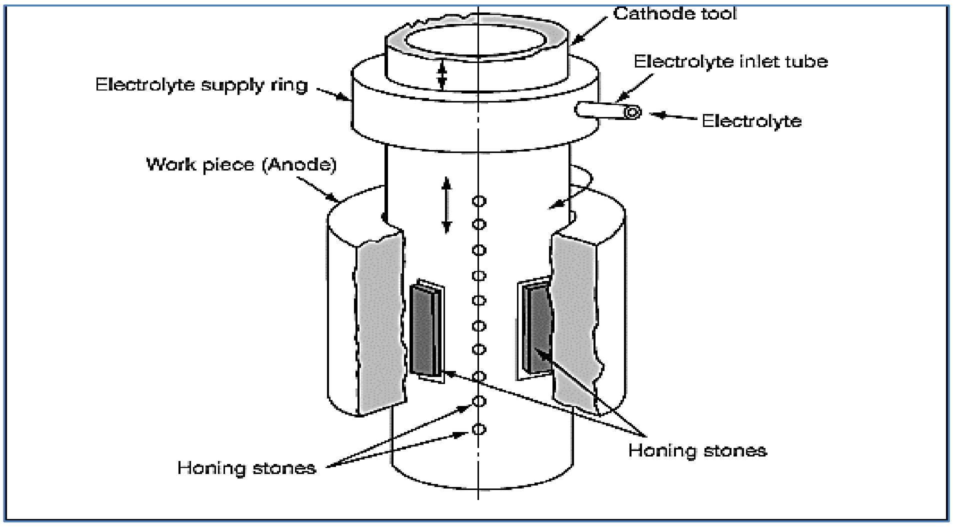


Fig. 4.10 Electro chemical Honing process

- ✓ Electrolyte is supplied about 112lit/min under a pressure of upto 1.05 N/mm^2 depending upon the work piece 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 of Electro Chemical Honing Process

- ✓ A mild D.0 voltage of about 25V is applied between the honing 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 honing tool (cathode) while the negative ions move towards the work piece (anode).
- ✓ The electrochemical reaction takes place due to this flow of the ions and it causes the removal of metal from the work piece.
- ✓ It can be seen that work piece (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 time faster than the conventional honing
- ✓ Burr free and stress free component are produced. It is used for machining burred edges.
- ✓ Noise and distortion are reduced when honing thin walled tube.

Applications:

- ✓ Honing thin walled tubes, Internal cylindrical grinding

<u>Electro Chemical Deburring process</u>

5. Briefly discuss Electro Chemical Deburring process? (Nov/Dec 2014)

- ✓ 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 is solves 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.
- ✓ 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.

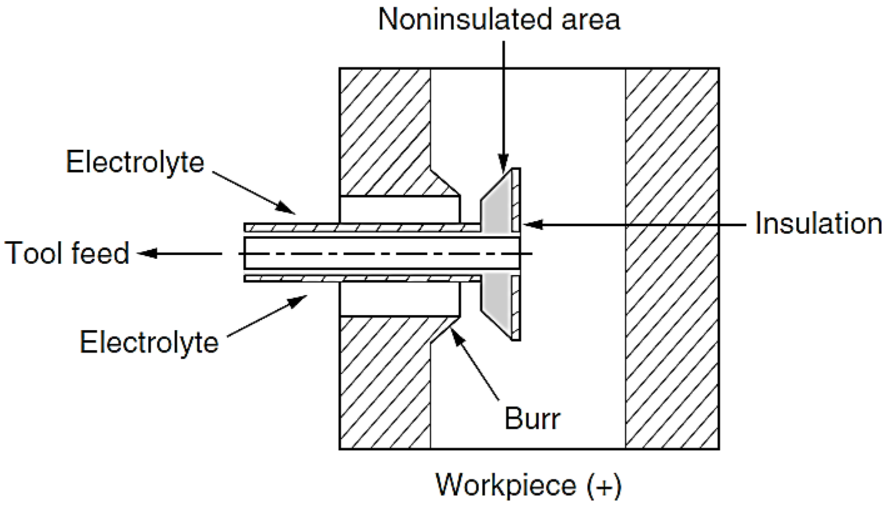


Fig. 4.11HoleDeburring

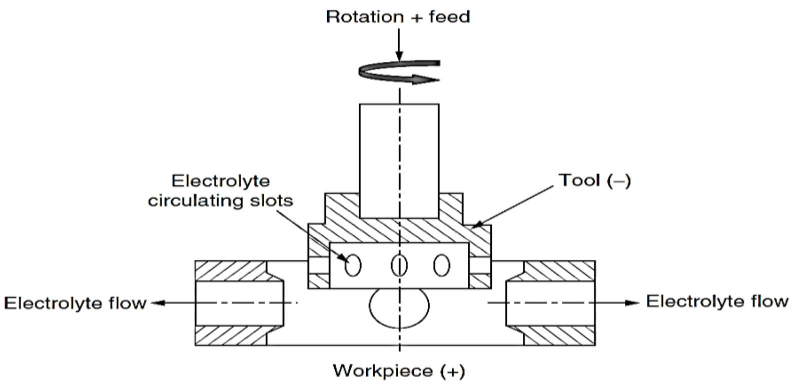


Fig. 4.12 Electrochemical Deburring

- ✓ In simple Deburring when the tool is placed over the workpiece, a burr height of 0.5 mm can be removed to a radius of 0.05 to 0.2 mm leaving a maximum surface roughness of 2 to 4 μm
- ✓ When burrs are removed from intersections of passages in housing, the electrolyte is directed and maintained under a pressure of 0.3 to 0.5 M Pa using a special tool.
- ✓ That tool has as many working areas as practical so that several intersections are deburred at a time. Proper tool insulation guarantees the flow of current in areas nearby the burr.
- ✓ The Deburring tool should also have a similar contour of the work part thus leaving a 0.1 to 0.3 mm inter electrode gap.
- ✓ Moreover the tool tip should overlap the machined area by 1.5 to 2 mm in order to produce a proper radius.
- ✓ The choice of the electrolyte plays an important role in the Deburring process.

- ✓ Table 4.5 presents different electrolytes and the operating conditions for ECDB of some materials.
- ✓ ECDB power units supply a maximum current of 50 A.
- ✓ However, power units having 500 Aare used to remove burrs generated by turning and facing operations on large forged parts.

Advantages

- ➢ Elimination of costly hand Deburring
- ➢ Increase of product quality and reliability
- ➢ Ensures the removal of burrs at the required accuracy, uniformity, proper radius, and clean edge
- ➢ Reduced personnel and labour cost
- ➢ can be automated for higher productivity

UNIT – III

THERMAL AND ELECTRICAL ENERGY BASED PROCESSES

Part A (2 Marks)

Electric Discharge Machining (EDM)

1. **What is the working principle of Electrical discharge machining process?**

   In electrical discharge machining process, metal is removed by producing powerful electric spark discharge between the tool (cathode) and the work material (anode).

2. **How the tool materials are classified in EDM? (May / June 2007)**

   Tool or electrode can be classified into four groups

   1. Metallic electrodes - Brass, Copper tungsten, Chromium copper, Aluminium tungsten, Silver tungsten
   2. Non-metallic -Graphite
   3. Combined metallic and non-metallic - Copper graphite
   4. Metallic coating as insulators - Copper on moulded plastic and copper on ceramic

3. **Brief the material removal mechanism in EDM process. (Apr/May-2023)**

   Material removal in EDM occurs through controlled electrical discharges (sparks) between the tool and workpiece, creating a conductive plasma channel that melts and vaporizes the material, while dielectric fluid flushes away debris, resulting in precise erosion of the workpiece.

4. **Define tool wear ratio. Or Define the tool wear ratio in EDM.(Nov/Dec 2022)**

   The wear ratio is defined as the ratio of volume of work material removed to the volume of electrode (tool) consumes.

   $$\textbf{Tool wear ratio} = \frac{\text{Volume of the work material removed}}{\text{Volume of electrode consumed}}$$

5. **Mention few types of power supply circuits used in EDM? (Nov./Dec. 2007, 2008, May/June-2021)**

   - Resistance-capacitance circuit (R-C)
   - R-L-C circuit
   - Rotary pulse generator circuit
   - Controlled pulse generator circuit

6. **What the dielectric fluids commonly used in EDM?**

   What kind of dielectric fluid is commonly used in wire electric discharge machining? Nov/Dec 2023

   - Petroleum based hydrocarbon fluids.

- Paraffin, white sprite, transformer oil.
- Kerosene, mineral oil.
- Ethylene glycol and water miscible compounds.

7. **What are the various materials of which electrode are made for EDM process and what are their advantages? (Nov/Dec 2021)**
   - Electrode for EDM process are usually made of fine grain carbon i.e. graphite or a mixture of carbon-copper as there are cheap and can be easily machined to any shape.
   - Sometimes copper, brass, copper-tungsten and silver tungsten electrodes can also be used.
   - Copper-tungsten and silver-tungsten electrodes are having the advantage of excellent finish, tough difficult to shape. It is most important that the material of electrode should be same as of work piece.
8. **What are the desirable properties of good dielectric fluid? (Nov / Dec 2005), (Apr / May 2010)**
   - It does not conduct electricity
   - It must not be hazardous
   - It must be non- corrosive to equipment
   - It should act as an insulating medium
9. **What are the functions of an adoptive control system used for EDM?(April / May 2008) (May/ June 2012)**

   The main function of adaptive control system is to maintain a very small gap known as spark gap ranges from 0.005 to 0.05 mm between work piece and tool.
10. **What is the principle of operation of wire-cut EDM process? (Nov/ Dec 2008)**

    In wire cut EDM, the metal is removed by producing powerful electric spark discharge between the tool (cathode) and the work material (anode). A very thin wire (0.02 to 0.3mm) made of brass or molybdenum having circular cross section is used as electrode.

11. State the difference between the wire cut EDM and EDM.(Nov/ Dec 2006)

Sl.No	Wire cut EDM	EDM
1	Very thin wire made of brass or molybdenum is used as the electrode (tool)	Expensive alloy of silver and Tungsten are used as the electrode (tool) which are traditionally made by cutting and grinding.
2	The whole workpiece is not submerged in dielectric medium instead the working zone alone is supplied with a co-axial jet of dielectric medium.	The whole work piece is submerged in dielectric medium.
3	It is easy to machine complex two dimensional profiles	It is difficult to cut complex two dimensional profiles.

12. What is the principle of LBM? (Nov/Dec-2005, 15)

In laser beam machining the powerful, monochromatic, collimated laser beam is focused on the work piece. The focused laser beam melts and vaporizes the work material.

13. State the characteristics of laser beam. (Nov/Dec-2006) (Nov/Dec-13)

- ✓ High intensity
- ✓ Monochromatic
- ✓ Highly Coherent

14. State the types of lasers used in manufacturing operation. (Nov/Dec 2021)

There are several types of lasers used for different purposes. (e.g.)

- ✓ Solid state laser,
- ✓ Gas laser.
- ✓ Liquid laser and
- ✓ Semi-conductor laser.

In general, only the solid state lasers can provide the required power levels.

15. What is meant by laser beam drilling? (Apr/May-15)

Laser drilling is a process in which a laser is used to make holes, instead of conventional drilling. Lasers can be used to drill holes in a variety of materials, ranging from wood and plastics to metals and ceramics.

Typical examples of laser drilled holes are practical applications in cooling holes of aero-engine components, holes in fuel injection nozzles and ink-jet printer heads.

16. What do you mean by plasma? (Nov/Dec-2016)

When a flowing gas is heated to a sufficiently high temperature of the order of 11, 000^{0}C to 28000^{0}C it becomes partially ionized and this ionized gas is known as plasma.

17. What is the principle of PAM? (May/Jun-2009), (May/Jun-2016)

- In plasma machining process, material is removed by directing a high velocity jet of high temperature (11000^{0}C to 28000^{0}C) ionized gas on the work piece.
- In PAM the high temperature plasma (ionized gas) melts and blasts away the work material.

18. Can you machine electrically non-conductive materials by PAM? Justify your answer. (Apr/May-2011)

Yes, Indirect Arc plasma torches can be used for machining electrically non-conductive materials

19. What is transferable and non-transferable arc in Plasma Arc Machining? (Nov/Dec-2004)(May/Jun-2012)

Differentiate between transferred and non-transferred are plasma **(Nov/Dec-2022)**

Transferable Arc	**Non-Transferable Arc**
The work piece is directly connected to the positive terminal.	The positive terminal connected to the nozzle instead of work piece.
Used for conductive materials	Used for non-conductive materials

20. List any two gases used in PAM. (Apr/May-2005)

- ✓ Hydrogen
- ✓ Nitrogen
- ✓ Argon

21. Write the advantages of Plasma Arc Machining? (May/Jun-14)

- ✓ It can virtually cut any material.
- ✓ High cutting rate.
- ✓ It is used for rough turning and milling of hard and difficult to cut materials.
- ✓ Reasonable surface quality.

22. What are the limitations of EBM? (Nov/Dec-2004) (Apr/May-2023)

- ✓ The primary limitations are the high capital cost of the equipment and necessary regular maintenance applicable for any equipment using vacuum system.

- ✓ Moreover in EBM there is significant amount of non-productive pump down period for attaining desired vacuum.
- ✓ Though heat affected zone is rather less in EBM but recast layer formation cannot be avoided.
- ✓ Skilled operator is required for operation.
- ✓ Limited to 10mm material thickness.

23. Contrast LBM and EBM. (Nov/Dec-2005), (May/Jun 2014) (Nov/Dec 2016)

LBM	EBM
Material is removed by high intensity LASER beam	Material removal is done by high velocity of electrons
Limited for only thin materials	Used for micro drilling, narrow slots

24. Why vacuum is needed in Electron Beam Machining Processes? (May/Jun-2009), (Apr/May-2011)

In order to avoid collision of accelerated electron with air molecules, vacuum is required.

25. What are the techniques used for controlling beam in EBM Process (May/Jun-2016,Apr/May- 2015)

Here are two types of techniques used to control the beam in EBM Process. They are

- ✓ Thermal type
- ✓ Non-thermal Type.

Thermal type EBM:

In this type the electron beam is used to heat the material up to the point where it is selectively vaporized.

Non-thermal type EBM:

In this type, the EBM produces a chemical reaction.

PART-B (13 Marks and 15 marks)

Electric Discharge Machining (EDM)

1. **Explain the EDM process and list its advantages, disadvantages and applications (Nov/Dec-2008, 2016), (Apr/May-20011, 2014, 2016) (Nov/Dec 2021)**

Working Principle Of EDM

In electrical discharge machining (also known as spark erosion machining or electro-erosion machining), metal is removed by producing powerful electric spark discharge between the tool (cathode) and the work material (anode). This principle is followed in this process.

CONSTRUCTION

- ✓ The main components are the electric power supply, dielectric medium, work piece, tool and a servo control mechanism.
- ✓ The work piece and the tool are electrically connected to a D.C. power supply.
- ✓ The work piece is connected to the positive terminal of the electric source, so that it becomes the anode. The tool is connected to the negative terminal of the electric source, so that it becomes the cathode.
- ✓ The tool and workpiece are submerged in a dielectric fluid medium such as paraffin, white spirit or transformer oil having poor electrical conductivity.
- ✓ The function of the servo mechanism is to maintain a very small gap, known as 'spark gap' ranges of 0.005 to 0.05 mm between the work piece and the tool.

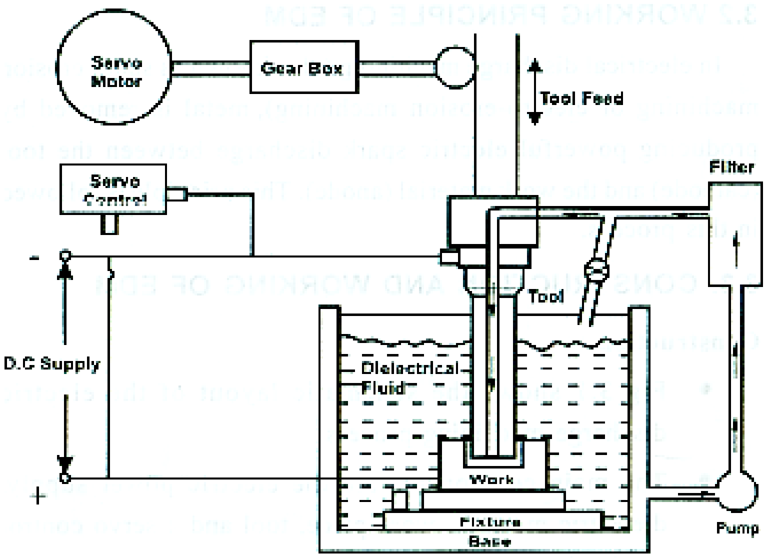


Fig. 3.1Schematic diagram of EDM process

Working:

- ✓ When the D.C supply is given to the circuit, spark is produced across the gap between the tool and the work piece.
- ✓ When the voltage across the gap becomes sufficiently larger (more than 250 V), the high power spark is produced. So, the dielectric breaks down and electrons are emitted from the cathode (tool) and the gap is ionized.
- ✓ This spark occurs in an interval of 10 to 30 microseconds and with a current density of 15-500A per mm' approximately. So, thousands of spark-discharge occur per second across the gap between the tool and the work, which results in increasing temperature of about 10,000°C
- ✓ At this high pressure and temperature, workpiece metal is melted. Eroded and some of it is vaporized. In this way the metal is removed from the workpiece.
- ✓ The removed fine material particles are carried away by dielectric fluid circulated around it.
- ✓ The metal removal rate depends on the spark gap maintained. If anode and cathode are made of same material, it has been found that the greatest erosion takes place at anode.
- ✓ Therefore, in order to remove maximum metal and have minimum wear on the tool, the tool is made as cathode the work piece as anode.
- ✓ When the voltage drops to about 12 volts, the spark discharge extinguishes and the dielectric fluid once again

Advantages of EDM:

The major advantages of the process are:

- ✓ Any materials that are electrically conductive can be machined by EDM.
- ✓ Materials, regardless of their hardness, strength, toughness and microstructure can be easily machined / cut by EDM process
- ✓ The tool (electrode) and work piece are free from cutting forces.
- ✓ Edge machining and sharp corners are possible in EDM process
- ✓ The tool making is easier as it can be made from softer and easily formable materials like copper, brass and graphite.
- ✓ The process produces good surface finish, accuracy and repeatability.
- ✓ Hardened work-pieces can also be machined since the deformation caused by it does not affect the final dimensions.
- ✓ EDM is a burr free process.

- ✓ Hard die materials with complicated shapes can be easily finished with good surface finish and accuracy through EDM process.
- ✓ Due to the presence of dielectric fluid, there is very little heating of the bulk material.

Limitations of EDM:

- ✓ Material removal rates are low, making the process economical only for very hard and difficult to machine materials.
- ✓ Re-cast layers and micro-cracks are inherent features of the EDM process, thereby making the surface quality poor.
- ✓ The EDM process is not suitable for non-conductors.
- ✓ Rapid electrode wear makes the process more costly.
- ✓ The surfaces produced by EDM generally have a matt type appearance, requiring further polishing to attain a glossy finish.

Applications of EDM:

- ✓ Hardened steel dies, stamping tools, wire drawing and extrusion dies, header dies, forging dies, intricate mould cavities and such parts are made by the EDM process.
- ✓ The process is widely used for machining of exotic materials that are used in aerospace and automatic industries.
- ✓ EDM being a non-contact type of machining process, it is very well suited for making fragile parts which cannot take the stress of machining.
- ✓ The parts that fit such profiles include washing machine agitators; electronic components, printer parts and difficult to machine features such as the honeycomb shapes.
- ✓ Deep cavities, slots and ribs can be easily made by EDM as the cutting forces are less and longer electrodes can be used to make such collets, jet engine blade slots, mould cooling slots etc.
- ✓ Micro-EDM process can successfully produce micro-pins, micro-nozzles and micro-cavities.

Wire Electric Discharge Machining (Wire Cut EDM)

2. **Explain the Wire cut EDM and list its advantages, disadvantages and applications (Apr/May-2010, Nov/Dec-16) (May/Jun-14, 16) (Nov/Dec- 15) (Apr/May-15)**
   Travelling Wire Electro-Discharge Machining (TWEDM) or Wire cut EDM
   Outline wire cut EDM with a need sketch and explain its significant process parameters for good surface finish. (Apr/May-2023)

CONSTRUCTION:

- ✓ A very thin wire (0.2 to 0.3mm) made of brass or molybdenum having circular cross section is used as an electrode (tool).
- ✓ The wire is stretched and moved between two rollers. The part of wire is eroded by the spark.
- ✓ The prominent feature of a moving wire is that a complicated cutout can easily machine without using an electrode.

It consist of

i. Work piece movement control unit.
ii. Work piece mounting table.
iii. Wire drives section for accurately moving the wire at constant tension.
iv. Dielectric fluid supplying unit
v. Power supplying unit.

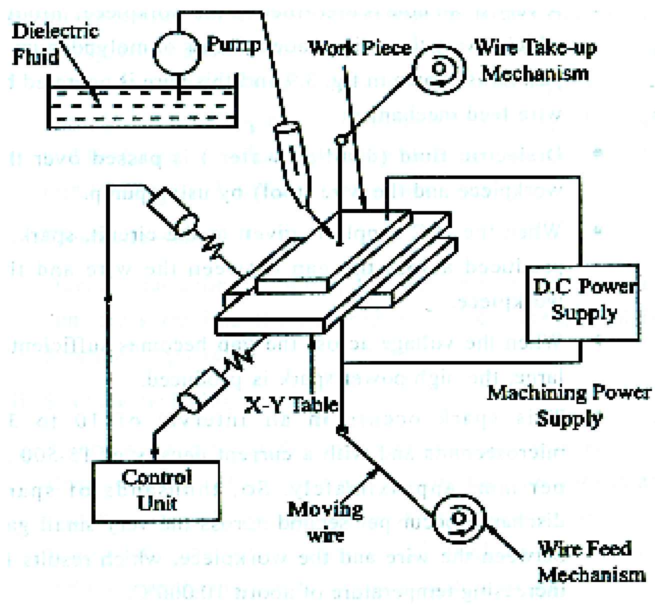


Fig 3.2 Schematic of Wire cut EDM

Working:

- ✓ Work piece to be machined is mounted on the table which is operated by control unit.
- ✓ A very small hole is predrilled in the work piece, through which a very thin wire made of brass or molybdenum is passed as shown in fig. 3.9 and this wire is operated by wire feed mechanism.
- ✓ Dielectric fluid (distilled water) is passed over the work piece and the wire (tool) by using pump.
- ✓ When the D.C supply is given to the circuit, spark is produced across the gap between the wire and the work piece.

- ✓ When the voltage across the gap becomes sufficiently large, the high power spark is produced.
- ✓ This spark occurs in an interval of 10 to 30 microseconds and with a current density of 15-500 A per mm^2 approximately. So, thousands of spark discharge occur per second across the very small gap between the wire and the work piece, which results in increasing temperature of about 10000°C.
- ✓ At this high pressure and temperature, work piece metal is melted, eroded and some of it is vaporized. The metal is thus removed in this way from the work piece.
- ✓ The removed fine material particles are carried away by dielectric fluid circulated around it.

Process of Material Removal in Wire-Cut EDM:

- ✓ In the WEDM process, the motion of wire is slow. It is fed in the programmed path and material is cut/ removed from the work piece accordingly.
- ✓ Electrically conductive materials are cut by the WEDM process by the electro-thermal mechanisms. Material removal takes place by a series of discrete discharges between the wire electrode and work piece in the presence of a dielectric fluid.
- ✓ The di-electric fluid gets ionized in between the tool-electrode gap thereby creating a path for each discharge.
- ✓ The area wherein discharge takes place gets heated to very high temperatures such that the surface gets melted and removed.
- ✓ The cut particles (debris) get flushed away by the continuously flowing dielectric fluid.
- ✓ WEDM is a non-conventional process and is very widely used in tool steels for pattern and die making industries.
- ✓ The process is also used for cutting intricate shapes in components used for the electric and aerospace industries.

Advantage of Wire Cut EDM:

- ✓ Complex shapes that would otherwise be difficult to produce with conventional cutting tools.
- ✓ Extremely hard material to very close tolerances.
- ✓ Very small work pieces where conventional cutting tools may damage the part from excess cutting tool pressure.
- ✓ There is no direct contact between tool and work piece. Therefore delicate sections and weak materials can be machined without any distortion.
- ✓ A good surface finish can be obtained.

- ✓ Very fine holes can be easily drilled.

Disadvantage of Wire Cut EDM:

- ✓ The slow rate of material removal.
- ✓ Potential fire hazard associated with use of combustible oil based dielectrics.
- ✓ The additional time and cost used for creating electrodes for ram/sinker EDM.
- ✓ Reproducing sharp corners on the work piece is difficult due to electrode wear.
- ✓ Specific power consumption is very high.
- ✓ Power consumption is high.
- ✓ "Overcut" is formed.
- ✓ Excessive tool wear occurs during machining.
- ✓ Electrically non-conductive materials can be machined only with specific set-up of the process.

Applications of Wire-Cut EDM

Wire EDM is used for cutting aluminium, brass, copper, carbides, graphite, steels and titanium. The wire material varies with the application requirements.

Example: for quicker cutting action, zinc-coated brass wires are used while for more accurate applications, molybdenum wires are used.

The process is used in the following areas:

- ✓ Aerospace, Medical, Electronics and Semiconductor applications
- ✓ Tool & Die making industries.
- ✓ For cutting the hard Extrusion Dies
- ✓ In making Fixtures, Gauges & Cams
- ✓ Cutting of Gears, Strippers, Punches and Dies
- ✓ Manufacturing hard Electrodes.

3. Explain the process parameters which govern the EDM/ Wire cut EDM process. (Nov/Dec-2013, May/June-2021) (Nov/Dec 2021)

The process parameters that can affect the quality of machining or cutting or drilling in WEDM process are shown through an Ishikawa cause-effect diagram as shown in fig.3.3.

The major parameters are as follows:

- ✓ Electrical parameters: Peak current, pulse on time, pulse off time and supply
- ✓ Voltage and polarity.
- ✓ Non-electrical parameters: Wire speed; work feed rate, machining time, gain and rate of flushing.
- ✓ Electrode based parameters: Material and size of the wire.

- ✓ Dielectric System: Type, viscosity, and other flow characteristics

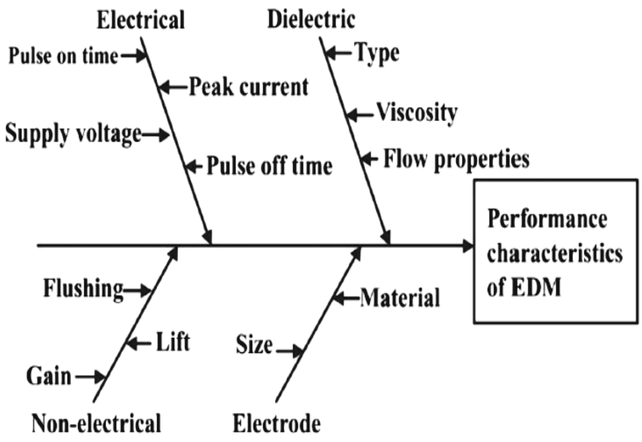
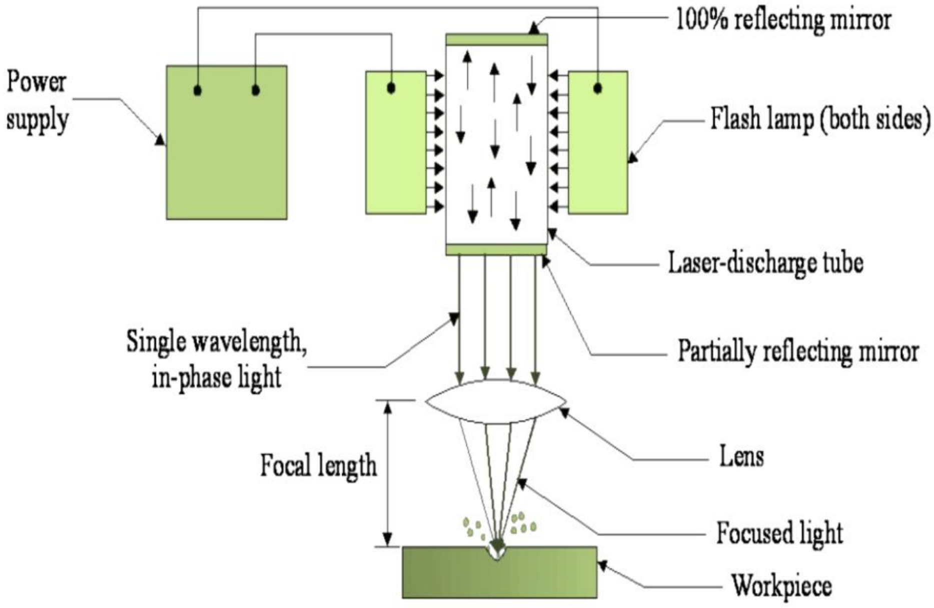


Fig. 3.3 Cause and effect diagram for EDM / Wire EDM

4. Discuss in detail about the thermal feature and analysis of laser beam machining

Thermal Feature and Analysis of Laser Beam Machining:

- ✓ Laser-beam machining is a thermal material-removal process that utilizes a high-energy, coherent light beam to melt and vaporize particles on the surface of metallic and non-metallic work pieces.
  - ✓ Lasers can be used to cut, drill, weld and mark. LBM is particularly suitable for making accurately placed holes. A schematic of laser beam machining is shown in below



✓ **Fig: 5.19 Laser beam machining schematic diagram**

Different types of lasers are available for manufacturing operations which are as follows:

- ✓ CO_2 (pulsed or continuous wave): It is a gas laser that emits light in the infrared region. It can provide up to 25 kW in continuous-wave mode.
- ✓ Nd-YAG: Neodymium-doped Yttrium-Aluminum-Garnet ($Y_3Al_5O_{12}$) laser is a solid state laser which can deliver light through a fiber-optic cable. It can provide up to 50kW power in pulsed mode and 1 kW in continuous-wave mode.
- ✓ LBM can make very accurate holes as small as 0.005 mm in refractory metals ceramics, and composite material without warping the work pieces.
- ✓ This process is used widely for drilling and cutting of metallic and non-metallic materials. Laser beam machining is being used extensively in the electronic and automotive industries.

Laser beam cutting (drilling)

- ✓ In drilling, energy transferred (e.g., via Nd-YAG laser) into the work piece melts the material at the point of contact, which subsequently changes into a plasma and leaves the region.
- ✓ A gas jet (typically, oxygen) can further facilitate this phase transformation and departure of material removed.
- ✓ Laser drilling should be targeted for hard materials and hole geometries that are difficult to achieve with other methods.

Laser beam cutting (milling)

- ✓ A laser spot reflected onto the surface of a work piece travels along a prescribed trajectory and cuts into the material.
- ✓ Continuous-wave mode (CO_2) gas lasers are very suitable for laser cutting providing high-average power, yielding high material-removal rates, and smooth cutting surfaces.

Advantages:

- ✓ In laser machining there is no physical tool. Thus no machining force or wear of the tool takes place.
- ✓ Large aspect ratio in laser drilling can be achieved along with acceptable accuracy or dimension, form or location
- ✓ Micro-holes can be drilled in difficult – to – machine materials
- ✓ Though laser processing is a thermal processing but heat affected zone specifically in pulse laser processing is not very significant due to shorter pulse duration.

Limitations:

- ✓ High initial capital cost
- ✓ High maintenance cost

- ✓ Not very efficient process
- ✓ Presence of Heat Affected Zone – specially in gas assist CO_2 laser cutting
- ✓ Thermal process – not suitable for heat sensitive materials

Application:

Laser can be used in wide range of manufacturing applications

- ✓ Material removal
    - drilling,
    - cutting
- ✓ Welding
- ✓ Cladding
- ✓ Alloying

- ✓ Drilling micro-sized holes using laser in difficult – to – machine materials is the most dominant application in industry.
- ✓ In laser drilling the laser beam is focused over the desired spot size. For thin sheets pulse laser can be used.
- ✓ For thicker ones continuous laser may be used.

5. **What is the principle of plasma arc machining? What are the two stages in which the process of material removal is affected? What is the main industrial application of plasma cutting systems? (Nov/Dec-08, 15) (Apr/May-2015) (May/June-2021)**

Introduction

- ✓ Solids, liquids and gases are the three familiar state of matter. In general when solid is heated, it turns to liquids and the liquids eventually become gases.
- ✓ When a gas is heated to sufficiently high temperature, the atoms (molecules) are split into free electrons and ions.
- ✓ The dynamical properties of this gas of free electrons and ions are sufficiently different from the normal unionized gas.
- ✓ So, it can be considered a fourth state of matter, and is given a new name as PLASMA. In other words, when a following gas is heater to a sufficiently high temperature of the order of 11000°C to 28000°C.

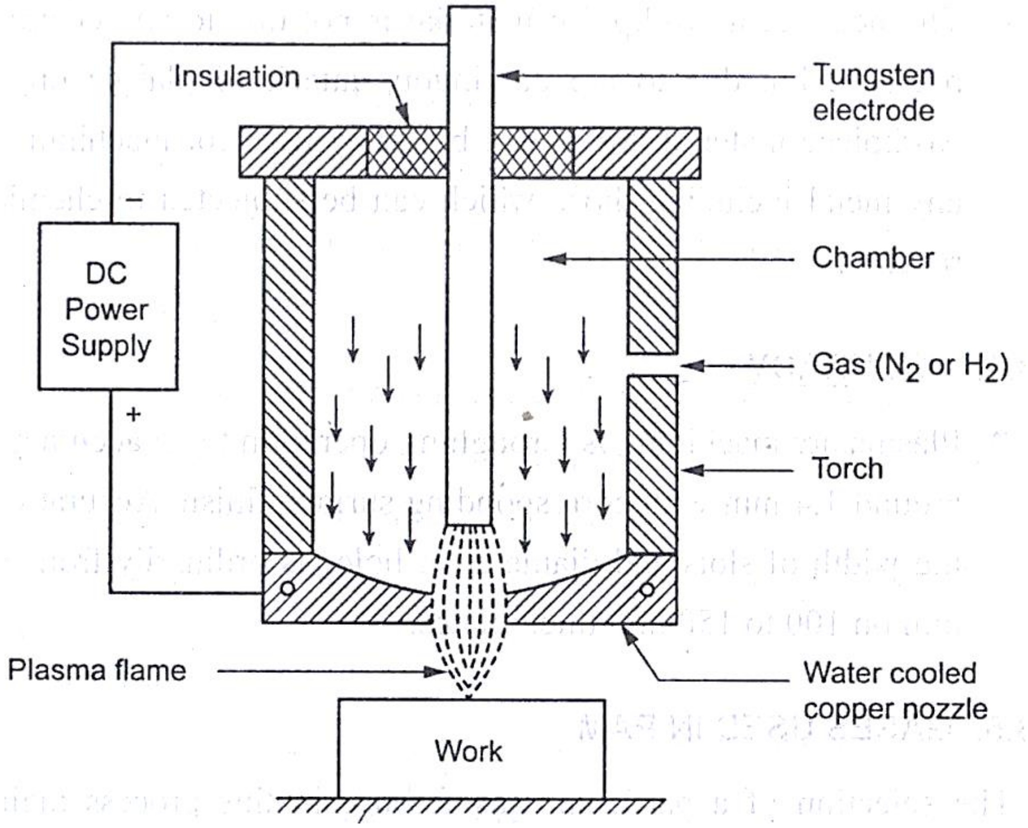


Fig: 5.10 Working Principle and Process Details of PAM

Principle

- ✓ In plasma arc machining process, material is removed by directing a high velocity jet of high temperature (11000°C to 28000°C) ionized gas on the workplace.
- ✓ This high temperature plasma jet melts the material of the workplace.

Construction of PAM

- ✓ The schematic arrangement of plasma arc machining is shown in Fig.5.10.
- ✓ Plasma Gun:
- ✓ The plasma arc cutting torch carries a tungsten electrode fitted in a small chamber.
- ✓ This electrode is connected to the negative terminal of a DC power supply. So it acts as a cathode.
- ✓ The positive terminal of a DC power supply is connected to the nozzle formed near the bottom of the chamber. So, nozzle acts as an anode.
- ✓ A small passage is provided on one side of the torch for supplying gas into the chamber.
- ✓ Since there is a water circulation around the torch, the electrode and the nozzle remains water cooled.

Working of PAM

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

- ✓ A gas usually Argon, Nitrogen (N2) is passed into the chamber.
- ✓ This gas is heated to a sufficiently high temperature of the order of 11,000°C to 28,000°C by using an electric arc produced between the electrode and the nozzle.
- ✓ In this high temperature, the gases are ionized and large amount of thermal energy is liberated.
- ✓ This high velocity and high temperature ionized gas (plasma) is directed on the work piece surface through nozzle.
- ✓ This plasma jet melts the metal of the work piece and the high velocity gas stream effectively blows the molten metal away.
- ✓ The heating of work piece material is not due to any chemical reaction. But due to the continuous attack of plasma on the work piece material. So, it can be safely used for machining of any metal including those which can be subjected to chemical reaction.

Plasma Arc Cutting System

- ✓ PAC system uses DC power source.
- ✓ PAC systems operate either on Transferred arc mode or non-transferred arc mode (Fig.5.11). In the earlier case, the thermal efficiency is low (65-75%) and power is transferred between the electrode and the nozzle.
- ✓ The non-transferred arc ionizes a high velocity gas that is streaming towards the work piece.
- ✓ The work piece may be electrically conductive or non-conductive.

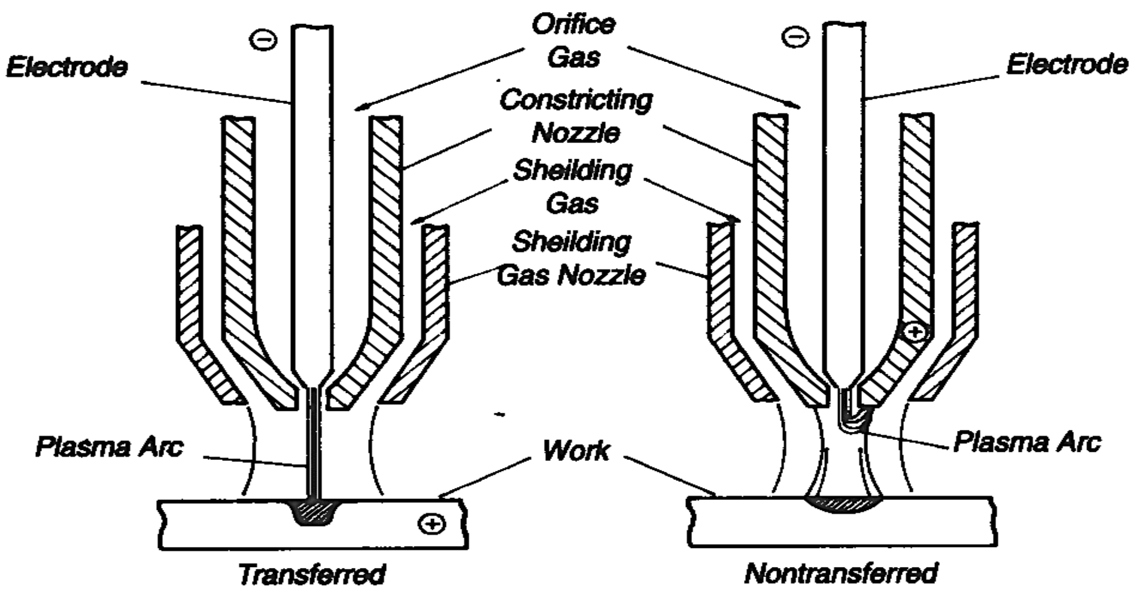


Fig: 5.11 schematic diagrams for non-transferred and transferred arcs

- ✓ In case of a **transferred arc mode PAM**, the arc is maintained between the electrode (negative polarity) and the electrically conductive work piece (positive polarity).
- ✓ Note that only electrically conductive work piece can be machined or cut by transferred arc system. The arc heats a coaxial-flowing gas and maintains it in a plasma state.
- ✓ The electro thermal efficiency is up to 85-90%. PAC system can deliver up to 1000 A at about 200 V (DC).
- ✓ The flowing gas pressure may be up to 1.4 MPa resulting in a plasma velocity of several hundred meters /second.
- ✓ Higher the gas flow rate more will be momentum of the plasma jet.
- ✓ It will ease out removal of the molten material from the machining zone.
- ✓ The plasma jet is constricted by the flowing gas which acts as a cooling agent sandwiched between the nozzle wall and the plasma jet.
- ✓ In case of PAC, The material may be removed either by melting, or by melting and vaporization both.
- ✓ In either case, the material (in molten state or vaporized state) is blown off from the machining zone by high velocity plasma jet.

Advantages:

- ✓ It can virtually cut any material.
- ✓ High cutting rate.
- ✓ It is used for rough turning and milling of hard and difficult to cut materials.
- ✓ Reasonable surface quality

Limitations:

- ✓ It gives tapered surface.
- ✓ High cost.
- ✓ Required skilled operators and needs high safety precautions.
- ✓ Oxidation and scale forming takes place. Needs shielding to avoid this.
- ✓ Heat affected zone. Metallurgical changes take place at cutting zone.

Applications:

- ✓ It is used to cut any material regardless of its strength, hardness. It can cut titanium, nickel alloys, Monel etc.
- ✓ Used for profile cutting.
- ✓ Stack cutting, piercing, shape cutting and under water cutting.

- ✓ Film spraying of refractory materials can also be done using plasma arc.

6. **Explain the principle, equipment, working, advantages, limitations and applications of Electron Beam Machining [EBM].(Apr/May-2010),(Apr/May-2011), (May/Jun-2012)&(May/Jun-2013) (Nov/Dec-14,15)(Apr/May-2015)**

Electron Beam Machining (EBM)

Introduction:

- ✓ In Electron Beam Machining process, high velocity focused beam of electrons are used to remove the metal from the work piece.
- ✓ These electrons are travelling at half the velocity of light i.e., 1.6×10^8 m/s.
- ✓ This process is best suited for micro-cutting of materials.

Principle:

- ✓ When the high velocity beam of electrons strike the work piece, its kinetic energy is convened into heat.
- ✓ This concentrated heat raises the temperature of work piece material and vaporizes a small amount of it, resulting in removal of material from the work piece.

Construction of EBM

(Machining Inside the Vacuum Chamber)

Construction

- ✓ It consists of electron gun, diaphragm, focusing lens, deflector coil, work table, etc.
- ✓ In order to avoid collision of accelerated electrons with air molecules, vacuum is required.
- ✓ So, the entire EBM setup is enclosed in a vacuum chamber, which carries vacuum of the order 10^{-5} to 10^{-6} mm of mercury.
- ✓ This chamber carries a door, through which the work piece is placed over the table. The door is then closed and sealed.
- ✓ The electron gun is responsible for the emission of electrons, which consists of the following three main parts.
- ✓ **Tungsten Filament** - it is connected to the negative terminal of the DC power supply and acts as cathode.
- ✓ **Grid cup** - it is negatively based with respect to the filament.
- ✓ **Anode** - it is connected to positive terminal of the DC power supply.
- ✓ The focusing lens is used to focus the electrons at a point and reduces the electron beam up to the cross sectional area of 0.01 to 0.02 mm diameter.

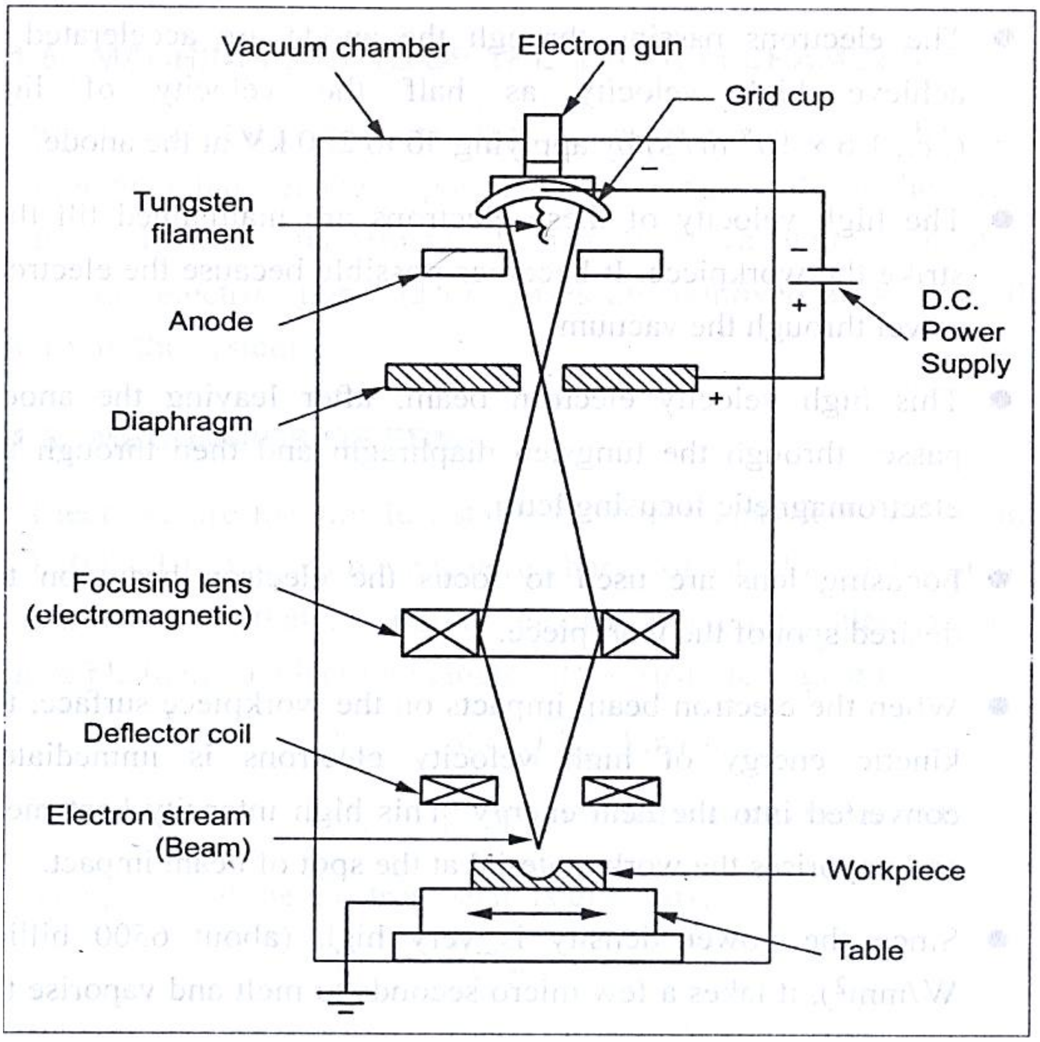


Fig: 5.16 Electron beam machining

Working

- ✓ When the high voltage DC source is given to the electron gun, tungsten filament wire gets heated and the temperature rises up to 2500°C.
- ✓ Due to this high temperature, electrons are emitted from tungsten filament.
- ✓ These electrons are directed by grid cup to travel towards downwards and they are attracted by anode.
- ✓ The electrons passing through the anode are accelerated to achieve high velocity as half the velocity of light (i.e., 1.6×10^8 m/s) by applying 50 to 200 kV at the anode.
- ✓ The high velocity of these electrons was maintained till they strike the work piece.
- ✓ It becomes possible because the electrons travel through the vacuum.
- ✓ This high velocity electron beam, after leaving the anode, passes through the tungsten diaphragm and then through the electromagnetic focusing lens.
- ✓ Focusing lens is used to focus the electron beam on the desired spot of the work piece.

- ✓ When the electron beam impacts on the work piece surface, the kinetic energy of high velocity electrons is immediately converted into the heat energy. This high intensity heat melts and vaporizes the work material at the spot of beam impact.
- ✓ Since the power density is very high (about 6500 billion W/mm^2), it takes a few micro seconds to melt and vaporize the material on impact.
- ✓ This process is carried out in repeated pulses of short duration. The pulse frequency may range from 1 to 16000 Hz and duration may range from 4 to 65000 microseconds.
- ✓ By alternately focusing and turning off the electron beam, the cutting process can be continued as long as it is needed.

Advantages of EBM Process

Electron beam machining has the following advantages:

- ✓ It is an excellent process for micro finishing.
- ✓ Very small holes can be machined in any type of material to high accuracy.
- ✓ Holes of different sizes and shapes can be machined.
- ✓ There is no mechanical contact between the tool and workpiece.
- ✓ It is a quicker process. Harder materials can also be machined at a faster rate than conventional machining.
- ✓ Electrical conductor materials can be machined.
- ✓ The physical and metallurgical damage to the work piece arc very less.
- ✓ This process can be easily automated.
- ✓ Extremely close tolerances are obtained.
- ✓ Brittle and fragile materials can be machined.

Disadvantages (Limitations)

- ✓ The metal removal rate is very slow.
- ✓ Cost of equipment is very high.
- ✓ It is not suitable for large work pieces.
- ✓ High skilled operators are required to operate this machine.
- ✓ High specific energy consumption.
- ✓ A little taper produced on holes.
- ✓ Vacuum requirements limit the size of work piece.
- ✓ It is applicable only for thin materials.
- ✓ At the spot where the electron beam strikes the material, a small amount of recasting and metal splash can occur on the surface.
- ✓ It has to be removed afterwards by abrasive cleaning.

- ✓ It is not suitable for producing perfectly cylindrical deep holes.

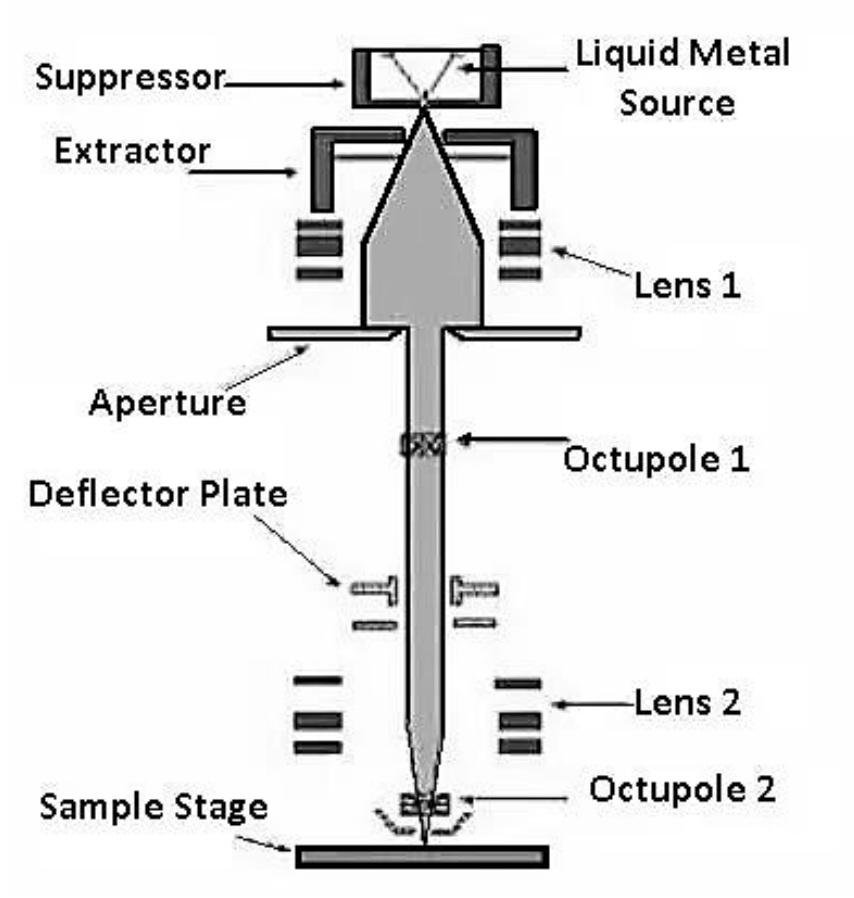
Applications

- ✓ EBM is mainly used for micro-machining operations on thin materials. These operations include drilling, perforating, slotting, and scribing etc.,
- ✓ Drilling of holes in pressure differential devices used in nuclear reactors, air craft engines, etc.
- ✓ It is used for removing small broken taps from holes.
- ✓ Micro-drilling operations (upto 0.002 mm) for thin orifices.
- ✓ Dies for wire drawing, pans of electron microscopes, injector nozzles for diesel engines, etc.,
- ✓ A micromachining technique known as "Electron beam lithography" is being used in the manufacture of field emission cathodes, integrated circuits and computer memories.
- ✓ It is particularly useful for machining of materials of low thermal conductivity and high melting point.

7. Explain the principle, equipment, working, advantages, limitations and applications of Ion

Beam Machining [IBM] Nov/Dec 2023

- ➢ IBM or etching is generally a surface finishing process in which the material removal takes place by sputtering of ions.
- ➢ The process is different from electric discharge, electron beam, laser and plasma arc machining in that the process does not depend on heating of the workpiece to the point of evaporation.
- ➢ This sputter etching mechanism is very simple. It consists in bombarding the work with accelerated ions which collide with the surface atoms of the work.
- ➢ Each bombarding ions, as a result of collisions, dislodges surface atoms by transferring kinetic energy from itself to the atoms of the surface layer.



- It consists of an electron gun which discharges free electrons into a chamber filled with argon gas. The gas is then ionized by the electrons.
- The top of the chamber is called an Ion-Beam generating apparatus. At the other end, the workpiece is fixed to a table which can be oscillated and rotated so that different points on the work surface can be subjected to ion-beam.

Ion Beam Machining Accuracy

- Practical etching rates vary up to 2000 A (2 x 10-4 mm) per min. The accuracy of the etching process is considerably high mainly due to the small amount of material removal.
- Tolerances in the vicinity of + 50 Å (+ 5 x 10-mm) are possible.

Applications of Ion-Beam Machining

- It is applied mostly in micro-machining (etching) of electronic components like computer parts, figuring optical surfaces and for the precision fabrication of fine wire dies in refractory materials. Typical materials that can be etched include glass, alumina, quartz, crystals, silica, agates, porcelain, cermets. and numerous metals and oxides.

Advantages

Ion-beam has many advantages which include:

- The process is almost universal.
- No chemical reagents or etching compounds are required.
- There is no undercutting as with another chemical etching process.
- Etching rates are easily controlled.

Disadvantages

However, the process has many disadvantages which are as follows:

- It is relatively expensive.
- Etching rates are slow.
- Although virtually no heat is generated there is little possibility of some thermal or radiation damage.

8. Compare and contrast the applications advantages and limitations of wire electric discharge machining and electric discharge machining. **Nov/Dec 2023**

Erosion, is a specific type of Electric Discharge Machining (EDM). Both WEDM and EDM share the basic principle of material removal using electrical discharges, but they differ in the method of tool movement and application. Here's a comparison between Wire EDM and conventional EDM:

Electric Discharge Machining (EDM):

Tool Movement:

In EDM, a tool (electrode) and the workpiece are submerged in dielectric fluid. The tool can be a simple shape, and material removal occurs as electrical discharges erode the workpiece.

Tool Types:

Electrodes in EDM can be simple or complex shapes, often mimicking the desired features of the final workpiece.

Material Removal:

Material removal in EDM is achieved by repeated sparks (discharges) between the tool and the workpiece, causing small craters and gradually shaping the workpiece.

Applications:

EDM is suitable for a wide range of materials, including metals and alloys, and is commonly used for intricate and complex shapes where precision is crucial.

Process Characteristics:

EDM allows for the machining of hardened materials and produces minimal tool wear due to the absence of direct physical contact between the tool and workpiece.

Wire Cut Electric Discharge Machining (WEDM or Wire EDM):

Tool Movement:

In WEDM, a thin, electrically conductive wire is used as the electrode. The wire is continuously fed through the workpiece, creating a cut. The tool does not make direct contact with the workpiece.

Tool Types:

The wire itself is the tool in WEDM. The wire can be made of materials like brass or coated with materials like zinc. The wire is typically very thin, allowing for precise cuts.

Material Removal:

WEDM removes material by creating a spark discharge between the wire and the workpiece. The continuous movement of the wire through the workpiece forms a cut.

Applications:

WEDM is especially effective for cutting intricate shapes and profiles in thin materials. It is commonly used for the production of dies, molds, and parts with tight tolerances.

Process Characteristics:

WEDM is known for its high precision and is suitable for cutting complex contours. It is also effective for materials that are difficult to machine using traditional methods.

Common Features:

Non-Contact Machining:

Both EDM and WEDM are non-contact machining processes, meaning there is no direct tool-to-workpiece contact, resulting in minimal tool wear.

Material Versatility:

Both processes are versatile and can be applied to a wide range of conductive materials.

Precision Machining:

Both EDM and WEDM are capable of achieving high levels of precision, making them suitable for applications where tight tolerances are required.

9. Explain the differences between laser beam machining and electron beam machining in terms of the principles, equipment used application under potential challenges. Nov/Dec 2023

Laser Beam Machining (LBM) and Electron Beam Machining (EBM) are both non-traditional machining processes that utilize high-energy beams for material removal. Despite sharing some similarities, they differ in terms of the energy source, beam characteristics, and applications. Here are the key differences between Laser Beam Machining and Electron Beam Machining:

Laser Beam Machining (LBM):

Energy Source:

LBM uses a high-intensity laser beam as the energy source. The laser can be generated using various methods, such as gas lasers, solid-state lasers, or fibre lasers.

Nature of Beam:

The laser beam is coherent, monochromatic, and collimated, meaning it consists of light waves with a single wavelength, travels in parallel rays, and has minimal divergence. This results in high precision.

Material Interaction:

Laser energy is absorbed by the material surface, leading to localized heating. The material may melt, vaporize, or undergo thermal stress-induced fracture depending on the intensity and duration of the laser exposure.

Applications:

LBM is suitable for cutting, welding, engraving, and surface treatment of a variety of materials, including metals, ceramics, plastics, and composites. It is widely used for precise and intricate tasks.

Heat-Affected Zone (HAZ):

LBM tends to produce a heat-affected zone (HAZ) in the material, which can impact the surrounding material properties. However, the HAZ is generally smaller compared to traditional thermal cutting methods.

Electron Beam Machining (EBM):

Energy Source:

EBM utilizes a focused beam of high-speed electrons as the energy source. Electrons are accelerated by an electromagnetic field to high velocities before striking the workpiece.

Nature of Beam:

The electron beam is highly focused and can achieve very high power densities. It is not visible like a laser beam, and its interaction with the workpiece is characterized by kinetic energy transfer.

Material Interaction:

Electrons in the beam transfer kinetic energy to the atoms of the workpiece, resulting in rapid heating. The material typically undergoes vaporization or sublimation, and the process is carried out in a vacuum to prevent scattering of electrons.

Applications:

EBM is often used for drilling, welding, and cutting operations, particularly in materials that are challenging for other machining methods. It is commonly applied to high-melting-point materials and is used in aerospace and precision engineering.

Heat-Affected Zone (HAZ):

EBM generally produces a smaller heat-affected zone compared to traditional thermal cutting processes. The vacuum environment helps minimize heat dissipation and prevents oxidation.

Shared Characteristics:

Non-Contact Machining:

Both LBM and EBM are non-contact machining processes, meaning there is no physical tool that directly engages with the workpiece. This reduces tool wear.

High Precision:

Both processes are capable of achieving high precision, making them suitable for applications where tight tolerances are essential.

Material Versatility:

LBM and EBM can be applied to a wide range of materials, including metals, ceramics, and some non-metallic materials.

UNIT IV

NANO FINISHING PROCESSES

1. **Write the principle of abrasive flow machining process.**

   Abrasive Flow Machining (AFM) is one of the non-conventional finishing processes in which a semi-solid medium consisting of a visco-elastic polymer and **abrasive** particles mixed in a definite proportion. This media is extruded under pressure through or across the surface to get the required finish.

2. **List out the types of abrasive flow machining processes.**
   - ✓ One way
   - ✓ Two Way
   - ✓ Orbital

3. **Define one way AFM.**

   One-way flow AFM processing pushes abrasive media through the work piece in only one direction, allowing the media to exit freely from the part.

4. **List out the Advantages of One-way AFM:**
   - ✓ Faster cycle processing
   - ✓ Easy clean-up
   - ✓ Media temperature control generally not required
   - ✓ Able to process larger parts
   - ✓ Simpler tooling and part change-over
   - ✓ Accurately replicates air or liquids natural flow
   - ✓ Does not encapsulate work-part in media

5. **Define two way AFM.**
   - ✓ The typical two-way flow AFM process uses two vertically opposed cylinders to extrude an abrasive media back and forth through or around passages formed by the workpiece and tooling.
   - ✓ Abrasive action occurs wherever the media enters and passes through the most restrictive passages

6. **What are the Advantages of Two-way AFM?**
   - ✓ Excellent process control
   - ✓ Can finish both ID and OD of component
   - ✓ Good control of radius generation
   - ✓ Fully automated system capabilities

7. Define orbital AFM.

- ✓ Surface and edge finishing are achieved by rapid, low- amplitude, oscillations of the work piece relative to a self- forming elastic plastic abrasive polishing tool.
- ✓ The tool is a pad or layer of abrasive-laden elastic plastic medium (similar to that used in two way abrasive flow finishing), but typically higher in viscosity and more in elastic.

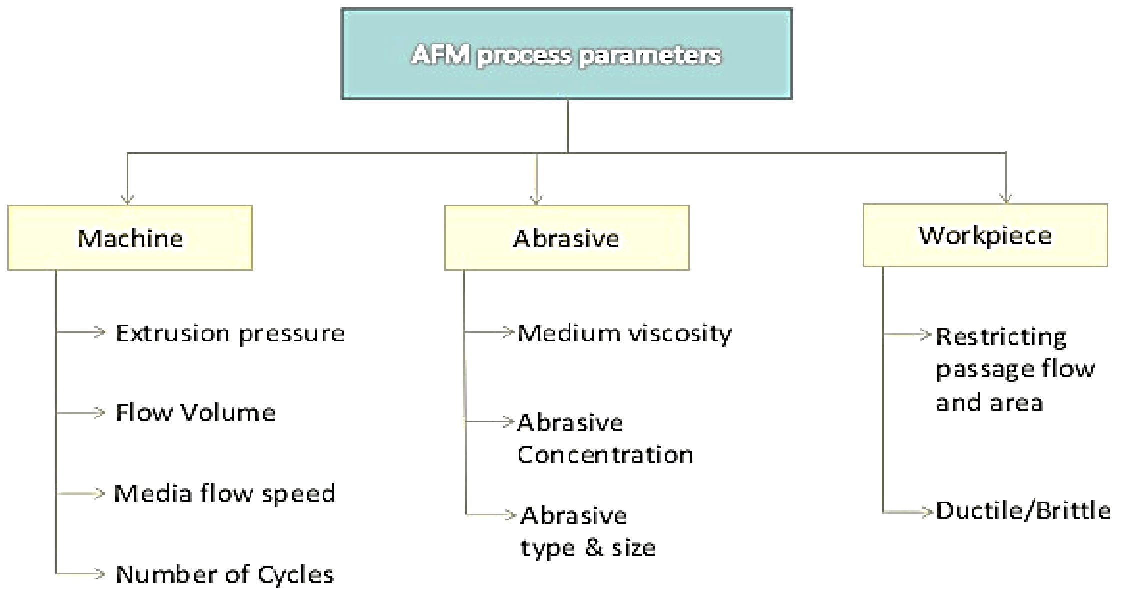
8. List out the elements of AFM.

- ✓ Machine
- ✓ Tooling
- ✓ Media.

9. List out the two aims of Tooling for AFM machine.

- ✓ To hold the parts in position, and
- ✓ To contain the media and direct its flow,

10. Write the process parameters of abrasive flow machining. (May/June-2021)

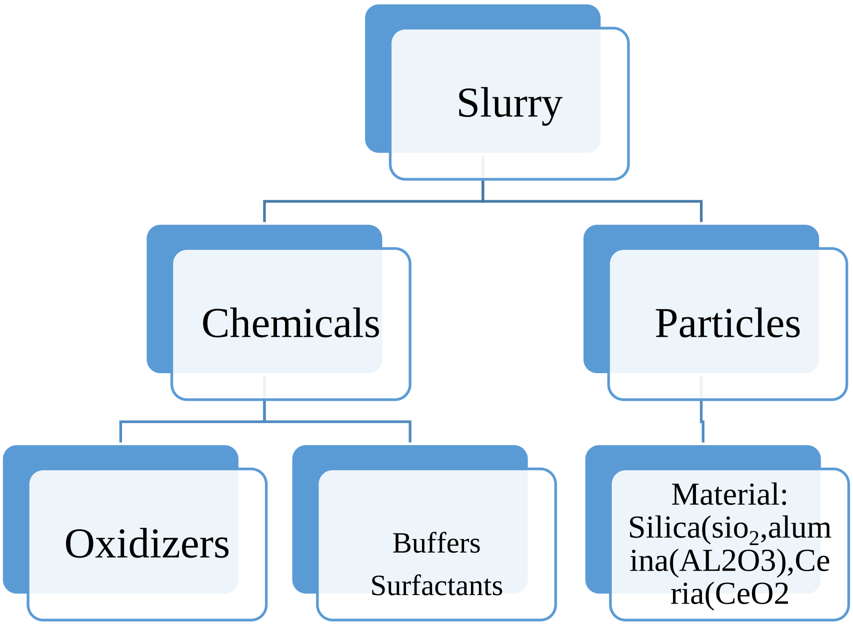


11. Write the working principle of Chemo mechanical polishing.

What is chemo-mechanical polishing? Nov/Dec 2023

Chemical Mechanical Polishing is more commonly known as CMP Polishing. This is the process where the top surface of a wafer is polished with slurry containing an abrasive grit, suspended within reactive chemical agents. The polishing action is partly mechanical and partly chemical.

12. What are the slurry used in CMP Processes?



13. List out the applications of CMP Process.

Identify the applications of the chemo-mechanical polishing process. (Apr/May-2023)

- ✓ Photolithographic applications
- ✓ Semiconductor devices

14. Write the working principles of magnetic abrasive finishing process.

State the principle of magnetic abrasive finishing process. (Nov/Dec 2022)

Magnetic abrasive finishing is a finishing process that involves the use of a magnetic field to apply particulate matter onto the surface of a workpiece or object. The purpose of magnetic abrasive finishing is to apply a powder coating.

15. List out the applications of Magnetic abrasive finishing processes.

State the applications of magnetic abrasive finishing. Nov/Dec 2023

- ✓ Polishing of balls and rollers:
- ✓ Finishing of inner tube surface:
- ✓ Polishing of fine components such as printed circuit boards
- ✓ The removal of oxide layers and protective coatings
- ✓ Chamfering and deburring of gears and cams

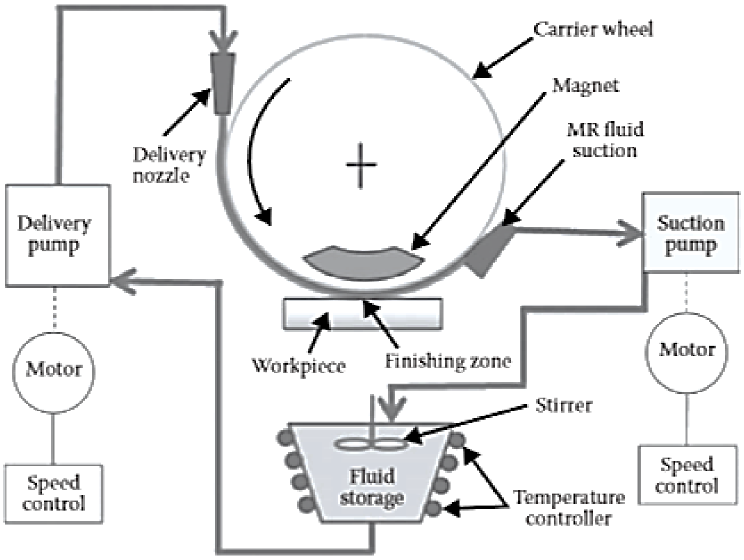
16. What is the purpose of abrasives in the magnetic abrasive finishing process? (Apr/May-2023)

The purpose of abrasives in magnetic abrasive finishing is to remove material from the workpiece surface through controlled abrasion, resulting in improved surface quality.

17. Write down the principle of magneto rheological finishing. (Nov/Dec 2021)

Magneto rheological finishing (MRF) is a precision surface finishing technology. Optical surfaces are polished in computer-controlled magnetorheological (MR) finishing slurry. Unlike conventional rigid lap polishing, the MR fluid's shape and stiffness can be magnetically manipulated and controlled in real time.

18. Draw the diagram for Magneto rheological finishing.



19. State the materials preferred as an abrasive particle and its size in nano finishing. Nov/Dec 2021)

Types of abrasives used are Al_2O_3, Sic, cubic boron nitride (CBN) and diamond.

20. Define the magneto-rheological effect. (Nov/Dec 2022)

Magnetorheological (MR) fluids are a class of smart materials whose yield stress increases considerably in the presence of externally applied magnetic field. These fluids are composed of soft, spherical, magnetic particles whose diameters range from 0.01 to 20 µm dispersed in an organic liquid.

<u>**PART-B (13 and 15 Marks)**</u>

Abrasive Flow Machining:

1. **Explain Abrasive flow machining process principles, working, process parameters, advantage, disadvantage and application in details. Nov/Dec 2023**

   Discuss the abrasive flow machining with a neat illustration and mention its applications. (Apr/May-2023)

   Introduction:

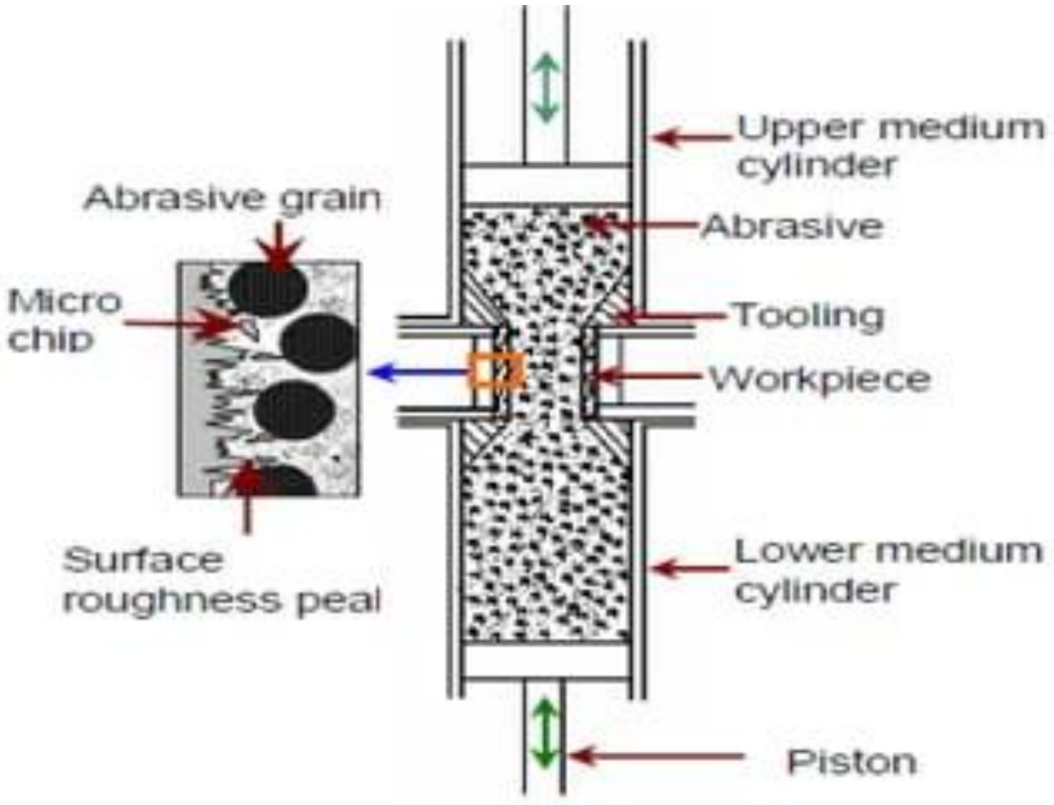
   - ✓ The need for high accuracy and high efficiency machining of difficult to machine materials is making the application of abrasive finishing technologies increasingly important.
   - ✓ The most labour intensive, uncontrollable area in the manufacture of precision parts involves final machining (or finishing) operations.
   - ✓ The cost of surface finish increases sharply for a roughness value of less than one micron.
   - ✓ The result of high quality finish on the parts is improved performance, and considers-able increase in the length of life of the component.
   - ✓ The basic idea of abrasive fine finishing processes is to use a large number of random cutting edges with indefinite orientation and geometry for effective removal of material with chip sizes smaller than those obtained during machining using cutting tools with defined edges.
   - ✓ Because of extremely thin chips produced in machining, it allows better surface finish, close tolerances, generation of more intricate finish and difficult to machine materials.

S.No	Process Features	Lapping	Honing	MAF	AFM
1.	Surface finish (μm)	0.025 -0.1	0.025-0.5	0.04-1.0	0.05-1.0
2.	Dimensional tolerance(μm)	0.5	0.5-1.25	0.5	5.0
3.	Material removal(mm)	< 0.0025	0.061-0.183	0.002-0.007	0.008-0.010

4.	Pressure	0.01-0.2 N/sq.mm	1-3 N/sq.mm	0.007 kPa	0.69-22.0 MPa
5.	Abrasive Product 1 type	Abrasive grain entrained in a liquid Vehicle.	Bonded Abrasive	Magnetic abrasive composed of ferro magnetic particles and conventional abrasive grills	Semisolid abrasive media composed of viscoelastic carrier and abrasive grills
6.	Work surface configuration	Flat, Cylindrical and Spherical surfaces	Cylindrical surfaces	Flat, Cylindrical surfaces	Inaccessible areas and complex internal passages

Working Principle:

- ✓ Developments in the area of materials science are taking place at a fast rate; at the same time demand for better quality and lower cost products is also increasing.
- ✓ There is a consistent demand for a decreases lead time from design to production. Further, finishing operations usually cost approximately 15% of the total machining cost in a production cycle.



Abrasive flow machining process

Workpiece alone. This process is good for operations like deburring, radiusing, polishing, removing recast layer, producing compressive residual stresses, etc.

- ✓ The process can be employed to machine tens of parts at the same time to enhance productivity.
- ✓ This has a high flexibility, i e, the same machine can be used to do a variety of jobs by changing tooling's, machining parameters, media and abrasives.
- ✓ The semisolid abrasive media is forced through the work piece or through them restrictive passage formed by work piece and tooling together. Force may be applied hydraulically or mechanically.
- ✓ Velocity of media is governed by cross-sectional area of passageways.
- ✓ More the restriction offered by the passageway, larger is the force required. Abrasive particles act as cutting tools; hence it is a multi-point cutting process giving very low MRR.
- ✓ It is employed both for metals and non-metals. It is equally suitable for work piece which contain passage ways that are not accessible (Fig. 4.3) for conventional deburring and polishing tools.

Classification of AFM

i. One way

ii. Two Way

iii. Orbital

(i) One-way AFM:

- ✓ One-way flow AFM processing pushes abrasive media through the work piece in only one direction, allowing the media to exit freely from the part.

Advantages of One-way AFM:

- ✓ Faster cycle processing
- ✓ Easy clean-up
- ✓ Media temperature control generally not required
- ✓ Able to process larger parts
- ✓ Simpler tooling and part change-over
- ✓ Accurately replicates air or liquids natural flow
- ✓ Does not encapsulate work-part in media

(ii) Two-way AFM:

- ✓ Most widely used among the three.
- ✓ The typical two-way flow AFM process uses two vertically opposed cylinders to extrude an abrasive media back and forth through or around passages formed by the workpiece and tooling.
- ✓ Abrasive action occurs wherever the media enters and passes through the most restrictive passages

Advantages of Two-way AFM:

- ✓ Excellent process control
- ✓ Can finish both ID and OD of component
- ✓ Good control of radius generation
- ✓ Fully automated system capabilities
- ✓ Faster setup & quick-change tooling
- ✓ Faster change-over of media

(iii) Orbital AFM:

- ✓ Surface and edge finishing are achieved by rapid, low- amplitude, oscillations of the work piece relative to a self- forming elastic plastic abrasive polishing tool.
- ✓ The tool is a pad or layer of abrasive-laden elastic plastic medium (similar to that used in two way abrasive flow finishing), but typically higher in viscosity and more in elastic.

Chemo-Mechanical Polishing

2. Explain Chemo-Mechanical Polishing process principles, working, process parameters, advantage, disadvantage and application in details. (July 2021) (Nov/Dec 2021)

Introduction:

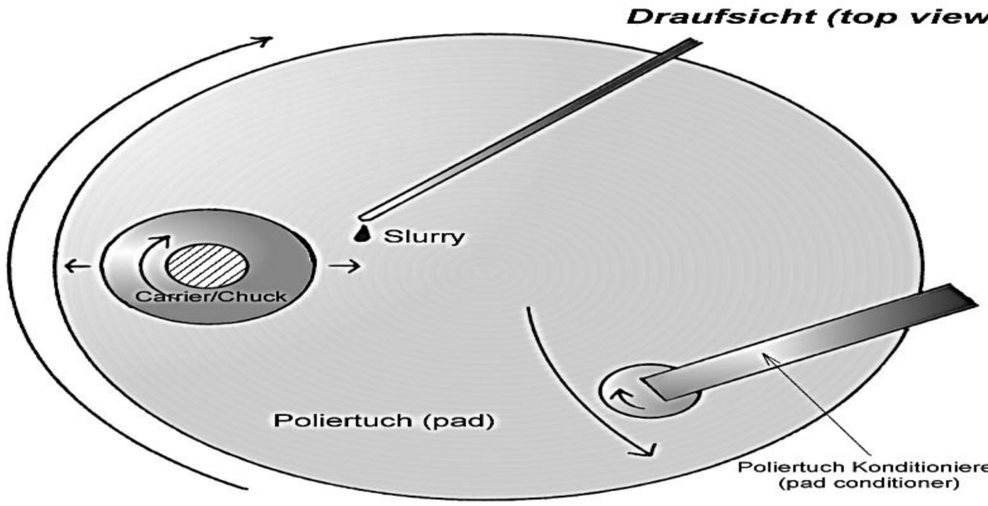
- ✓ The process uses an abrasive and corrosive chemical slurry (commonly a colloid) in conjunction with a polishing pad and retaining ring, typically of a greater diameter than the wafer.
- ✓ The pad and wafer are pressed together by a dynamic CMP can bring the entire surface within the depth of field of a photolithography system, or selectively remove material based on its position.
- ✓ Typical depth-of-field requirements are down to Angstrom levels for the latest 22 nm technology.
- ✓ Polishing head and held in place by a plastic retaining ring.
- ✓ The dynamic polishing head is rotated with different axes of rotation (i.e., not concentric).
- ✓ This removes material and tends to even out any irregular topography, making the wafer flat or planar.
- ✓ This may be necessary to set up the wafer for the formation of additional circuit elements. For example,

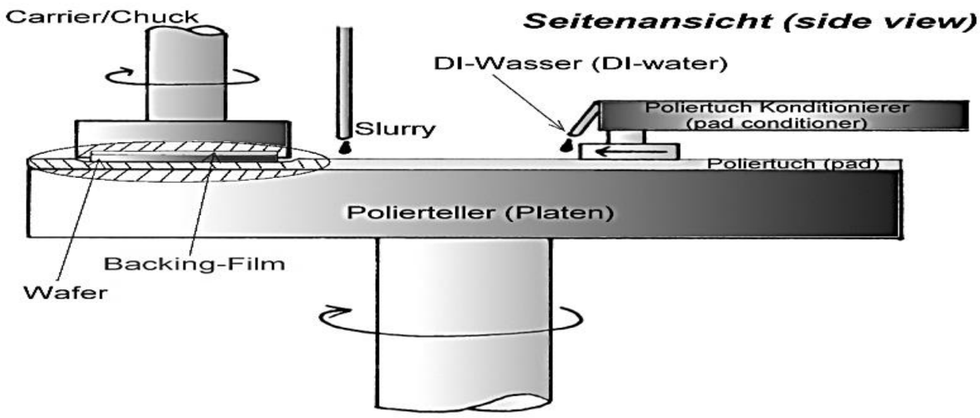
Working principles

Physical action

- ✓ Typical CMP tools, such as the ones seen on the right, consist of a rotating and extremely flat plate which is covered by a pad.
- ✓ The wafer that is being polished is mounted upside-down in a carrier/spindle on a backing film.
- ✓ The retaining ring (Figure 1) keeps the wafer in the correct horizontal position.
- ✓ During the process of loading and unloading the wafer onto the tool, the wafer is held by vacuum by the carrier to prevent unwanted particles from building up on the wafer surface.

- ✓ Down force is an average force, but local pressure is needed for the removal mechanisms.





- ✓ Down force depends on the contact area which, in turn, is dependent on the structures of both the wafer and the pad.
- ✓ Typically the pads have a roughness of 50 μm; contact is made by asperities (which typically are the high points on the wafer) and, as a result, the contact area is only a fraction of the wafer area. In CMP, the mechanical properties of the wafer itself must be considered too.
- ✓ If the wafer has a slightly bowed structure, the pressure will be greater on the edges than it would on the center, which causes non-uniform polishing.

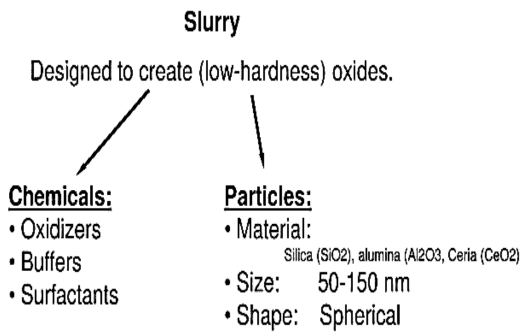
Chemical action

- ✓ Chemical mechanical polishing or planarization is a process of smoothing surfaces with the combination of chemical and mechanical forces. It can be thought of as a hybrid of chemical etching and free abrasive polishing.

Process description:

- ✓ A water is pushed against a polymeric polishing pad Pa = 1-10 psi

- ✓ Pad and water rotate independently (60 rpm)
- ✓ Slurry, containing oxidizing chemicals and abrasive particle is supplied into the interface.
- ✓ Material removed occurs due to particle abrasion of the chemically passivated water surface.



Limitations

- ✓ In particular, an improvement in wafer metrology is required.
- ✓ Poor brightness
- ✓ Gas overflow
- ✓ The need for ventilation
- ✓ Heating difficulties.
- ✓ In addition, it was discovered that the CMP process has several potential defects including stress cracking, delaminating at weak interfaces, and corrosive attacks from slurry chemicals.

Advantages

- ✓ Less investment in processing equipment,
- ✓ Complex parts can be thrown,
- ✓ Fast speed,
- ✓ High efficiency,
- ✓ Good corrosion resistance.

Application

- ✓ Shallow trench isolation (STI), a process used to fabricate semiconductor devices, is a technique used to enhance the isolation between devices and active areas.
- ✓ Moreover, STI has a higher degree of planarity making it essential in photolithographic applications, depth of focus budget by decreasing minimum line width.
- ✓ To planarize shallow trenches, a common method should be used such as the combination of resist etching-back (REB) and chemical mechanical polishing (CMP).

Magnetic Abrasive Finishing

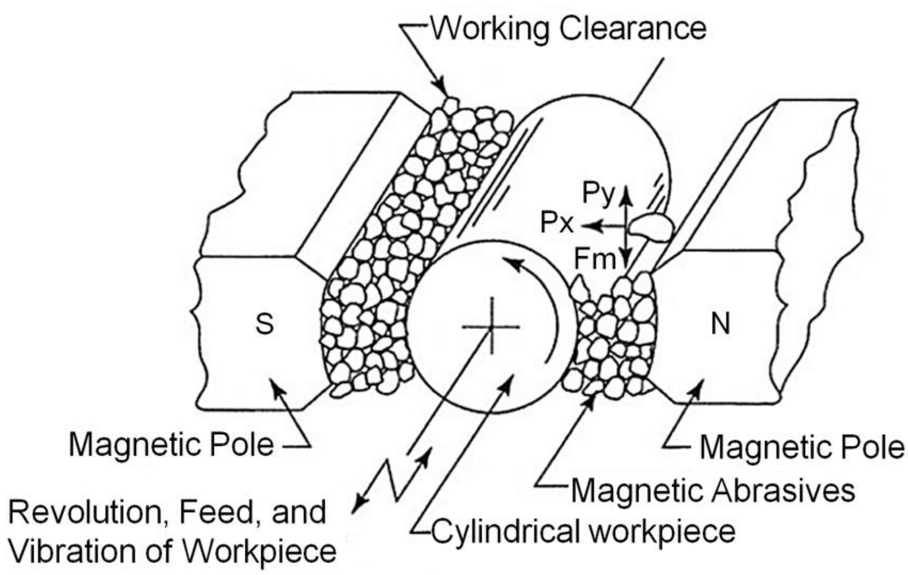
3. Explain Magnetic abrasive finishing process principles, working, process parameters, advantage, disadvantage and application in details. (Nov/Dec 2021) (Apr/May-2023)

Introduction:

- ✓ Traditionally finishing processes are crucial, expensive uncontrolled and a labour intensive phase in the overall production.
- ✓ It also includes total production cost and time.
- ✓ The ever increasing demand from the industry for better quality & cost competitive product with complex design material need to good surface finishing.
- ✓ In case of some application like internal finishing of capillary tube, machining of titanium alloy, aircraft application, and medical application where high surface finish parts are required.
- ✓ Magnetic abrasive finishing (MAF) is the process which capable of precision finishing of such work pieces.
- ✓ Accordingly, finish polishing is achieved without the need for expensive, rigid, ultra precision, vibration- and error-free machine tools by incorporating the magnetic polishing elements necessary into the existing machine tools.

The machining system:

- ✓ Figure shows a schematic diagram of MAF apparatus. A cylindrical work piece is clamped into the chuck of the spindle that provides the rotating motion.
- ✓ The work piece can be a magnetic (steel) or a nonmagnetic (ceramic) material; the magnetic field lines go through the work- piece. Axial vibratory motion is introduced in the magnetic field by the oscillating motion of the magnetic poles relative to the work piece.
- ✓ A mixture of fine abrasives held in a ferromagnetic material (magnetic abrasive conglomerate, Fig) is introduced between the work piece and the magnetic heads where the finishing process is exerted by the magnetic field.
- ✓ Typically the sizes of the magnetic abrasive conglomerates are 50 to 100 microns and the abrasives are in the 1 to 10 micron range.
- ✓ With nonmagnetic work materials, the magnetic abrasives are linked to each other magnetically between the magnetic N and S poles along the lines of the magnetic forces, forming flexible magnetic abrasive brushes.



Roller Speed	Up to 1.3 m/s
Magnetic field density	0-0.53 Tesla (T)
Magnetic pressure	0-30 kPa
Abrasive type	80% Fe (40) + 20 % SiC (1200)
Vibration frequency	12-25 Hz
Lubricant	Dry or oil

Applications

Polishing of balls and rollers:

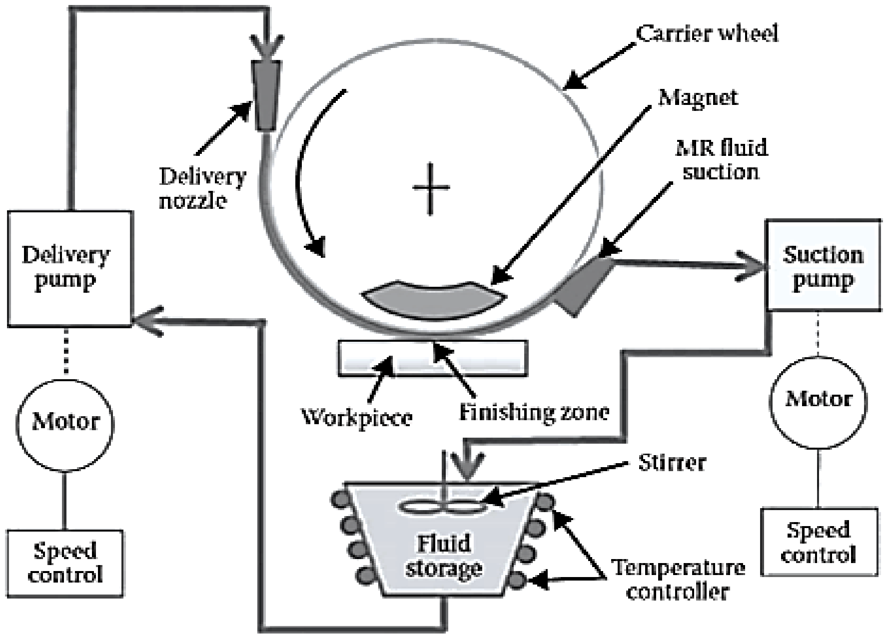
- ✓ Conventional finishing of ceramic balls, for bearing applications, uses low polishing speeds and diamond abrasives as a polishing medium.
- ✓ The long processing time and the use of expensive diamond abrasives result in high processing costs. Diamond abrasives at high loads can result in deep pits, scratches, and micro cracks. Consequently the high processing cost and the lack of the machining system reliability form possible limitations.
- ✓ To minimize the surface damage, gentle polishing conditions are required, namely, low levels of controlled force and abrasives not much harder than the work material.

Magnetorheological Finishing

4. Explain Magneto rheological finishing process principles, working, process parameters, advantage, disadvantage and application in details. Nov/Dec 2023

- ✓ The MRF process is based on MR fluids that finish high-precision optical components effectively, replacing the manual technology that previously took hours or weeks.

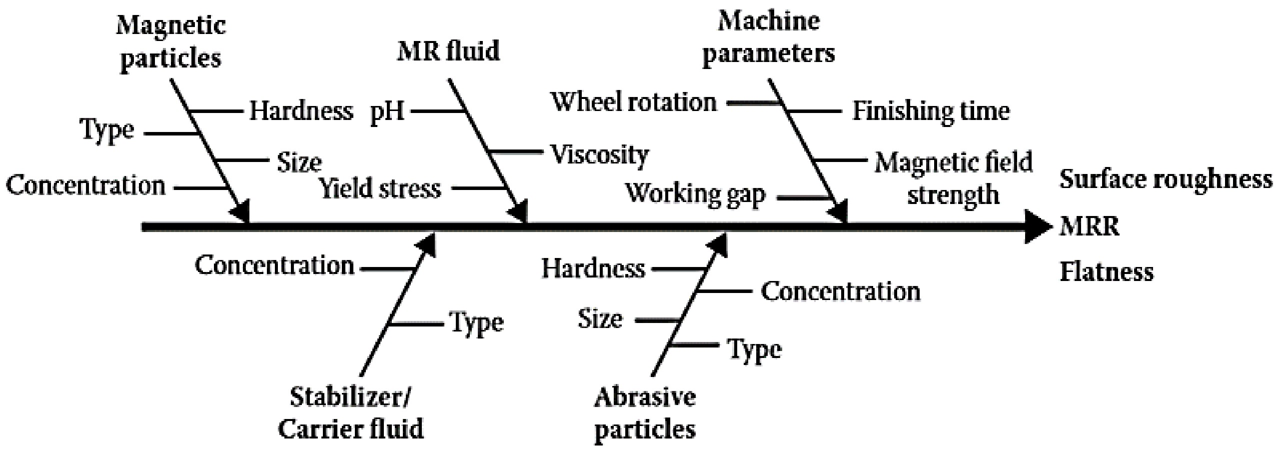
- ✓ An MR fluid temporarily hardens when exposed to a magnetic field and conforms to the surface of the work piece to be polished, making it ideal to polish many types of components. It offers various ways to overcome many of the limitations of conventional polishing.
- ✓ MRF was developed for polishing optics by a team of scientists led by William Kordonski at the Luikov Institute of Heat and Mass Transfer in Minsk, Belarus in 1988. However, the concept of using MRF as an automated process to polish high-precision optics was first introduced by the Center for Optics Manufacturing (COM) at the University of Rochester in 1993 in collaboration with William Kordonski. Later in 1996, the MRF technology was commercialized by QED Technologies.
- ✓ MRF is a deterministic finishing process based on an MR fluid consisting of non- magnetic polishing abrasives and magnetic CIPs in water or some other carrier.
- ✓ The MR fluid forms a polishing tool that is perfectly conformal and therefore can polish a variety of shapes, including flats, spheres, aspheres, and prisms, with a variety of aperture shapes. With the appropriate combination of MR fluid and other finishing parameters, MRF has been successfully used to polish a variety of materials to sub nano meter surface roughness values.
- ✓ In the MRF process, as schematically shown in Figure, a convex, flat, or concave work piece is positioned below a rotating carrier wheel.
- ✓ An MR fluid ribbon is deposited on the carrier wheel.
- ✓ Two MR fluid pumps (peristaltic or centrifugal) are used for delivery and suction of the MR fluid from the carrier wheel.
- ✓ By applying a magnetic field using an electromagnet or a permanent magnet, the stiffened region forms a transient work zone or finishing spot.



Schematic diagram of the MR-fluid-based finishing process

There are a few problems associated with a high concentration of solid particles such as the following:

- ✓ Low fluidity of the MR fluid (high off-state viscosity)
- ✓ Difficulty in circulation of the MR fluid through the pipes and pumps
- ✓ Difficulty in remixing the MR fluid (low re-dispersibility)



Fishbone diagram of MRF process parameters.

- ✓ The magnetic interaction force (F) is the attracting force between two magnetic particles as given by Equation. This force increases with the increasing size of magnetic particles.

Advantage

- ✓ High Accuracy

- ✓ Enhances product quality and repeatability
- ✓ Increased production rate, productivity, yield, and cost effectiveness.
- ✓ Stable in nature Manufacture precision optics... better, faster, and cheaper.
- ✓ Flexible and fast,
- ✓ Optical glasses micro roughness of less than 10 angstroms rms.
- ✓ Polishing tool is easily adjusted, and conforms perfectly to the work piece surface,
- ✓ No subsurface damage.

Disadvantage

- ✓ High-quality fluids are expensive.
- ✓ Fluids are subject to thickening after prolonged use and need replacing.
- ✓ Settling of ferro-particles can be a problem for some applications.
- ✓ Not suitable for finishing internal and external surfaces of cylindrical components.

Applications

- ✓ Obtain high-precision surfaces.
- ✓ Optical glasses, single crystals (calcium fluoride, silicon…) and ceramics.
- ✓ Square and rectangular aperture surfaces such as prisms, cylinders, and photo blank substrates.
- ✓ The Nano diamond doped MR fluid removes edge chips, cracks, and scratches in sapphire bend bars.
- ✓ High-aspect-ratio optics and substrates (thin film filters, etalon substrates, semiconductor

5. Explain Magneto rheological abrasive flow finishing process principles, working, process parameters, advantage, disadvantage and application in details (July 2021)

Introduction:

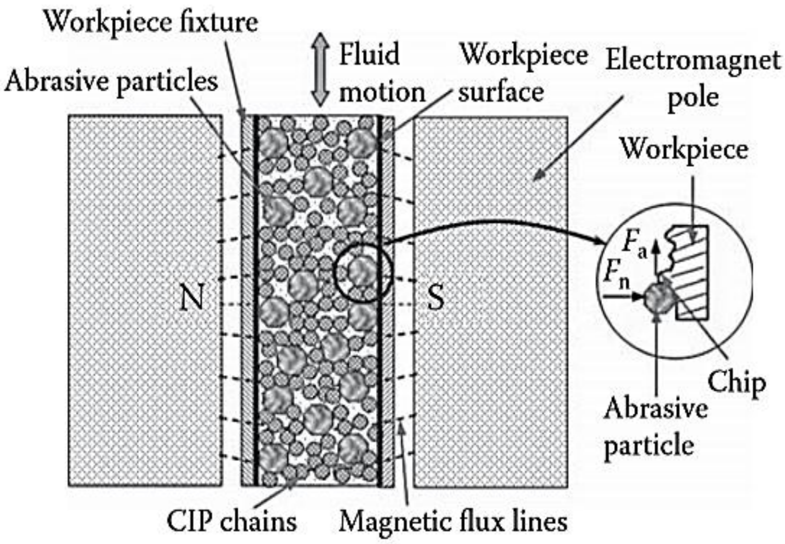
- ✓ Magneto rheological abrasive flow finishing (MRAFF) process provides better control over rheological properties of abrasive magneto rheological finishing medium.
- ✓ Magneto rheological (MR) polishing fluid comprises of carbonyl iron powder and silicon carbide abrasives dispersed in the visco plastic base of grease and mineral oil; it exhibits change in rheological behaviour in presence of external magnetic field.
- ✓ This smart behaviour of MR-polishing fluid is utilized to precisely control the finishing forces, hence final surface finish.
- ✓ MRAFF is a new precision finishing process that has been developed by taking advantage of both AFM and MRF for nano finishing of parts even with complicated geometries.
- ✓ MRAFF is a fine-finishing process that uses abrasives mixed with the MR fluid in a controlled manner.

- ✓ MR fluids exhibit real-time controllable change in flow properties of the fluid, enabling in-process control of finishing forces through the magnetic field.
- ✓ Any complex geometrical surface, internal or external, inaccessible to existing finishing processes can be finished by the MRAFF process by suitably designing the workpiece–fixture assembly.
- ✓ In the MRAFF process, the MR fluid is a homogeneous mixture of CIPs and abrasive particles in a base medium of liquid paraffin and grease.
- ✓ When an external magnetic field is applied, the CIPs in the fluid form chainlike structures along the lines of the magnetic field between two magnets, as shown in Figure.
- ✓ Nonmagnetic abrasive particles are embedded into the CIP chains, and these chains give bonding strength to the abrasive particles.
- ✓ When the MR fluid is extruded back and forth through the passage formed by the workpiece or fixture, abrasive particles embedded into/between the chains of CIPs and in contact with the work piece surface perform finishing by shearing off peaks of surface undulations.
- ✓ Among the three main variables, magnetic flux density, extrusion pressure, and number of finishing cycles, magnetic flux density is most significant in the MRAFF process that influences improvement of surface finish.
- ✓ Furthermore, MR polishing fluid composition also plays an important role in process performance for finishing of hard materials such as stainless steel.

Rotational-Magneto rheological Abrasive Flow Finishing (R-MRAFF)

- ✓ The concept of R-MRAFF has evolved from the MRAFF process. In R-MRAFF, rotational motion is also provided to the magnets, which rotate the MR fluid inside the cylindrical work piece.
- ✓ This rotation of magnets provides a circular motion to the MR fluid in addition to the axial motion provided as in the MRAFF process.
- ✓ A unique attribute of the R-MRAFF process is the determinism attained through the use of a precisely controlled magnetic field and guided flow of the MR fluid to minimize known surface irregularities and defects.
- ✓ The computer-controlled R-MRAFF process will demonstrate the ability to meet high standards of surface accuracy by overcoming many of the fundamental limitations inherent in traditional finishing techniques.

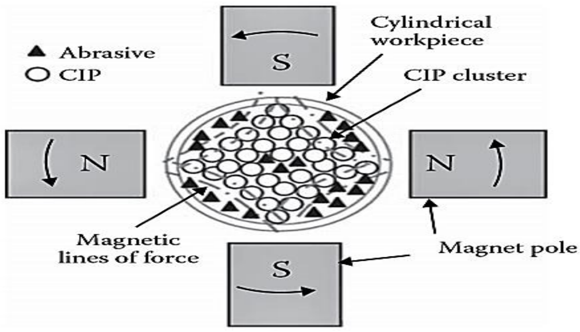
- ✓ R-MRAFF employs a rotating magnetic field that is applied vertically with respect to the cylindrical work pieces in order to best utilize the fluid characteristics. The working principle of R-MRAFF process is shown in Figure.

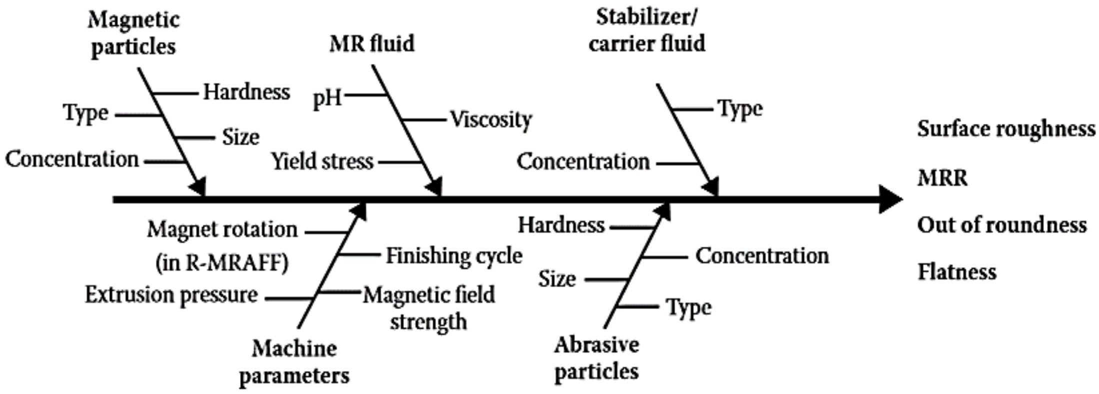


Mechanism of finishing in the MRAFF process

- ✓ The polishing mechanism involves abrasive particles aggregating at a certain section of the polished wall.
- ✓ When the magnets rotate with respect to the axis of the cylindrical workpiece along with the extruding motion of the MR fluid through the hydraulic unit, abrasives shear off roughness peaks uniformly from the internal surface of the work piece (similar to a honing operation but in a precisely controlled manner).
- ✓ Figure (a) and (b) shows movement of the abrasive inside the work piece in the MRAFF and R-MRAFF processes, respectively. In MRAFF, the abrasive moves parallel to the cylindrical work piece because the MR fluid has only reciprocating motion, while in case of R-MRAFF, the abrasive moves in a helical path that follows the additional circular motion of the MR fluid provided by rotation of the magnets.
- ✓ So, the abrasive has greater interaction length/area with the work piece in the case of R-MRAFF compared to MRAFF. In the R-MRAFF process, the path of the abrasive followed at the surface of the cylindrical fixture due to the resultant motion is helical (Figure b).
- ✓ Therefore, it generates a crosshatch pattern (similar to a honing operation) on the finished surface. Figure (a) and (b) shows the unfinished and finished internal surfaces of a stainless steel work piece, respectively.

- ✓ It is clear from the figure by comparing the reflection of the letters "IITK" on the surfaces that R-MRAFF can finish even hard materials efficiently. Surface roughness of the stainless steel work piece is reduced from 330 (Figure c) to 16 nm (Figure d).





6. Discuss the importance and emergence of nano finishing processes in detail. (Nov/Dec 2021)

- ➢ The quality of surface is one of the significant parameters which affects the life and functionality of any product.
- ➢ Many products require nano-level surface finish as their functional indispensability. Those processes having flexible finishing tool can be employed for such type of components.
- ➢ These finishing processes can be classified into two categories: with and without magnetic field assistance.
- ➢ The former includes magnetic abrasive finishing, magnetorheological finishing, and allied processes, and the latter includes abrasive flow finishing.
- ➢ This article reports the critical review of mainly three processes: abrasive flow finishing, magnetorheological finishing, and magnetorheological abrasive flow finishing. In this article, the issues that need attention of the researchers have been categorically mentioned.

- The magnetorheological finishing process in terms of rheological characterization of magnetorheological fluid, experimental investigation, theoretical analysis, and applications.
- This article deals with various advancements in abrasive flow finishing and hybrid processes.
- The developments in magnetorheological abrasive flow finishing and its allied processes have been discussed in detail.
- By suitable modification of magnetorheological abrasive flow finishing process, it can achieve surface finish up to nano-meter on different materials such as brass, aluminium, stainless steel, and silicon-nitride.
- The surface finishing techniques can be divided into two categories: traditional and advanced. To overcome some of the problems of traditional finishing techniques, hybridized processes have been evolved by the researchers.
- Some of the advanced finishing processes that have been reviewed are
    - ✓ Abrasive flow machining (AFM),
    - ✓ Magnetorheological finishing (MRF),
    - ✓ Magnetorheological abrasive flow finishing (MRAFF),
    - ✓ Magnetic abrasive finishing (MAF),
    - ✓ Chemo mechanical polishing (CMP), etc.

- ❖ Most of these processes have been developed in the recent past and they can be employed to produce optical, mechanical, and electronic components with micrometer or sub-micrometer form accuracy and surface roughness within nanometer range with hardly any surface defects. However for large size flat components, MAF seems to be the most suitable finishing process.
- ❖ In MAF, DC power supply is given to the electromagnet hence intermixing of ferromagnetic abrasive particles during the process does not take place and the worn out cutting edges keep interacting with the workpiece surface. As a result, the finishing rate is quite low.
- ❖ The use of pulsed DC power supply to the electromagnet results in pulsating flexible magnetic abrasive brush (P-FMAB), which substantially enhances the finishing rate.
- ❖ The on-line measurement of the forces has helped in understanding the mechanism of material removal during Static-FMAB (S-FMAB) and Pulsating-FMAB.

- The magnitude of normal magnetic force (originating indentations) in P-FMAB has been found to be dynamic in nature and substantially high in magnitude as compared to S-FMAB
- In the era of nanotechnology, high precision finishing methods are of utmost importance, and they are the need of present day manufacturing industries.
- There are noteworthy developments in high technology industries such as electronics, automobile, medical, and aviation, where the focus is to increase precision of the products at micro-/nano-scale to perform certain functions.
- Many products exist in the market where highest level of surface finish is necessary to increase their life and performance.
- Some of them are silicon in IC industries, micro-channels in micro-fluidics, optics and free-form surfaces in medical science, and moving assembly such as piston cylinder and bearings in automobile.
- The traditional finishing processes alone are incapable of producing.
- The required surface characteristics to meet the demand of nanotechnology. Many components require high level of surface finish to reduce fluid flow resistance, friction, and optical losses. Fatigue strength of a component is also affected by surface conditions.
- Usually, a surface finish improvement operation is required during or after fabrication of a part. Abrasive-based traditional finishing processes, such as grinding, honing, and lapping, are not capable of producing ultrafine surface on three-dimensional (3D) complex-shaped components and very hard material components due to the abrasives in the bonded form and high specific cutting energy requirement.
- Therefore, loose abrasive finishing processes, such as chemo-mechanical polishing/planarization, abrasive flow finishing (AFF), and magnetic field-assisted finishing processes, are preferable over the traditional finishing processes.

UNIT – V

Hybrid Non-Traditional Machining Processes

PART- A

(2 MARKS)

1. **What is a hybrid process?**

A process developed by combining the advantages of two non-traditional machining processes and eliminating the limitations of those processes is called hybrid process.

2. **List the needs for hybrid machining processes. (April/May 2023)**

- It enhances volumetric material removal rate
- Computer control of the processes has good result and better performance.
- Awareness of adaptive control machining becomes easier.

3. **How material removal takes place in Electro Chemical Spark Machining?**

- Melting and vaporization
- Chemical reaction when proper electrolyte is not selected
- Mechanical shock and cavitation's effect

4. **Write down the chemical reaction in ECSM?**

At cathode, reduction reaction takes place

$2H_2O + 2e^- \rightarrow H_2\uparrow\ 2OH^-$

At anode, oxidation, reaction takes place

$4OH^- \rightarrow 2H_2O + O_2\uparrow + 4e^-$

5. **What are the applications of ECSM?**

- It is used in machining materials like Al, Quartz and composites
- It is used in preparation of blind holes in quartz materials
- It is used in automobile, electrical and manufacturing fields.

6. **Why do we choose electric discharge diamond grinding?**

Electric Discharge Diamond Grinding is chosen because this process takes the advantage of EDM and diamond grinding such as grinding of hard materials, increase thermal softening of the work piece which requires less force and better accuracy with surface dressing.

7. **Name the dielectric fluids used in EDDG**.

The dielectric fluid used in EDDG is water or water based cutting fluid such as kerosene, paraffin oil and hydrocarbon oil.

8. **Name the two configurations used in EDDG.**

(1) When the work piece is electrically conductive material

(2) When the work piece is electrically non- conductive material.

9. List the advantages of EDDG.

Write the advantages of hybrid non-traditional machining processes. Nov/Dec 2023

- Less corrosive effect is produced.
- Higher material removal rate than EDM
- Lower operating cost

10. Define Faraday`s law of electrolysis.

Faraday`s law of electrolysis states that the amount of substance deposited or dissolved is proportional to the quantity of electricity that is passed through the electrolyte.

11. List the function of electrolyte in ECMM.

- It completes the electric circuit between the tool and the workpiece and also allows desired machining reaction.
- It carries away the heat and reaction produced from the machining zone.
- Improper circulation of electrolyte results in micro sparks

12. Why sodium nitrate is more advantage in ECMM?

- It has less throwing power
- Maximum feed rate
- High and controlled material removal

13. List the application of ECMM.

- It is used in 3D micromachining of micro structure in copper sheet used in electronic circuit board.
- Manufacture of nozzle plate for inkjet printer heads.
- It is used in aerospace, automobile and other heavy industries for shaping, sizing, deburring and finish operation.

14. List the types of thermal advanced micromachining processes.

List two examples of hybrid non-traditional machining processes. Nov/Dec 2023

- Electric discharge micromachining
- Electron beam micromachining
- Laser beam micromachining

15. Name the work piece materials used in EDMM.

- Cobalt
- Alumina
- Tantalum
- Titanium
- Tungsten

- Vanadium
- Wasp alloy

16. What are the main components of EBMM?

The main components of EBMM are the electron gun, anode, cathode, magnetic lens and deflection coils with a vacuum chamber.

17. List the applications of EBMM?

- Used for drilling and cutting of metals, non-metals, ceramics and composites
- Used for making fine gas orifices in space nuclear reactors
- Used for drilling holes in wire drawing dies.
- Used for metering holes in injector nozzle of diesel engine.

18. What are the types of laser used in LBMM?

The types of laser used in LBMM are CO2, laser, excimer laser yattrium, aluminium, sapphire laser.

19. Write down the reaction that takes place in ECMM.

At Anode : $Fe \rightarrow Fe^{++} + 2e^{-}$

At cathode: $2H_2O + 2e^{-} \rightarrow 2(OH)^{-} + H_2\uparrow$

At Electrolyte: $NaNO_3 \rightarrow Na^{+} + (NO_3)^{-}$

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

$$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3 \downarrow \text{sludge}$$

20. List the applications of LBMM?

- It is used in machining threads in a single polyfibre.
- Machining of micro holes and micro channels in integrated chips.
- Machining micro fluidic devices in silicon showing laser drilled holes and
- Connecting channels.
- Cutting of LBMM tube cutting, 100 um wide V grooves.

21. Define Micro machining.

Micro machining is machining of miniature components. It is also defined as removal of materials in the form of chips or debris having the size in the range of micron with dimension greater than or equal to 1 micron.

22. What are the mechanical advanced micro machining processes?

- Abrasive jet micro machining
- Abrasive water jet micro machining
- Ultrasonic micro machining

23. Detail the type of nozzle used in AJMM.

It focuses and accelerates the abrasive stream generated by the blaster. The nozzle is made of tungsten carbide to resist wear.

The nozzle used is Laval type it has a converging diverging geometry with a throat and minimum nozzle diameter.

24. Detail the focus tube used in AJMM.

These tubes focuses the abrasive water jet into the work surface for machining purpose. These focus tubes are made of tungsten carbide, poly crystalline diamond and chemical vapour deposition diamond.

25. List the functions of slurry used in USMM.

- It acts as coolant for the horn, tool and workpiece.
- Supplies fresh abrasives to cutting zone and removes debris from the cutting area.
- Low viscous slurry provide free transport of the medium
- The slurry from a good acoustic bond between the work pieces allowing efficient energy transfer.

26. Mention the limitations of non-traditional machining process. (Apr/May-2023)

- Higher setup and equipment costs, making them less cost-effective for small-scale production.
- Limited applicability to certain materials, as some processes may struggle with ceramics, composites, or heat-sensitive materials.
- Potential surface integrity issues, such as recast layers or heat-affected zones, requiring additional post-processing.
- Slower process speeds compared to traditional methods, affecting overall production rates.
- Complexity and specialized knowledge required, leading to higher labor costs and dependence on skilled operators.

PART- B & C (13 & 15 MARKS)

Introduction

Introduction to Hybrid Non-Traditional Machining Processes:

- Traditional machining processes, such as turning, milling, drilling, and grinding, have been the backbone of manufacturing for a long time.
- However, with the advancement in technology and the need for greater precision and efficiency, non-traditional machining processes have emerged.
- These processes are also known as unconventional or advanced machining techniques and are characterized by their ability to shape, cut, or remove material using innovative methodologies.
- Hybrid non-traditional machining processes take this concept further by combining the principles of two or more non-traditional machining methods.
- The integration of multiple techniques allows for enhanced capabilities, improved surface quality, reduced machining time, and greater flexibility in dealing with a wider range of materials.

Various hybrid non-traditional machining processes

Some common hybrid non-traditional machining processes include:

1. **Laser-Assisted Machining (LAM):** In this hybrid process, traditional machining (like milling or turning) is combined with laser technology. The laser beam preheats the workpiece, making it easier to remove material during the subsequent mechanical machining, which results in reduced cutting forces, improved material removal rates, and minimized tool wear.
2. **Electrochemical Discharge Machining (ECDM):** This process combines the principles of electrochemical machining (ECM) and electrical discharge machining (EDM). It involves the use of an electrically conductive tool that generates sparks in the presence of a dielectric fluid, resulting in material removal through a combination of electrochemical dissolution and electrical discharges.
3. **Abrasive Waterjet Machining (AWJM):** AWJM is a hybrid process that combines the principles of waterjet machining and abrasive machining. It uses a high-velocity jet of water mixed with abrasive particles to erode and cut through various materials. The abrasive particles in the water intensify the cutting action, allowing for the machining of hard and brittle materials.

4. **Ultrasonic-Assisted Machining (UAM):** In UAM, ultrasonic vibrations are superimposed onto the tool's movement during conventional machining processes such as drilling or milling. These vibrations help in reducing cutting forces, improving surface finish, and enabling machining of delicate materials with precision.
5. **Water-Assisted Laser Cutting (WALC):** This hybrid process combines the cutting capabilities of lasers with a water jet. The water jet is used to guide and cool the laser beam, resulting in enhanced cutting efficiency and reduced heat-affected zone in the workpiece.

The advantages of hybrid non-traditional machining processes include increased material removal rates, improved surface finish, reduced tool wear, and the ability to machine intricate shapes and complex geometries that may be challenging for traditional methods.

However, it's important to note that each hybrid process has its **limitations and specific applications**. The selection of a particular hybrid machining process depends on factors like material type, part geometry, required precision, and production volume. As technology continues to evolve, we can expect further innovations in hybrid non-traditional machining processes, contributing to the advancement of modern manufacturing capabilities.

1. **Explain the benefits of hybrid unconventional machining technologies and elaborate on the challenges and opportunities. (Apr/May-2023)**

   While hybrid non-traditional machining processes offer many advantages, they also come with specific challenges. Discuss these limitations and potential solutions to address them. Nov/Dec 2023

Benefits of Hybrid Unconventional Machining Technologies:

1. **Improved Material Removal Rates:** Combining the principles of multiple unconventional machining processes allows for higher material removal rates, increasing the efficiency of the machining operation.
2. **Enhanced Surface Finish:** Hybrid processes can result in superior surface finishes compared to individual unconventional machining methods, reducing the need for additional finishing operations.
3. **Reduced Tool Wear:** By leveraging the strengths of different processes, hybrid machining can distribute the cutting load more effectively, leading to reduced tool wear and longer tool life.
4. **Expanded Material Compatibility:** Hybrid techniques can overcome the limitations of individual processes, enabling the machining of a broader range of materials, including those that might be challenging to process with conventional methods.

5. **Precision and Accuracy:** The integration of multiple processes can contribute to improved dimensional accuracy and precision, making hybrid machining suitable for intricate and complex geometries.
6. **Minimized Heat-Affected Zone (HAZ):** Some hybrid processes can reduce the heat-affected zone in the workpiece, resulting in less distortion and improved structural integrity, especially for heat-sensitive materials.
7. **Flexibility and Adaptability:** Hybrid machining offers flexibility in tailoring the process to suit specific machining requirements, allowing manufacturers to adjust and optimize the process for different materials and components.
8. **Synergy of Process Characteristics:** Hybrid technologies capitalize on the strengths of each individual process, creating a synergistic effect that enhances overall machining performance.
9. **Environmental Benefits:** In certain cases, hybrid machining can lead to reduced energy consumption and lower emissions, contributing to a more environmentally friendly manufacturing process.
10. **Innovation and Advancements:** The combination of different machining technologies often leads to innovation and the development of new hybrid processes, driving advancements in the field of unconventional machining.

Overall, hybrid unconventional machining technologies offer a compelling solution to address the limitations of individual processes while providing manufacturers with the capability to achieve higher productivity, improved quality, and extended machining possibilities.

Unconventional Machining Technologies:

1. **Electrochemical Machining (ECM):** ECM utilizes the principle of electrochemical dissolution to remove material from the workpiece. It is commonly used for complex shapes, hard materials, and delicate components.
2. **Electrical Discharge Machining (EDM):** EDM employs electrical discharges to erode the material. It is ideal for intricate shapes, hard materials, and materials with high melting points.
3. **Laser Cutting:** This technology uses a high-energy laser beam to melt, vaporize, or blow away material, making it suitable for precise cutting and engraving.
4. **Waterjet Machining:** Waterjet technology employs a high-velocity stream of water mixed with abrasive particles to erode material and is used for cutting a wide range of materials.
5. **Ultrasonic Machining (USM):** USM uses ultrasonic vibrations to remove material through abrasive action, enabling precise machining of hard and brittle materials.

Challenges of Unconventional Machining Processes:

1. Cost: Unconventional machining processes often require specialized equipment, tooling, and skilled operators, leading to higher setup and operating costs compared to traditional methods.
2. Material Limitations: Some unconventional machining processes may not be suitable for certain materials, limiting their application range and requiring alternative manufacturing methods.
3. Surface Integrity: Some processes, such as EDM or laser cutting, can produce a heat-affected zone or recast layer, affecting the surface integrity and requiring additional post-processing.
4. Environmental Impact: Some unconventional machining processes generate hazardous waste or emit harmful fumes, necessitating proper waste management and adherence to environmental regulations.
5. Process Complexity: Operating unconventional machining processes can be complex, requiring specialized knowledge and skilled operators, which may lead to increased training and labour costs.

Opportunities of Unconventional Machining Processes:

1. Precision Machining: Unconventional processes can achieve high precision and accuracy, making them suitable for manufacturing parts with intricate geometries and tight tolerances.
2. Hard Material Machining: Unconventional processes excel in machining hard materials like ceramics, hardened steels, and super alloys, which are challenging for traditional methods.
3. Multi-Material Machining: These processes can handle dissimilar materials, allowing the creation of hybrid components and structures with distinct material properties.
4. Miniaturization: Unconventional machining processes are valuable for micro-machining applications, enabling the creation of tiny components used in electronics and medical devices.
5. Rapid Prototyping: Unconventional processes can facilitate rapid prototyping and fast iteration cycles in product development, reducing time-to-market for new designs.
6. Energy-Efficiency: Some unconventional processes can be more energy-efficient than traditional methods, contributing to sustainable manufacturing practices.
7. Unique Surface Finishes: Unconventional machining can achieve unique surface textures and finishes, enhancing aesthetics and functionality for specific applications.

By addressing the challenges and capitalizing on the opportunities, manufacturers can leverage unconventional machining processes to improve production capabilities, explore new design possibilities, and cater to diverse customer demands in various industries.

2. Explain with neat sketches of Electrochemical Spark Machining.

Electrochemical Spark Machining:

- Electrochemical spark machining, also known as electrochemical discharge machining (ECDM) or electrochemical spark erosion (ECSE), is a non-traditional machining process that combines principles of electrochemical machining (ECM) and electrical discharge machining (EDM).
- It is a specialized technique used for precision machining of materials that are difficult to machine using conventional methods.
- The process involves the controlled removal of material from a workpiece through localized electrochemical dissolution, aided by the application of a series of electrical sparks.
- It is particularly useful for cutting intricate shapes, especially in materials that are electrically conductive but hard and brittle, such as super alloys, ceramics, and composites.

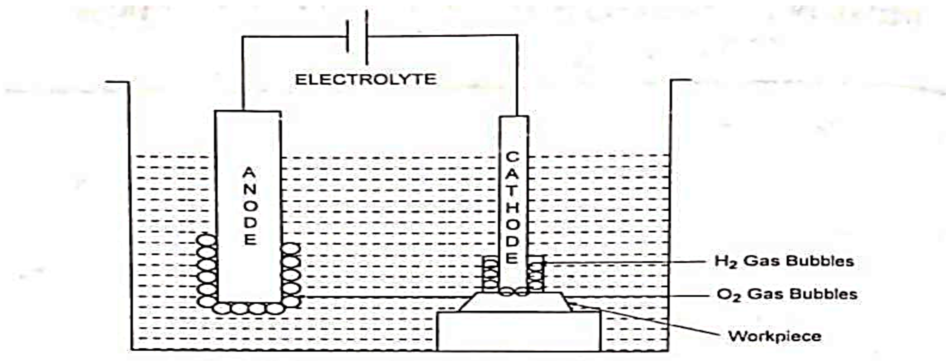


Fig. 5.1. Electro Chemical Spark Machining Process

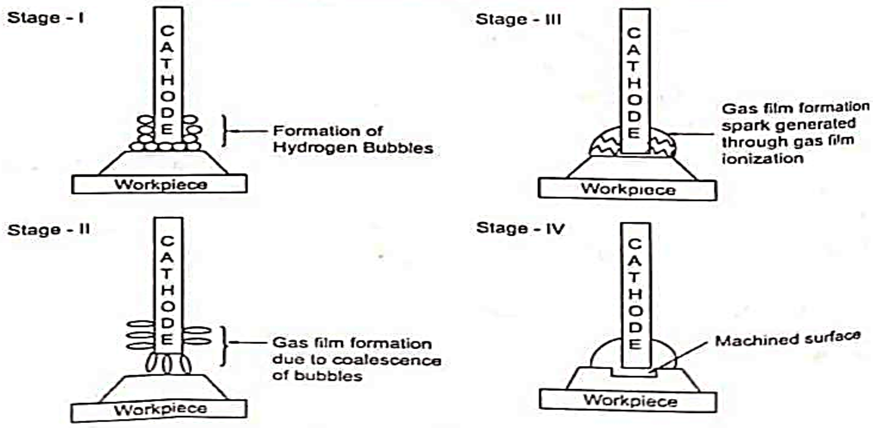


Fig. 5.2. Stages in Electro Chemical Spark Machining

Here's a general overview of how the electrochemical spark machining process works:

1. Setup: A workpiece, typically made of an electrically conductive material, is mounted on the machine. The workpiece acts as an anode in the setup.

2. Tool Electrode: A tool electrode, made of a conductive material such as copper, brass, or tungsten, is positioned close to the workpiece, acting as the cathode.

3. Electrolyte: An electrolyte solution, usually a conductive salt-based liquid, is used to create a conductive path between the tool electrode and the workpiece. It also helps carry away the dissolved material and controls the sparking process.

4. Sparking: An electric potential difference is applied between the tool electrode and the workpiece, creating a localized electric spark discharge in the small gap between them. This sparks the electrochemical reaction, resulting in the controlled dissolution of material from the workpiece.

5. Material Removal: The electrochemical dissolution and sparking action continuously remove material from the workpiece, shaping it according to the desired pattern.

6. Accuracy and Precision: The process can achieve high precision and accuracy due to the localized nature of the material removal.

A**dvantages**:

1. Non-contact and burr-free machining: Since the process does not involve direct contact between the tool and workpiece, there is minimal risk of tool wear and burr formation.

2. High material removal rate: The combination of electrochemical dissolution and sparking action allows for efficient material removal, especially in hard and brittle materials.

3. Complex shapes: It is well-suited for machining intricate and complex shapes that may be challenging using traditional methods.

4. Reduced heat-affected zone: ECDM generates less heat during the machining process compared to conventional methods, reducing the risk of thermal damage to the workpiece.

Limitations:

1. **Limited to conductive materials:** Electrochemical spark machining can only be applied to materials that are electrically conductive.

2. **Specific electrolyte requirements:** The choice of electrolyte and its properties can impact the machining performance and results.

3. **Initial setup and cost**: Setting up the process and acquiring the necessary equipment can be costly, making it more suitable for specialized applications.

3. Explain the various applications of hybrid non traditional machining processes across industries. Nov/Dec 2023

Applications:

- Overall, electrochemical spark machining is a valuable technique in industries where high precision, intricate shapes and challenging materials are involved, such as aerospace, medical devices, and electronics.
- Aerospace Industry: ECSM is employed to machine high-strength and heat-resistant materials used in aerospace components, such as turbine blades, combustion chambers, and engine parts. These materials, like super alloys, are difficult to machine with traditional methods due to their hardness and brittleness.
- Medical Device Manufacturing: In the medical field, ECSM is used to produce complex and precise components for surgical instruments, implants, and medical devices. Materials like titanium, stainless steel, and certain ceramics can be machined with high accuracy using ECSM.
- Electronics and Microelectronics: ECSM can be utilized to fabricate microelectrodes, micro channels, and other intricate structures for electronic components and micro electromechanical systems (MEMS). The process allows for precise control over dimensions and shapes in micro-scale applications.
- Tool and Die Manufacturing: In the production of specialized tools, moulds, and dies, ECSM can be used to create intricate features and contours that are challenging to achieve with traditional machining techniques.
- Semiconductor Industry: In the semiconductor manufacturing sector, ECSM can be employed for the precision shaping and machining of certain semiconductor materials.
- Energy Sector: ECSM finds use in machining components for energy-related applications, such as parts for fuel cells, heat exchangers, and other high-performance energy systems.

The process parameters involved in ECSM process:

- A supply voltage ranges between 35- 50 Volt
- Cutting tool has a wire diameter of 200 Newton metres.
- The work piece used here is soda lime glass The gap to be maintained between the cathode and work piece is around 52 5 100 metre, depending on the type of application
- The electrolyte solution is 14 to 20 percentages of water and sodium chloride.
- The table speed is 4RPM.

Electrical Discharge Diamond Grinding (EDDG):

4. Explain working principle of electrical discharge diamond grinding with neat sketch.

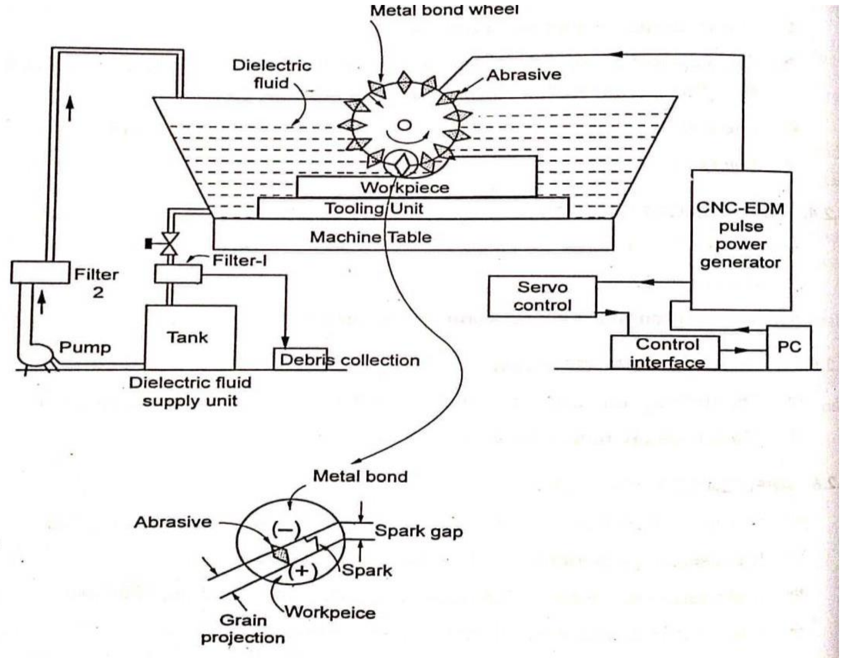


Fig. 5.4. Schematic Arrangement of Electric Discharge Diamond Grinding

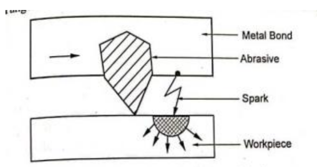


Fig. 5.5. Formation of Spark in an Abrasive

Principle:

Electrical discharge diamond grinding process is a spark erosion process used for precision grinding. For kids produced between metal bonded grinding wheel and workpiece Heat generated earring sparking softens the workpiece surface under material surface is easily upgraded using diamond abrasive Particles.

Construction and working of EDGG:

- The schematic arrangement of electric diamond grinding process is as shown in fig.
- EDDG process consists of dielectric fluid metal bonded diamond grid wheel Workplace serviceable control system and CNC-EDM controlled pulse power generator.
- **Dielectric fluid:** The dielectric fluid used in EDDG may Be water based cutting fluid such as kerosene paraffin oil and hydrocarbon oil The arrangement consists of tank which receives the dil refugee from the bottom of EDG setup The fluid is filtered twice and pumped into arrangement again by using water This fluid filtration is done in order to remove the chips and debris formed during grinding.

- **Tool**: The aluminium metal bonded diamond grid wheel is used as a tool This tool is an electrically conductive mater This tool is connected to negative terminal of Pulse Power Generator The abrasive in the wheel are diamond grits which are arranged on outer surface of grinding wheel and used for material removal.
- **Work piece**: The work piece is connected to the positive terminal of the old generator. The work piece used in EDDG process is a hard hand electrically conductive material the material that is used as workpiece or high speed steel and cemented carbides.
- **Servo control system:** In EDDG process the survivor control system maintains a constant gap between the grinding wheel and work piece during active feeding of the wheel into the work piece. The system monitors the desired gap between distance and the wheel feeding into the workpiece will be equal to the material removed rate the circuit senses the gap distance effectively if there is a blog in the gap. They get melted out due to high heat generator.
- **Pulse power generator**: The pulse power generator generates the DC power supply to the tool and workpiece the whole set in CNC-EDM controlled using computer arrangement.

Basic configuration of EDDG:

The process of material removal in EDG is done through two basic configurations they are

(i) When the workpiece is electrically conductive material

(ii) When the workpiece is electrically nonconductive material

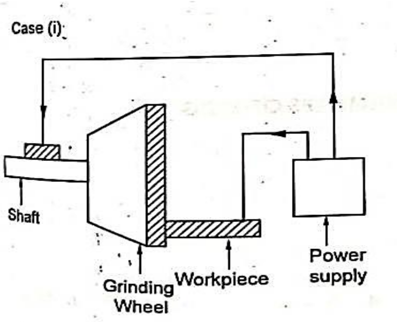


Fig. 5.6. Configuration of electrically conductive workpiece and wheel

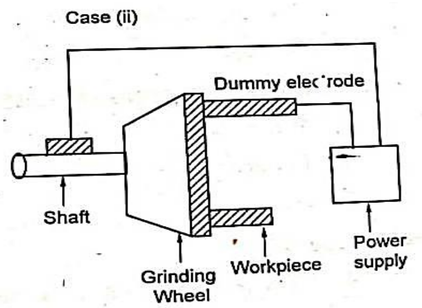


Fig. 5.7. Configuration of electrically conducted wheel and nonconductive workpiece

Case (i)

When the workpiece and the grinding wheel are electrically conductive materials, they are connected to positive and negative terminal of the power supply sparking producers continuously under high heat is produced, resulting in material removal in workpiece in the form of creates as shown in figure.

Case (ii)

The grinding wheel is electrically conductive material under work piece is electrically nonconductive material. A dummy electrode is used to separately for producing thus far, which soften the material in the relative motion between the workpiece and the wheel helps in material removal.

The main parameters used in the process are

1. Wheel speed.
2. Current
3. Pulse on time.

Some of the parameters are

1. Diamond particles size,
2. Bond material.
3. Dielectric material
4. Voltage.

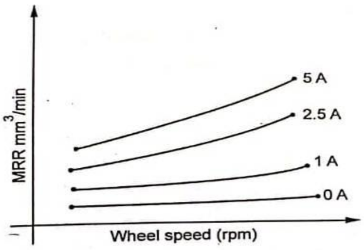
Factors affecting Process Parameter of EDDG

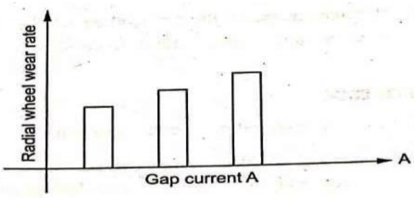
Wheel speed.

- It is clear that a current increases the middle removal rate also increases.
- In EDDG process the input current plays a major role. When the current is 1 amps. The Wheel speed is low under material removal is also less.
- As the current increases from 1 Amps. To 5 Amps there is drastically increase in wheel speed and material Removal rate.

Current:

- From the graph, it is clear that as current increases. The radial wheel wear rate also increases.
- The radial wheel wear rate. Depends or affects the lifespan of the grinding wheel.
- In EDDG process the gap current is influenced by the radial wheel wear rate. As gap current
- Increases the radial wheel rear rate also get increased.





Abrasive Jet Micromachining (AJM)

5. Explain the working of Abrasive Jet Micro Machining.

Principle of Abrasive Jet Micromachining (AJM):

Abrasive Jet Micromachining (AJM) is a micro-machining process that involves the use of a high-velocity stream of abrasive particles entrained in a gas (usually air or nitrogen) to erode and remove material from the workpiece. The process is based on the principle of material removal through erosion, wherein the high-speed abrasive particles impact the work piece's surface and dislodge tiny fragments of material, gradually machining the desired features.

Construction of Abrasive Jet Micromachining (AJM):

The basic construction of an Abrasive Jet Micromachining system consists of the following components:

1. **Abrasive Feeder:** This component stores and supplies the abrasive material for the machining process. The abrasive particles can be materials such as aluminum oxide, silicon carbide, diamond, or other hard materials with varying grit sizes.
2. **Gas Supply System**: The gas supply system delivers the high-velocity gas (air or nitrogen) that carries the abrasive particles towards the workpiece. The gas pressure and flow rate can be controlled to adjust the cutting efficiency and velocity of the abrasive jet.

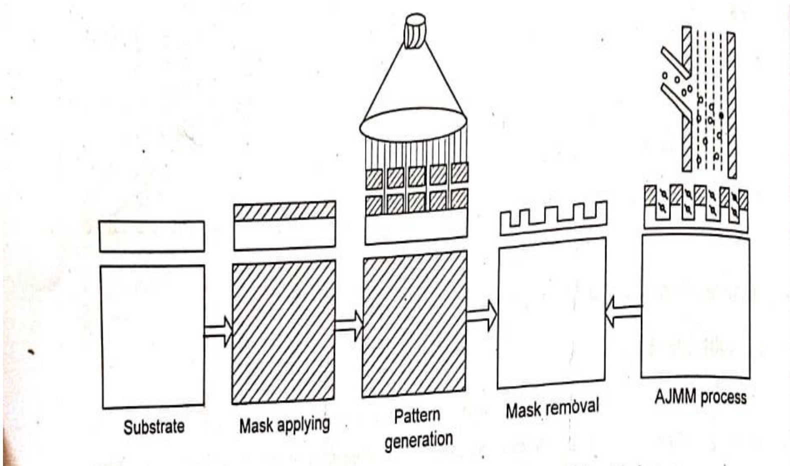


Fig. 5.13. Steps involved in Abrasive Jet Micro Machining

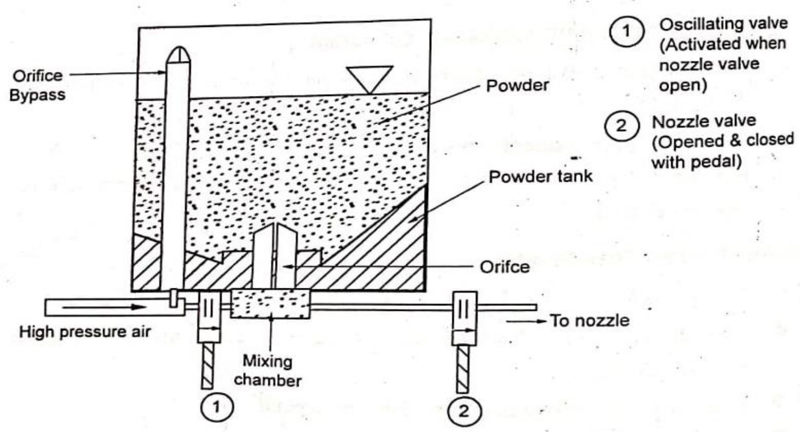


Fig. 5.14. Pressurized powder feed system

3. **Mixing Chamber**: The abrasive particles are mixed with the gas in the mixing chamber, creating an abrasive-laden gas stream. The proper mixing of abrasive particles with the gas is crucial for efficient material removal.

4. **Nozzle:** The nozzle is a critical component of the AJM system. It shapes the abrasive-laden gas into a high-velocity jet and directs it towards the work piece. The nozzle is designed to have a small orifice to ensure the desired level of jet velocity and accuracy.

5. **Work piece Holder**: The work piece holder or fixture holds the work piece in place during the machining process. It provides stability and precise positioning to achieve accurate micro-machining.

6. **Motion Control System**: In some AJM systems, the work piece or the nozzle may be movable to control the machining path and achieve complex shapes. The motion control system ensures precise movement of the workpiece or nozzle during the micro-machining process.

Working of Abrasive Jet Micromachining (AJM):

The working of Abrasive Jet Micromachining involves the following steps:

1. Abrasive particles are fed into the mixing chamber, where they are entrained with the high-velocity gas stream, creating an abrasive-laden gas mixture.
2. The high-velocity abrasive jet is directed towards the workpiece through the nozzle.
3. When the abrasive jet impacts the work piece's surface, it erodes and removes small fragments of material from the target area.
4. The nozzle or workpiece may be moved in a controlled manner to create the desired micro-machined features.
5. The eroded material is carried away by the gas stream and collected in a dust collector or filter system.
6. The process continues until the desired depth or shape is achieved on the workpiece.

Mass loss =k l/H x ½ mv^2

k- Dimensionless factor

m & v = Amount and velocity of particles

ρ& H = Density and hardness of the eroded material

Advantages of Abrasive Jet Micro Machining

- ✓ Versatility
- ✓ No mechanical forces
- ✓ No heat-affected zone
- ✓ Precision and accuracy
- ✓ No need for secondary finishing

Disadvantages of Abrasive Jet Micro Machining

- ✓ Slow material removal rate
- ✓ Surface roughness
- ✓ High equipment cost
- ✓ Abrasive consumption and disposal
- ✓ Noise and water usage:
- ✓ Limited thickness capacity

Applications of Abrasive Jet Micro Machining Method

- ✓ Microelectronics and Semiconductor Industry
- ✓ Medical Devices
- ✓ Aerospace and Defence
- ✓ MEMS (Micro electro mechanical Systems)
- ✓ Micro-optics
- ✓ Micro fluidics

- ✓ Jewellery and Art
- ✓ Watch making
- ✓ Automotive Industry
- ✓ Micro Metal Machining

Abrasive Water Jet Micro Machining (AWJMM)

6. Explain the working of Abrasive Water Jet Micro Machining.

Abrasive Water Jet Micro Machining (AWJMM)

Abrasive Water Jet Micro Machining (AWJMM) is a non-traditional micro-machining process that uses a high-velocity jet of water mixed with abrasive particles to remove material from a workpiece at a micro-scale level. AWJMM is known for its versatility, as it can machine a wide range of materials, including metals, composites, ceramics, and even some non-conductive materials. The process is particularly useful for micro-scale machining applications that require high precision, intricate shapes, and minimal heat-affected zones. Here's an overview of the principle and construction of Abrasive Water Jet Micro Machining:

Principle of Abrasive Water Jet Micro Machining:

The principle of Abrasive Water Jet Micro Machining is based on the combination of high-pressure water jet and abrasive particles to erode and remove material from the workpiece. The process involves the following steps:

1. **Pressurized Water:** Water is pressurized to very high levels (typically above 30,000 psi) using a high-pressure pump.
2. **Abrasive Mixing**: Abrasive particles, such as garnet or aluminum oxide, are introduced into the high-pressure water stream, creating a high-velocity abrasive water jet.
3. **Focused Jet**: The abrasive water jet is focused and directed through a small nozzle, which can have a diameter as small as a few thousandths of an inch (a few micrometres).
4. **Material Erosion:** When the focused abrasive water jet impinges on the workpiece surface, the high-velocity abrasive particles erode the material, gradually removing the material and creating the desired shape or profile.

Construction of Abrasive Water Jet Micro Machining Process:

The construction of Abrasive Water Jet Micro Machining setup typically includes the following components:

1. **High-Pressure Pump**: The high-pressure pump generates the required pressure to pressurize the water for the jet. It can achieve pressures in the range of 30,000 to 90,000 psi (2,000 to 6,000 bar).

2. **Mixing Chamber:** The mixing chamber is used to mix the abrasive particles with the high-pressure water, creating the abrasive water jet.
3. **Abrasive Hopper:** The abrasive hopper stores and feeds the abrasive particles into the mixing chamber.
4. **Nozzle**: The nozzle is a critical component that focuses the abrasive water jet into a narrow and high-velocity stream. It determines the machining precision and the size of the cut.
5. **CNC System**: A Computer Numerical Control (CNC) system controls the movement of the nozzle and the workpiece, allowing for precise control of the machining process.
6. **Workpiece Holder**: The workpiece is securely held in place during the machining process. The workpiece holder provides stability and precise positioning to achieve accurate micro-scale machining.

Working of Abrasive Water Jet Micro Machining:

The working of Abrasive Water Jet Micro Machining involves the following steps:

1. The high-pressure pump pressurizes water to very high levels.
2. Abrasive particles are introduced into the high-pressure water stream in the mixing chamber, creating an abrasive water jet.
3. The abrasive water jet is focused through the nozzle, creating a high-velocity stream.
4. The focused abrasive water jet is directed towards the workpiece surface, eroding the material and removing material in a controlled manner.
5. The CNC system precisely controls the movement of the nozzle and workpiece, allowing for intricate shapes and features to be machined.
6. The process continues until the desired shape or profile is achieved on the workpiece.

Advantages of Abrasive Water Jet Micro Machining:

1. **High precision and accuracy**: AWJMM can achieve extremely high levels of precision and accuracy in micro-scale machining, making it suitable for intricate and precise features.
2. **No heat-affected zone:** AWJMM is a cold cutting process, meaning there is minimal heat generation during machining, resulting in a negligible heat-affected zone around the machined area.
3. **Versatility:** AWJMM can machine a wide range of materials, including metals, composites, ceramics, and some non-conductive materials, providing versatility in micro-machining applications.
4. **No tool wear:** Since AWJMM is a non-contact process, there is no direct tool-to-workpiece contact, leading to minimal tool wear and longer tool life.

5. **Environmentally friendly:** AWJMM does not require the use of cutting fluids or coolants, making it an environmentally friendly machining process.

6. **Burr-free machining:** AWJMM typically produces no burrs or chips during the machining process, eliminating the need for post-machining deburring operations.

Disadvantages of Abrasive Water Jet Micro Machining:

1. **Material removal rate:** The material removal rate in AWJMM can be relatively slow compared to some other micro-machining processes, particularly for hard materials.

2. **Surface roughness:** Achieving a smooth surface finish in AWJMM can be challenging, and post-machining processes may be required to improve surface quality.

3. **Taper:** In some AWJMM applications, the material removal may cause taper or conical shapes, affecting dimensional accuracy.

Applications of Abrasive Water Jet Micro Machining:

1. In various precision engineering applications that require micro-scale machining and high accuracy. Microelectronics: AWJMM is used in microelectronics for creating microstructures, vias, and features on semiconductor devices and micro electromechanical systems (MEMS).

2. Medical Devices: AWJMM is used in manufacturing miniature medical devices, such as stents and micro fluidic components.

3. Aerospace: AWJMM is employed in aerospace applications for machining intricate components with high precision.

4. Micro fluidics: AWJMM is used in the fabrication of micro fluidic devices used in biomedical and chemical applications.

5. Optics: AWJMM can fabricate micro-optical components, such as diffraction gratings and micro-lenses.

6. Precision Engineering: AWJMM is applied

Ultrasonic Micro Machining:

7. **Ultrasonic Micro Machining**:
   - Ultrasonic micro machining is based on the principle of using high-frequency ultrasonic vibrations to remove material from the workpiece at a micro-scale level.
   - The process involves the application of mechanical energy in the form of ultrasonic vibrations to the cutting tool or the abrasive slurry, which is then transferred to the workpiece.

- The combination of ultrasonic vibrations and the abrasive action of the slurry or cutting tool allows for precise and controlled material removal, enabling micro-scale machining with high accuracy and surface quality.

Construction of Ultrasonic Micro Machining Process:

The **construction** of an ultrasonic micro machining system typically includes the following components:

1. **Ultrasonic Transducer:** The ultrasonic transducer is a critical component that generates high-frequency vibrations. It converts electrical energy into mechanical vibrations using the piezoelectric effect. The ultrasonic transducer is often made of piezoelectric materials such as quartz, PZT (Lead Zirconate Titanate), or ceramics.
2. **Horn or Booster:** The ultrasonic vibrations generated by the transducer are amplified and transmitted to the cutting tool or the abrasive slurry through a horn or booster. The horn magnifies the amplitude of the vibrations, enabling efficient material removal.
3. **Cutting Tool or Abrasive Slurry**: Depending on the specific application, either a cutting tool or an abrasive slurry is used for material removal. In ultrasonic grinding, an abrasive slurry containing abrasive particles is applied to the workpiece surface. The abrasive particles suspended in the slurry act as cutting tools. In ultrasonic drilling, a rotating tool with a diamond tip or other hard material is used to drill holes or shape the workpiece.
4. **Workpiece Holder:** The workpiece is securely held in place during the machining process. The workpiece holder provides stability and precise positioning to achieve accurate micro-scale machining.
5. **Control System**: The control system manages the ultrasonic transducer's frequency and amplitude, allowing for precise control over the vibrations. It also regulates the flow of the abrasive slurry (if applicable) and controls the movement of the cutting tool or workpiece (if required).
6. **Cooling and Lubrication System**: In some cases, a cooling and lubrication system is used to manage the heat generated during machining and to minimize wear on the cutting tool or abrasive particles.

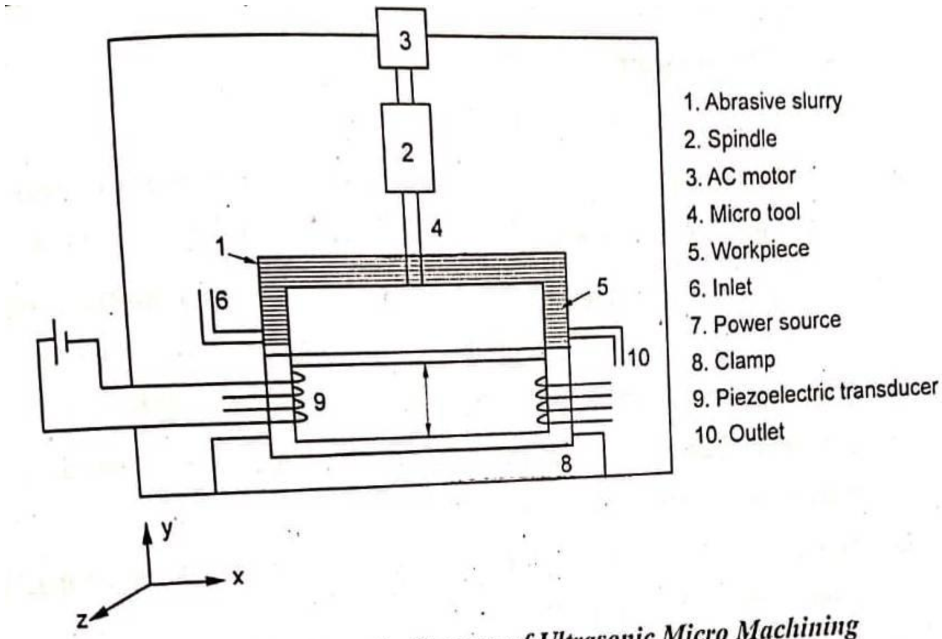


Fig. 5.18. Schematic diagram of Ultrasonic Micro Machining

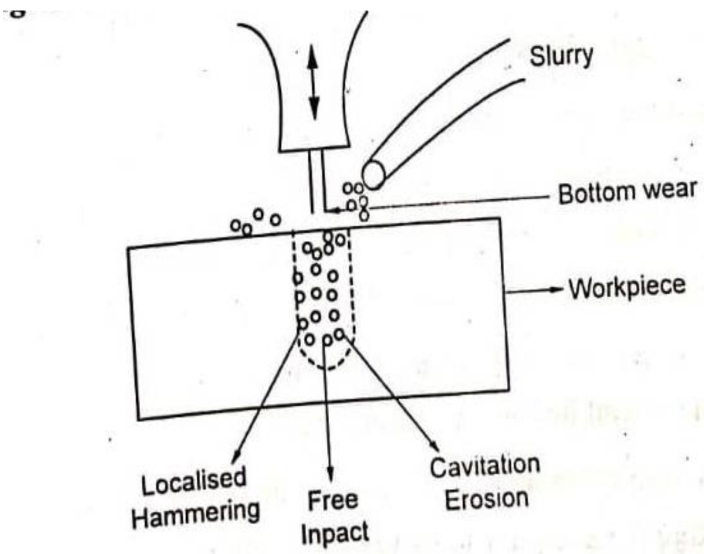


Fig. 5.19. Material removal in Ultrasonic Micro Machining

Working of Ultrasonic Micro Machining Process:

The ultrasonic micro machining process involves the following steps:

- The ultrasonic transducer generates high-frequency vibrations, which are amplified by the horn or booster.
- The vibrations are transferred to the cutting tool or abrasive slurry, providing the necessary energy for material removal.
- In ultrasonic grinding, the abrasive slurry is applied to the workpiece surface, and the abrasive particles in the slurry abrade the material, gradually machining the desired shape.

- ➢ In ultrasonic drilling, the rotating tool with a diamond tip is brought into contact with the workpiece. The combination of rotation and ultrasonic vibrations facilitates precise drilling of small holes or shaping of the workpiece.
- ➢ The ultrasonic vibrations, along with the abrasive action, allow for micro-scale machining with high precision and minimal thermal effects

Advantages of Ultrasonic Micro Machining:

- ✓ **High precision:** Ultrasonic micro machining can achieve extremely high precision and accuracy, making it suitable for applications that demand intricate and precise features.
- ✓ **Improved surface finish:** The non-impact nature of ultrasonic micro machining results in improved surface finish compared to traditional machining methods.
- ✓ **Machining of hard and brittle materials**: Ultrasonic micro machining is well-suited for machining hard and brittle materials such as ceramics, glass, and semiconductors, which can be challenging to machine using conventional methods.
- ✓ **Non-thermal process**: Ultrasonic micro machining is a non-thermal process, meaning it generates minimal heat during machining, reducing the risk of thermal damage to the workpiece.
- ✓ **Minimal tool wear**: The use of abrasive slurry or liquid in ultrasonic micro machining reduces tool wear, leading to longer tool life and reduced maintenance costs.
- ✓ **No burr formation**: Ultrasonic micro machining typically produces no burrs or chips during the machining process, eliminating the need for post-machining deburring operations.

Disadvantages of Ultrasonic Micro Machining:

- ✓ Limited material removal rate: Ultrasonic micro machining generally has a slower material removal rate compared to some conventional machining processes, which may affect production efficiency.
- ✓ Equipment cost: The equipment required for ultrasonic micro machining can be relatively expensive, which may be a consideration for some businesses.
- ✓ Complexity: Ultrasonic micro machining requires precise control over ultrasonic vibrations and abrasive slurry delivery, which can add complexity to the machining process.
- ✓ Limited applicability to certain shapes: Ultrasonic micro machining may be limited in its ability to create complex 3D shapes or features with varying depths.

Electric Discharge Micro Machining (EDMM):

8. Explain EDMM process with neat sketch.

Principle:

The principle of Electric Discharge Micro Machining involves the use of a tool electrode (either a solid electrode or a thin wire) and a workpiece, both immersed in a dielectric fluid. When an electrical potential difference is applied between the tool and the workpiece, an electrical discharge occurs in the small gap between them. This discharge creates intense heat, causing localized melting or vaporization of the workpiece material. The dielectric fluid cools the workpiece and removes the debris generated during the process. As the tool electrode advances, material is removed from the workpiece, shaping it according to the desired geometry.

Construction of Electric Discharge Micro Machining:

The construction of an Electric Discharge Micro Machining setup typically includes the following components:

- ✓ Power Supply: The power supply provides the electrical energy required for the electrical discharges between the tool electrode and the workpiece.
- ✓ Tool Electrode: The tool electrode can be a solid electrode or a thin, electrically conductive wire, depending on the type of EDMM process (EDM or WEDM).
- ✓ Workpiece Holder: The workpiece is securely held in place during the machining process. The workpiece holder provides stability and precise positioning to achieve accurate micro-scale machining.
- ✓ Dielectric Fluid System: The dielectric fluid, usually deionized water or specialized EDM oils, is used to flush away debris, cool the workpiece, and maintain a stable spark gap between the tool electrode and the workpiece.
- ✓ Control System: The control system manages the power supply, feed rates, and other process parameters to achieve the desired level of material removal and surface finish.

  Working of Electric Discharge Micro Machining:

The working of Electric Discharge Micro Machining involves the following steps:

1. The tool electrode and the workpiece are immersed in a dielectric fluid.
2. An electrical potential difference is applied between the tool electrode and the workpiece, creating a spark discharge in the small gap between them.

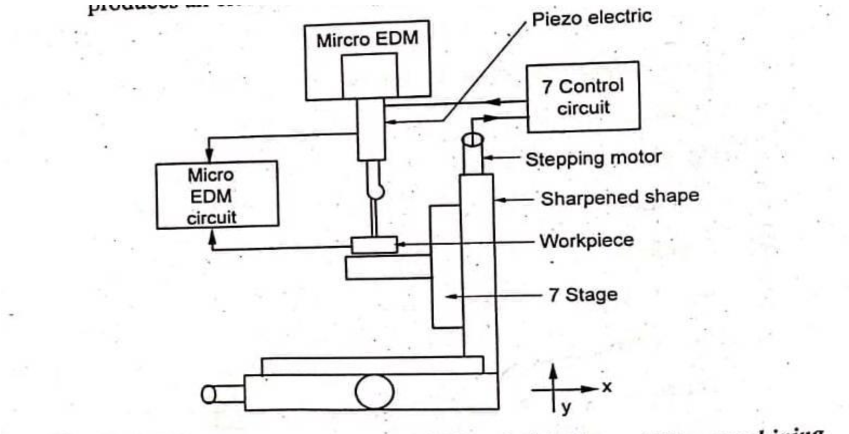
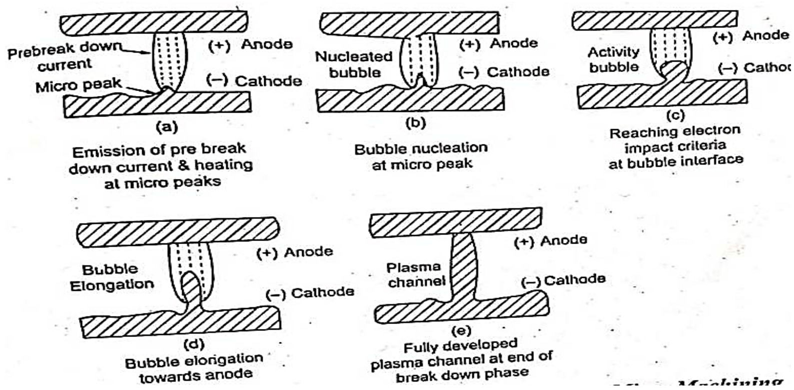


Fig. 5.20. Schematic arrangement of Electric Discharge Micromachining

3. The spark discharge generates intense heat, melting or vaporizing a small amount of the workpiece material.
4. The dielectric fluid cools the workpiece and flushes away the debris created during the process.
5. As the tool electrode advances or moves according to the programmed path, material is gradually removed from the workpiece, shaping it according to the desired geometry.
6. The process continues until the desired shape or profile is achieved on the workpiece.



- Electric Discharge Micro Machining is widely used in industries that require high precision, fine features, and intricate shapes in hard and conductive materials.
- Its ability to machine complex geometries and maintain high tolerances makes it valuable in various applications, including microelectronics, aerospace, medical devices, and precision manufacturing.

Effects of electric discharge micro machining:

Electric Discharge Micro Machining (EDMM) has several effects on the workpiece and the machining process. These effects play a crucial role in determining the overall machining performance and the quality of the finished micro-scale components. Some of the key effects of Electric Discharge Micro Machining are as follows:

1.Material Removal:

EDMM removes material through localized melting or vaporization caused by the intense heat generated during electrical discharges. This effect enables precise material removal in micro-scale dimensions, allowing for intricate shapes and features.

2.Surface Finish:

The surface finish achieved in EDMM depends on various factors, including the pulse duration, current, voltage, and dielectric fluid properties. Proper control of these parameters can lead to smooth surface finishes.

3.Heat-Affected Zone (HAZ):

The localized heat generated during electrical discharges can create a Heat-Affected Zone (HAZ) around the machined area. In some cases, this HAZ can cause changes in material properties, such as hardness or microstructure.

4.Material Recast Layer:

EDMM may form a thin recast layer on the machined surface due to the melting and re-solidification of material. The recast layer may have different properties compared to the base material and may require post-machining treatments.

5.Micro-Cracking:

In certain materials, such as brittle ceramics, electrical discharges can induce micro-cracks or micro-fractures in the vicinity of the machined area. These cracks can affect the structural integrity of the component.

6.Tool Wear:

The tool electrode in EDMM experiences wear during the machining process due to repeated electrical discharges. The wear can affect the accuracy and dimensional stability of the machining operation.

7.Accuracy and Tolerance:

The precision and accuracy of EDMM depend on the control of process parameters, machine rigidity, and stability. Proper calibration and control are essential to achieve tight tolerances in micro-scale machining.

8.Material Conductivity:

EDMM is most effective on electrically conductive materials. Non-conductive materials are generally not suitable for this machining process.

9.Machining Speed:

EDMM is generally a slower machining process compared to some traditional machining methods. This may limit its use in applications where high material removal rates are required.

10. Surface Integrity:

The surface integrity of the machined components, including residual stress and microstructural changes, can be influenced by the EDMM process parameters

Advantages and Disadvantages of Electric Discharge Micro Machining:

- ✓ High precision
- ✓ Complex shapes and details
- ✓ No mechanical force.
- ✓ Suitable for hard and brittle materials
- ✓ No tool wear
- ✓ Burr-free machining
- ✓ Non-thermal process
- ✓ Versatility

Disadvantages of Electric Discharge Micro Machining (EDMM):

- ✓ Slow material removal rate
- ✓ Limited to conductive materials
- ✓ Surface finish and recast layer
- ✓ Limited thickness capacity
- ✓ High initial cost
- ✓ Complexity
- ✓ Environmental considerations

Electron Beam Micro Machining Process

9. Explain the principle of Electron Beam Micro Machining Process

The principle of Electron Beam Micro Machining is based on the interaction between a focused electron beam and the workpiece material**.** When a high-energy electron beam is focused onto the workpiece surface, it imparts energy to the material. This energy is converted into heat, causing localized melting and vaporization of the material. The removal of material occurs as the molten material is expelled from the workpiece surface due to the high-pressure gas jet or vacuum environment. The focused electron beam can be precisely controlled to remove material in a highly controlled manner, allowing for micro-scale machining with exceptional precision and accuracy.

Construction of Electron Beam Micro Machining:

The construction of an Electron Beam Micro Machining setup typically includes the following components:

1. **Electron Gun:** The electron gun is the source of the high-energy electron beam. It generates a stream of electrons, which are accelerated to high velocities using electromagnetic fields.
2. **Electron Optics:** The electron optics system consists of magnetic and electrostatic lenses that focus and control the electron beam's trajectory. It helps to focus the electron beam to a small spot size, enabling micro-scale machining.
3. **Workpiece Holder**: The workpiece is securely held in place during the machining process. The workpiece holder provides stability and precise positioning to achieve accurate micro-scale machining.
4. High Vacuum **Chamber:** Electron Beam Micro Machining requires a high vacuum environment to prevent scattering and interaction of the electron beam with air molecules. The high vacuum chamber ensures the electron beam reaches the workpiece surface with minimal distortion.
5. **Gas Jet or Vacuum System:** Depending on the specific EBMM setup, either a gas jet or vacuum system is used to remove the molten material from the workpiece surface. The gas jet can blow away the molten material, while the vacuum system evacuates it from the machining zone.
6. **Control System:** The control system manages the electron beam intensity, scanning pattern, and workpiece movement to achieve the desired level of material removal and surface finish.

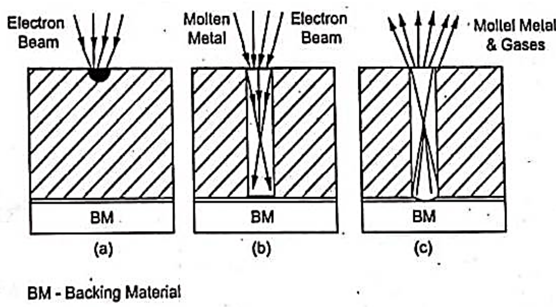


Fig. 5.23. Mechanism of material removal in drilling of Electron Beam Micro Machining

Working of Electron Beam Micro Machining:

The working of Electron Beam Micro Machining involves the following steps:

1. The electron gun generates a high-energy electron beam.

2. The electron optics system focuses the electron beam onto a small spot size.
3. The focused electron beam is directed onto the workpiece surface, causing localized melting and vaporization of the material.
4. The molten material is removed from the workpiece surface either by a gas jet or through vacuum suction.
5. As the electron beam scans across the workpiece, material is gradually removed, shaping it according to the desired geometry.
6. The process continues until the desired shape or profile is achieved on the workpiece.

Advantages of Electron Beam Micro Machining (EBMM):

- ✓ High precision
- ✓ Non-contact process
- ✓ Versatility
- ✓ Fine feature machining
- ✓ Minimal heat-affected zone
- ✓ No tool wear
- ✓ Burr-free machining
- ✓ Clean and environmentally friendly

Disadvantages of Electron Beam Micro Machining (EBMM):

- ✓ High initial cost
- ✓ Limited to conductive materials
- ✓ Vacuum requirement.
- ✓ Surface roughness
- ✓ Limited material thickness
- ✓ Complexity

Applications of Electron Beam Micro Machining:

- ➢ Microelectronics
- ➢ Aerospace
- ➢ Medical Devices
- ➢ Optics
- ➢ MEMS (Micro electromechanical Systems)
- ➢ Precision Engineering

Effects of Electron Beam Micro Machining Methods

1. **Material Removal:**

   EBMM removes material through localized melting and vaporization caused by the high-energy electron beam. This effect enables precise material removal in micro-scale dimensions, allowing for intricate shapes and features.

2. **Surface Finish:**

   The surface finish achieved in EBMM depends on various factors, including the electron beam intensity, scanning pattern, and material properties. Proper control of these parameters can lead to smooth surface finishes.

3. **Heat-Affected Zone (HAZ):**

   The localized heat generated during EBMM can create a Heat-Affected Zone (HAZ) around the machined area. In some cases, this HAZ can cause changes in material properties, such as hardness or microstructure.

4. **Microstructure and Grain Size:**

   The rapid solidification of the melted material in EBMM can influence the microstructure and grain size of the machined material, affecting its mechanical properties.

5. **Material Recast Layer:**

   EBMM may form a thin recast layer on the machined surface due to the melting and re-solidification of material. The recast layer may have different properties compared to the base material and may require post-machining treatments.

6. **Residual Stress:**

   The rapid heating and cooling in EBMM can induce residual stresses in the machined material, which may affect the dimensional stability and structural integrity of the component.

7. **Accuracy and Tolerance:**

   The precision and accuracy of EBMM depend on the control of process parameters, electron beam intensity, and workpiece movement. Proper calibration and control are essential to achieve tight tolerances in micro-scale machining.

8. **Material Conductivity:**

   EBMM is most effective on electrically conductive materials. Non-conductive materials are not suitable for this machining method.

9. **Surface Contamination:**

   Electron beam machining in a vacuum environment can reduce the risk of surface contamination and oxidation, preserving the material's integrity.

10. Electron Scattering and Absorption:

The interaction of the electron beam with the workpiece material can lead to scattering and absorption of electrons, affecting the machining efficiency and depth of material removal.

11. Beam Deflection:

External factors such as magnetic fields or misalignments can cause electron beam deflection, leading to inaccuracies in the machining process.

12. **Edge Taper:**

In some EBMM methods, such as Wire EDM, the electron beams focused spot size may result in edge taper or conical shapes, affecting dimensional accuracy.

<u>**Laser Beam Micro Machining**</u>

10. LASER BEAM MICROMACHINING PROCESS:

Describe anyone laser assisted machining process with constructional detail. (Apr/May-2023)

Principle of Laser Beam Micro Machining:

- Laser Beam Micro Machining is a non-contact, non-traditional micro-machining process that utilizes a highly focused laser beam to remove material from a workpiece at a micro-scale level.
- The principle of laser beam micro machining is based on the interaction between the focused laser beam and the workpiece material.
- When the intense laser beam is directed onto the workpiece surface, it imparts energy to the material. This energy is absorbed by the material, causing localized melting, vaporization, or ablation of the material. The removal of material occurs as the molten or vaporized material is expelled from the workpiece surface due to the rapid expansion of the heated material.
- The focused laser beam can be precisely controlled to remove material in a highly controlled manner, enabling micro-scale machining with exceptional precision and accuracy.

Construction of Laser Beam Micro Machining Process:

The construction of a Laser Beam Micro Machining setup typically includes the following components:

1.Laser Source: The laser source is the heart of the system, generating a high-intensity laser beam. The type of laser used can vary, including CO2, Nd:YAG, fibre lasers, or ultrafast lasers, depending on the specific application requirements.

2.Beam Delivery System: The beam delivery system consists of a series of mirrors and lenses that steer and focus the laser beam onto the workpiece. This system ensures the precise positioning and focus of the laser beam for accurate micro-machining.

3.Workpiece Holder: The workpiece is securely held in place during the machining process. The workpiece holder provides stability and precise positioning to achieve accurate micro-scale machining.

4.Assist Gas or Air Flow: An assist gas, such as nitrogen or compressed air, may be used during the laser micro-machining process. The assist gas helps to blow away the molten or vaporized material from the machining zone, improving material removal efficiency and preventing redeposition.

5.Control System: The control system manages the laser intensity, scanning pattern, and workpiece movement to achieve the desired level of material removal and surface finish.

6.Vision System (Optional): Some laser micro-machining setups may include a vision system for real-time monitoring and feedback, allowing for automated adjustments during the machining process.

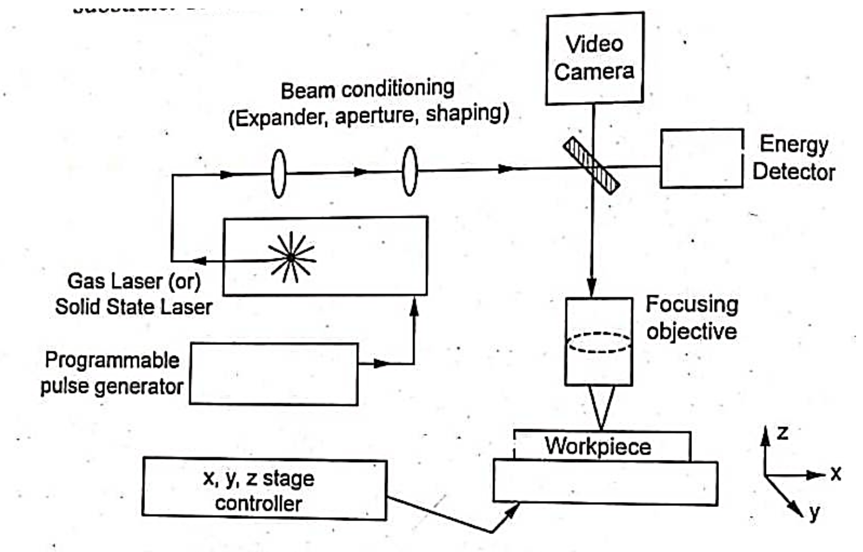


Fig. 5.24. Laser direct writing technique

Working of Laser Beam Micro Machining:

The working of Laser Beam Micro Machining involves the following steps:

- ❖ The laser source generates a high-intensity laser beam.
- ❖ The beam delivery system steers and focuses the laser beam onto a small spot size, achieving a high power density on the workpiece surface.
- ❖ The focused laser beam is directed onto the workpiece surface, causing localized melting, vaporization, or ablation of the material.

- The molten or vaporized material is expelled from the workpiece surface due to the rapid expansion of the heated material.
- As the laser beam scans across the workpiece or follows a programmed path, material is gradually removed, shaping it according to the desired geometry.
- The process continues until the desired shape or profile is achieved on the workpiece.

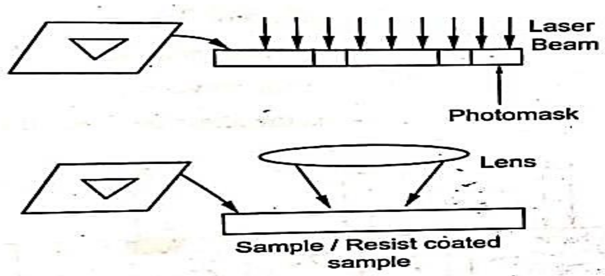


Fig. 5.25. Mask Projection Technique

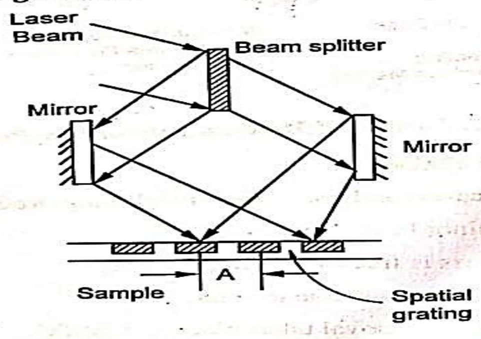


Fig. 5.26. Laser Interference Technique

Advantages of Laser Beam Micro Machining:

- ✓ High precision and accuracy
- ✓ Non-contact process
- ✓ Versatility
- ✓ Fine feature machining
- ✓ Minimal heat-affected zone
- ✓ No tool wear
- ✓ Burr-free machining
- ✓ Clean and environmentally friendly

Disadvantages of Laser Beam Micro Machining

- ✓ High initial cost
- ✓ Limited material thickness
- ✓ Surface roughness
- ✓ High reflectivity
- ✓ Beam divergence
- ✓ Thermal effects

Applications of Laser Beam Micro Machining:

- ✓ Microelectronics
- ✓ Optics
- ✓ MEMS (Micro electromechanical Systems)
- ✓ Precision Engineering

Electrochemical Micro Machining

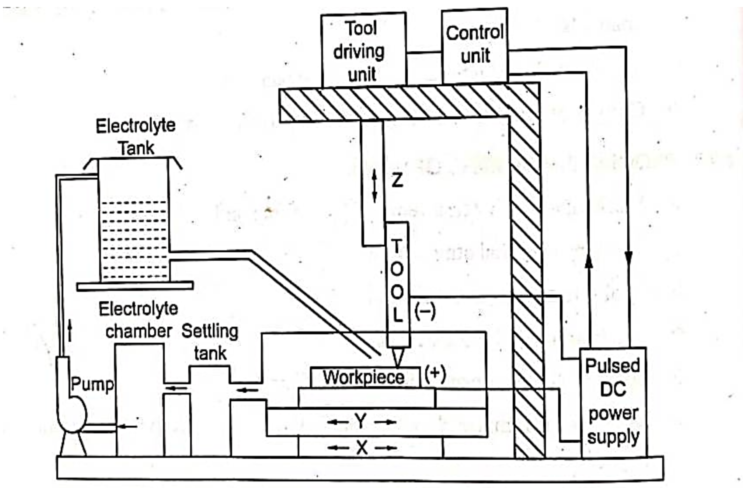
11. ELECTRO CHEMICAL MICRO MACHINING

Principle of Electrochemical Micro Machining:

- ❖ The principle of Electrochemical Micro Machining is based on the concept of electrochemical dissolution, where material removal occurs due to the electrochemical reaction between the workpiece and an electrolyte.
- ❖ The process requires a conductive workpiece that can act as the anode and an electrolyte solution that serves as the cathode.
- ❖ When a DC voltage is applied between the anode (workpiece) and cathode (electrolyte), an electrochemical reaction occurs, resulting in the dissolution of material from the workpiece surface.
- ❖ The dissolved material is carried away by the flowing electrolyte, leading to the desired shape and profile on the workpiece.

Construction of Electrochemical Micro Machining Process:

The construction of an Electrochemical Micro Machining setup typically includes the following components**:**



ig. 5.28. Schematic Arrangement of Electro Chemical Micro Machining Process

1. **Electrolyte Supply System**: The electrolyte supply system delivers the electrolyte solution to the machining zone, ensuring a constant flow to carry away the dissolved material and maintain a stable electrochemical reaction.

2. **Workpiece Holder:** The workpiece is securely held in place during the machining process. The workpiece holder provides stability and precise positioning to achieve accurate micro-scale machining.
3. **Electrode Tool:** The electrode tool, often made of an electrically conductive material, is used to direct the flow of the electrolyte and facilitate the electrochemical reactions at specific locations on the workpiece.
4. **DC Power Supply:** The DC power supply provides the electrical energy required for the electrochemical reaction to occur. The voltage and current are controlled to regulate the material removal rate.
5. **Control System:** The control system manages the power supply, electrolyte flow, and workpiece movement to achieve the desired level of material removal and surface finish.

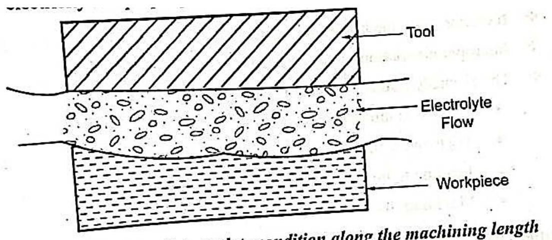


Fig. 5.29. Variation of electrolyte condition along the machining length

Working of Electrochemical Micro Machining:

The working of Electrochemical Micro Machining involves the following steps:

- ✓ The workpiece is placed in the electrolyte solution.
- ✓ A DC voltage is applied between the workpiece (anode) and the electrode tool (cathode).
- ✓ The electrochemical reaction causes material dissolution from the workpiece surface, leading to material removal.
- ✓ The dissolved material is carried away by the flowing electrolyte.
- ✓ As the electrode tool moves along the workpiece surface or follows a programmed path, material is gradually removed, shaping it according to the desired geometry.
- ✓ The process continues until the desired shape or profile is achieved on the workpiece.

Advantages of Electrochemical Micro Machining:

- ✓ High precision and accuracy
- ✓ Burr-free machining
- ✓ Delicate and complex materials
- ✓ Surface finish
- ✓ No tool wear

Disadvantages of Electrochemical Micro Machining:

- ✓ Limited to conductive materials
- ✓ Process complexity
- ✓ Material dissolution rate
- ✓ Tool design and fabrication

Applications of Electrochemical Micro Machining:

- ✓ Microelectronics
- ✓ Medical Devices
- ✓ Aerospace
- ✓ Microfluidics
- ✓ Precision Engineering

`Process Parameters of Electrochemical Micro Machining

1. **Voltage (V):**
   The DC voltage applied between the workpiece (anode) and the electrode tool (cathode) influences the material removal rate. Increasing the voltage typically leads to higher material removal rates, but it should be controlled to avoid excessive material dissolution and overcutting.
2. **Current (I):**
   The DC current passing through the workpiece affects the electrochemical dissolution rate. Higher current values usually result in faster material removal, but it should be regulated to prevent overheating and excessive material loss.
3. **Electrolyte Flow Rate:**
   The flow rate of the electrolyte solution affects the removal of dissolved material from the machining zone. Proper flow rate ensures efficient flushing of debris and maintains a stable electrochemical reaction.
4. **Electrolyte Composition:**
   The choice of electrolyte solution and its chemical composition can significantly impact the material removal rate and surface finish. Different electrolytes are used depending on the material being machined and the desired machining characteristics.
5. **Electrode Tool Design:**
   The design of the electrode tool influences the machining accuracy and surface finish. The geometry and shape of the tool should be optimized for the specific machining application.

6. **Gap Distance:**

   The gap distance between the electrode tool and the workpiece affects the machining precision and surface finish. A smaller gap distance allows for higher precision but may reduce material removal rates.

7. **Machining Time:**

   The total machining time affects the material removal depth and overall machining efficiency. Longer machining times result in more material removal but should be balanced with other process requirements.

8. **Temperature:**

   The electrolyte temperature can impact the electrochemical reaction rate and the thermal effects on the workpiece. Proper temperature control is essential to maintain stable machining conditions.

9. **Pulse Frequency (for Pulse Electrochemical Machining - PECM):**

   In Pulse Electrochemical Machining, the pulse frequency determines the on-time and off-time of the current. Adjusting the pulse frequency can influence material removal rates and surface finish.

10. **Pulse Duty Cycle (for Pulse Electrochemical Machining - PECM):**

    The pulse duty cycle refers to the ratio of on-time to the total cycle time. Modifying the pulse duty cycle can affect the amount of material removed and the machining accuracy.

11. **Tool Feed Rate (for Electrochemical Grinding - ECG):**

    In Electrochemical Grinding, the feed rate of the tool affects the material removal rate and the surface finish. Proper feed rate control is crucial for achieving desired results.

Recent Trends in Non-Traditional Machining Processes

12. Explain the recent developments in non-traditional machining processes. (Nov/Dec 2021)

Introduction

- In recent years there has been a massive growth in the usage of the non - traditional machining process. Especially in machining of hard materials likes titanium, stainless steels.
- These materials have wide use in modern industry due to their improved mechanical properties.
- These materials have various applications in the manufacturing of product. These materials cannot be machined economically using conventional manufacturing process.

- In the competitive business environment customer expects high accurate product with low cost, cost and process optimization using conventional manufacturing methods is not suitable, this forces to use non tradition manufacturing methods.
- The unique characteristics of this processes is that there is no direct contact between tool and the work piece and also in this process a huge amount of energy can be concentrated per unit area.
- Also the selection process becomes more important as all the machining processes cannot be done by using a single method we need to choose an efficient method for different machining processes.
- Also as we understand the importance and efficiency on non-traditional machining over traditional machining it gives us advantages over it and also this NTM processes leads to lot of advancement which has to be done day by day.
- This NTM process also gives us a path for various innovations as well as it makes us comfortable for designing of complex geometrical shapes.
- This situation leads to a great competition in the market.
- As there is difficulty in the selection of NTM process this selection is made easier using a 16-digit classification code (cogun, 1993, 1994).
- Here the optimization selection of process can be done as all the methods are stored in the database of the system.
- To conduct theses selection processes we require an expertise human resources and a structured approach is always made.

Different machining operations in NTM:

- Many complex designed products can be generated on the work piece material by the application of appropriate NTM processes.
    a. Deep cutting: The machining operations are carried out to generate the desired design on the work piece material with more depth of cut.
    b. Shallow cutting: In this operation the depth of cut is comparatively low.
    c. Drilling operation: This operation is used to cut or to machine a hole of circular cross section in a solid.
    d. Precision cavity: A cavity with close dimensional tolerances is produced for its internal application.
    e. Standard cavity: a cavity with clear set of dimensions is produced, but it cannot be employed for intrinsic applications.

b. The shape feature obtained is demarcated into two separate and different, top and bottom contours of the work piece material.
a. Surface of revolution: This operation is done to obtain good surface finish on the work-piece by rotating the work piece in two dimensional curve about its axis.
b. Finishing: This machining operation is done to attain mirror finish on the surface of the work piece with high accuracy and superior surface finish.

- Nonconventional or advanced machining processes such as electric discharge machining, electrochemical machining, abrasive water jet machining, and laser beam machining have been widely used as a viable alternate to the conventional processes to manufacture high-quality engineered parts having certain typical features.
- In spite of their special features, wider acceptance, and use, they suffer from certain inherent limitations with regard to sustainability such as high consumption of energy and resources; generation of toxic liquid, gases, and solid wastes; risk for health and safety; air pollution; generation of waste and its disposal problems; and work piece contamination and thermal damage to the parts being produced.
- It is found that these factors all adversely affect the environment to a certain extent. Innovative sustainable techniques such as dry, near-dry, and green electric discharge machining; green and hybrid electrochemical machining; ice-jet machining; and eco- and underwater laser beam machining, etc. have been developed to address sustainability challenges and greatly benefited with improvements in quality, productivity, and sustainability.
- The four major nonconventional machining processes, discusses their inherent sustainability issues and challenges, and presents state-of-the-art review of the work conducted using sustainable innovative techniques and strategies with an aim to encourage academics, researchers, and engineers for research and developments in order to establish the field further.

13. Explain the working principle of 3D printing technology for the production of parts. (July 2021)

- 3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file.
- The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the

object is created. Each of these layers can be seen as a thinly sliced cross-section of the object.

- 3D printing is the opposite of subtractive manufacturing which is cutting out / hollowing out a piece of metal or plastic with for instance a milling machine.
- 3D printing enables you to produce complex shapes using less material than traditional manufacturing methods.

How Does 3D Printing Work?

- It all starts with a 3D model. You can opt to create one from the ground up or download it from a 3D library.

3D Software

- There are many different software tools available. From industrial grade to open source. We've created an overview on our 3D software page.
- We often recommend beginners to start with Tinkercad. Tinkercad is free and works in your browser, you don't have to install it on your computer. Tinkercad offers beginner lessons and has a built-in feature to export your model as a printable file e.g .STL or .OBJ.
- Now that you have a printable file, the next step is to prepare it for your 3D printer. This is called slicing.

Slicing: From printable file to 3D Printer

- Slicing basically means slicing up a 3D model into hundreds or thousands of layers and is done with slicing software.
- When your file is sliced, it's ready for your 3D printer. Feeding the file to your printer can be done via USB, SD or Wi-Fi. Your sliced file is now ready to be 3D printed **layer by layer**.

3D Printing Industry

- The adoption of 3D printing has reached critical mass as those who have yet to integrate additive manufacturing somewhere in their supply chain are now part of an ever-shrinking minority. Where 3D printing was only suitable for prototyping and one-off manufacturing in the early stages, it is now rapidly transforming into a production technology.
- Most of the current demand for 3D printing is industrial in nature. Acumen Research and Consulting forecasts the global 3D printing market to reach $41 billion by 2026.

- As it evolves, 3D printing technology is destined to transform almost every major industry and change the way we live, work, and play in the future.

Examples of 3D Printing

- 3D printing encompasses many forms of technologies and materials as 3D printing is being used in almost all industries you could think of. It's important to see it as a cluster of diverse industries with a myriad of different applications.

A few examples:

- consumer products (eyewear, footwear, design, furniture)
- industrial products (manufacturing tools, prototypes, functional end-use parts)
- dental products
- prosthetics
- architectural scale models & maquettes
- reconstructing fossils
- replicating ancient artefacts
- reconstructing evidence in forensic pathology
- movie props

Rapid Prototyping & Rapid Manufacturing

- Companies have used 3D printers in their design process to create prototypes since the late seventies. Using 3D printers for these purposes is called **rapid prototyping**.

Why use 3D Printers for Rapid Prototyping?

- In short: it's fast and relatively cheap. From idea, to 3D model to holding a prototype in your hands is a matter of days instead of weeks. Iterations are easier and cheaper to make and you don't need expensive moulds or tools.
- Besides rapid prototyping, 3D printing is also used for **rapid manufacturing**. Rapid manufacturing is a new method of manufacturing where businesses use 3D printers for short run / small batch custom manufacturing.

Automotive

- Car manufacturers have been utilizing 3D printing for a long time. Automotive companies are printing spare parts, tools, jigs and fixtures but also end-use parts.
- 3D printing has enabled on-demand manufacturing which has lead to lower stock levels and has shortened design and production cycles.

- Automotive enthusiasts all over the world are using 3D printed parts to restore old cars. One such example is when Australian engineers printed parts to bring a Delage Type-C back to life. In doing so, they had to print parts that were out of production for decades.

Aviation

- The aviation industry uses 3D printing in many different ways. The following example marks a significant 3D printing manufacturing milestone: GE Aviation has 3D printed 30,000 Cobalt-chrome fuel nozzles for its LEAP aircraft engines.
- They achieved that milestone in October of 2018, and considering that they produce 600 per week on forty 3D printers, it's likely much higher than that now.

Consumer Products

- When we first started blogging about 3D printing back in 2011, 3D printing wasn't ready to be used as a production method for large volumes.
- Nowadays there are numerous examples of end-use 3D printed consumer products.

Footwear

- Adidas' 4D range has a fully 3D printed midsole and is being printed in large volumes. We did an article back then, explaining how Adidas were initially releasing just 5,000 pairs of the shoes to the public, and had aimed to sell 100,000 pairs of the AM-infused designs by 2018.
- With their latest iterations of the shoe, it seems that they have surpassed that goal, or are on their way to surpassing it. The shoes are available all around the world from local Adidas stores and also from various 3rd party online outlets.

Jewellery

- There are two ways of producing jewellery with a 3D printer. You can either use a direct or indirect production process.
- Direct refers to the creation of an object straight from the 3D design while indirect manufacturing means that the object (pattern) that is 3D printed eventually is used to create a mould for investment casting.

Healthcare

- It's not uncommon these days to see headlines about 3D printed implants. Often, those cases are experimental, which can make it seem like 3D printing is still a fringe technology in the medical and healthcare sectors, but that's not the case anymore.
- Over the last decade, more than 100,000 hip replacements have been 3D printed by GE Additive.

- The Delta-TT Cup designed by Dr. Guido Grappiolo and Lima Corporate is made of Trabecular Titanium, which is characterized by a regular, three-dimensional, hexagonal cell structure that imitates trabecular bone morphology.
- The trabecular structure increases the biocompatibility of the titanium by encouraging bone growth into the implant. Some of the first Delta-TT implants are still running strong over a decade later.
- Another 3D printed healthcare component that does a good job of being undetectable is the hearing aid. Nearly every hearing aid in the last 17 years has been 3D printed thanks to a collaboration between Materialise and Phonak.
- Phonak developed Rapid Shell Modelling (RSM) in 2001. Prior to RSM, making one hearing aid required nine laborious steps involving hand sculpting and mould making, and the results were often ill-fitting.
- With RSM, a technician uses silicone to take an impression of the ear canal, that impression is 3D scanned, and after some minor tweaking the model is 3D printed with a resin 3D printer.
- The electronics are added and then it's shipped to the user. Using this process, hundreds of thousands of hearing aids are 3D printed each year.

Dental

- In the dental industry, we see moulds for clear aligners being possibly the most 3D printed objects in the world. Currently, the moulds are 3D printed with both resin and powder based 3D printing processes, but also via material jetting.
- Crowns and dentures are already directly 3D printed, along with surgical guides.

Education

- Educators and students have long been using 3D printers in the classroom. 3D printing enables students to materialize their ideas in a fast and affordable way.
- While additive manufacturing-specific degrees are fairly new, universities have long been using 3D printers in other disciplines.
- There are many educational courses one can take to engage with 3D printing. Universities offer courses on things that are adjacent to 3D printing like CAD and 3D design, which can be applied to 3D printing at a certain stage.
  - In terms of prototyping, many university programs are turning to printers. There are specializations in additive manufacturing one can attain through architecture or industrial design degrees. Printed prototypes are also very common in the arts, animation and fashion studies as well.

14. Compare and contrast the principles of operation between abrasive jet machining, abrasive water jet machining and ultrasonic machining. Nov/Dec 2023

Abrasive Jet Machining (AJM), Abrasive Water Jet Machining (AWJM), and Ultrasonic Machining (USM) are non-traditional machining processes that utilize different principles for material removal. Let's compare and contrast the principles of operation for these three processes:

1. Abrasive Jet Machining (AJM):

Principle of Operation:

AJM involves the use of a high-velocity stream of abrasive particles (typically entrained in a gas) directed towards the workpiece surface.

The abrasive particles impact and erode the material, leading to the removal of material from the workpiece.

Characteristics:

The abrasive particles are propelled by a gas (usually air) through a nozzle to create a high-velocity jet.

The process is suitable for machining brittle and hard materials.

It is a non-contact process, and the material removal mechanism is mechanical erosion.

2. Abrasive Water Jet Machining (AWJM):

Principle of Operation:

AWJM is similar to AJM but incorporates the use of water as a carrier medium for the abrasive particles.

The water jet is pressurized and mixed with abrasives before being directed towards the workpiece.

Characteristics:

The abrasive particles in AWJM are suspended in a high-pressure water stream, enhancing the cutting ability.

AWJM can cut a wider range of materials compared to AJM and is particularly effective for softer materials.

The process can achieve higher material removal rates compared to AJM.

3. Ultrasonic Machining (USM):

Principle of Operation:

USM involves the use of ultrasonic vibrations to assist in the material removal process.

A tool, usually made of a softer material than the workpiece, vibrates ultrasonically while being pressed against the workpiece surface. Abrasive slurry is used as a medium between the tool and the workpiece.

Characteristics:

The tool's ultrasonic vibrations cause the abrasive particles in the slurry to impact the workpiece, resulting in **material removal.**

USM is suitable for hard and brittle materials.

It offers high precision and intricate machining capabilities due to the localized nature of material removal.

Comparison:

Medium Used:

AJM uses a gas (typically air) as the carrier medium for abrasive particles.

AWJM uses pressurized water as the carrier medium for abrasive particles.

USM uses an abrasive slurry, usually composed of water and abrasive particles.

Material Removal Mechanism:

AJM and AWJM rely on the mechanical erosion caused by the impact of abrasive particles.

USM combines mechanical abrasion with the ultrasonic vibrations of the tool.

Material Compatibility:

AJM and AWJM are suitable for a range of materials, with AJM being more effective for hard and brittle materials, while AWJM is versatile for a broader range, including softer materials.

USM is particularly effective for hard and brittle materials.

Precision:

USM is known for its high precision and can produce intricate shapes with fine details.

AJM and AWJM offer precision but may not achieve the same level of detail as USM.

Speed and Material Removal Rate:

AWJM typically has higher material removal rates compared to AJM due to the enhanced cutting ability of water.

USM can be relatively slower but excels in precision applications.

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Question Paper Code : 51439

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2023.

Sixth/Seventh Semester

Mechanical Engineering

ME 8073 – UNCONVENTIONAL MACHINING PROCESSES

(Common to: Manufacturing Engineering/Mechanical Engineering (sandwich)/Mechanical and Automation Engineering/Production Engineering)

(Regulations 2017)

Time : Three hours   Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Identify the types of abrasive feeding mechanism in AWJM.

2. Outline the properties of tools used in USM process.

3. Brief the material removal mechanism in EDM process.

4. Summarize the limitations of EBM process.

5. Mention the advantages of ECM over other machining process.

6. State the applications of chemical machining.

7. What is the purpose of abrasives in magnetic abrasive finishing process?

8. Identify the applications of chemo-mechanical polishing process.

9. List the needs for hybrid machining processes.

10. Mention the limitations of nontraditional machining processes.

PART B — (5 × 13 = 65 marks)

11. (a) Classify the advanced machining processes with a neat flow chart and compare.

Or

(b) Identify a suitable advanced machining process with the following properties: no dust, high cutting speed, multidirectional cutting capacity, no fire hazards, no thermal or deformation stresses with a typical sketch. Also discuss the process in detail.

12. (a) Outline wire cut EDM with a neat sketch and explain its significant process parameters for good surface finish.

Or

(b) Describe Laser Beam Machining (LBM) process with clear illustration, in terms of mechanism of metal removal, process characteristics, accuracy, surface quality and application.

13. (a) (i) Derive an equation for MRR in ECM process to evaluate machining efficiency. (7)

(ii) In electrochemical machining of pure iron, a material removal rate of 600 mm^3/min is required. Estimate current requirement. (6)

Or

(b) Describe Electrochemical grinding (ECG) process with clear illustration, in terms of mechanism of metal removal, process characteristics, accuracy, surface quality and application.

14. (a) Explain the mechanism of material removal during the magnetorheological AFF Process with a neat sketch. Also, mention the process capabilities, process parameters and application.

Or

(b) Discuss the abrasive flow machining with a neat illustration and mention its applications.

15. (a) Explain the benefits of hybrid unconventional machining technologies and elaborate the challenges and opportunities.

Or

(b) Describe any one laser assisted machining process with constructional details.

PART C — (1 × 15 = 15 marks)

16. (a) With a case study, explain the chemical machining process. Discuss in detail about selections of etchants and maskants according to the required work piece materials and process parameters.

Or

(b) With a suitable case study, analyse the volumetric material removal rate in USM process from the workpiece due to.

(i) Throwing mechanism. (8)

(ii) Hammering mechanism. (7)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 90842

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2022.

Sixth/Seventh Semester

Mechanical Engineering

ME 8073 — UNCONVENTIONAL MACHINING PROCESSES

(Common to Manufacturing Engineering/Mechanical Engineering (Sandwich)/Mechanical and Automation Engineering/Production Engineering)

(Regulations 2017)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are the characteristics of Unconventional machining process?
2. Mention the functions of accumulator and intensifier in water jet machining.
3. Define the tool wear ratio in EDM.
4. Differentiate between transferred and non transferred arc plasma.
5. The machinability of the workpiece is decided by hardness alone in Electro chemical grinding. Justify.
6. What is etch factor and under cut in chemical machining process?
7. State the principle of magnetic abrasive finishing process.
8. Define the magneto-rheological effect.
9. Differentiate between electrochemical discharge machining and electrolytic in process dressing processes.
10. Mention any two applications of electro-discharge diamond grinding process.

PART B — (5 × 13 = 65 marks)

11. (a) (i) Enumerate the classification of non-traditional machining processes based on type of energy, mechanics and its energy source. (7)

(ii) Explain the effect of mixing ratio, nozzle pressure and stand-off distance on material removal rate in abrasive jet machining process. (6)

Or

(b) (i) Explain the parameters which affect the performance of abrasive water jet machining process. (7)

(ii) Discuss in detail the tool feeding mechanism in ultrasonic machining. (6)

12. (a) (i) With neat schematic, explain the various flushing methods used in Electrical Discharge Machining process. (7)

(ii) Explain the wire drive system in wire-electrical discharge machining process. (6)

Or

(b) (i) With neat schematic, explain the construction and working of laser beam machining processes. (7)

(ii) Explain the process parameters involved in electron beam machining process. (6)

13. (a) (i) Enumerate the steps involved in chemical machining process. (8)

(ii) Explain the functions and advantages of cut and peel maskant and photo resist maskant in chemical machining processes. (5)

Or

(b) (i) Explain the effect of voltage, electrolyte concentration and current in material removal rate in electrochemical machining processes. (7)

(ii) Explain the constructional features of electrochemical honing process. (6)

14. (a) (i) Identify the important factor that affects the performance of process and product quality in abrasive flow polishing process. (7)

(ii) With neat schematic, explain the finishing process used for silicon wafers in semiconductor industry. (6)

Or

(b) (i) Select and explain appropriate method for finishing ceramic balls and rollers. (7)

(ii) Explain the effect of process variables in magneto rheological abrasive flow finishing process. (6)

15. (a) (i) With neat schematic, explain the electrical energy based hybrid process to machine non-conductive materials like glass and ceramics. (7)

(ii) Compile the various material removal mechanisms in electrochemical spark micro machining process. (6)

Or

(b) (i) Compare EDM and ECM processes. (8)

(ii) Compare and give application examples of drilling holes by EDM and LBM process. (5)

PART C — (1 × 15 = 15 marks)

16. (a) Illustrate the effect of magnitude of current, frequency and pulse time on crater size formed in EDM. (15)

Or

(b) Analyze the mechanism of material removal in the form of small grains in ultrasonic machining and derive the expression for material removal rate using grain hammering model. (15)

Reg. No. :

Question Paper Code : 40813

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2021.

Sixth/Seventh Semester

Mechanical Engineering

ME 8073 — UNCONVENTIONAL MACHINING PROCESSES

(Common to Manufacturing Engineering/Mechanical Engineering (Sandwich)/Mechanical and Automation Engineering/Production Engineering)

(Regulations 2017)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. List out the parameters which improves the material removal rate in water jet machining.

2. State the demerits of the ultrasonic machining.

3. List out the electrode materials used in electric discharge machining.

4. State the types of lasers used in manufacturing operations.

5. List out the type of etchants used in chemical machining.

6. Define masking in electro chemical machining.

7. State the materials preferred as an abrasive particle and its size in nano finishing.

8. Write down the principle of magneto rheological finishing.

9. Define non traditional machining processes.

10. State the nessecity of non traditional machining processes.

PART B — (5 × 13 = 65 marks)

11. (a) Explain with neat sketch the working principle and the parametral influence of abrasive jet machining.

Or

(b) Discuss the physics of ultrasonic waves. Explain the generation of waves and machining process.

12. (a) Discuss the considerations in EDM tool design. Explain in detail about the tool parameters and its role in material removal rate and surface finish.

Or

(b) Distinguish and explain the high energy machining processes.

13. (a) Distinguish and explain the chemical machining and electro chemical machining processes.

Or

(b) List out and explain the specific advancements in electro chemical machining processes.

14. (a) Explain the working principle and the tooling of chemo-mechanical polishing.

Or

(b) Distinguish between the magnetic abrasive and magneto rheological finishing processes and explain about both the processes.

15. (a) Explain the recent developments in non traditional machining processes.

Or

(b) Discuss the factors to be considered, while selecting the non traditional machining processes.

PART C — (1 × 15 = 15 marks)

16. (a) Explain the energy and cost efficient non-traditional machining processes that call be used for profile cutting in detail.

Or

(b) Discuss the importance and emergence of nano finishing processes in detail.

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : X10683

B.E./B.Tech. DEGREE EXAMINATIONS, NOV/DEC 2020 AND APRIL / MAY 2021
Sixth/ Seventh Semester
Mechanical Engineering
ME 8073 – UNCONVENTIONAL MACHINING PROCESSES
(Common to Manufacturing Engineering Mechanical and Automation Engineering and Production Engineering)
(Regulations 2017)

Time : Three Hours Maximum : 100 Marks

Answer ALL questions

PART – A **(10×2=20 Marks)**

1. List down various mechanical energy based unconventional machining processes.

2. Write the elements and characteristics of USM.

3. List the process parameters of PAM.

4. Mention a few varieties of power supply circuits commonly used in EDM.

5. What are the different types ECM operations ?

6. Write the Faraday's second law of electrolysis.

7. Classify the different types of Advanced Machining Processes based on different criteria.

8. Write the process parameters of abrasive flow machining.

9. Need for the development of unconventional machining methods.

10. Difference between conventional and unconventional machining processes.

PART – B **(5×13=65 Marks)**

11. a) Discuss in detail about the AJM process variables that influence the rate of material removal and accuracy in the machining. **(13)**

(OR)

b) Explain the working principle and process parameters in WJM processes. List the applications, advantages and limitations of WJM. **(13)**

12. a) Discuss the process parameters of EBM and their influence on machining quality. **(13)**

(OR)

b) Explain the process parameters which govern the EDM/wire EDM process. **(13)**

13. a) Explain the principle of working, equipment's and Applications of Electro Chemical Grinding. **(13)**

(OR)

b) Describe the working principle and elements of chemical machining. What are the factors on which the selection of a resist for use in chemical machining ? **(13)**

14. a) Explain the principle of working, equipment's and applications of chemo-mechanical polishing. **(13)**

(OR)

b) Explain the process parameters which govern the magneto rheological abrasive finishing process with neat sketch. **(13)**

15. a) Explain the reasons for the development of Unconventional Machining Process. Discuss about the criteria recommended in selection of these processes. **(13)**

(OR)

b) Explain the working principle of 3D printing technology for the production of parts. **(13)**

PART – C **(1×15=15 Marks)**

16. a) What is the principle of plasma arc machining ? What are the two stages in which the process of material removal is affected ? What is the main industrial application of plasma cutting systems ?

(OR)

b) How will you carry out the analysis for optimization of metal removal rate in EDM process ? What are the steps that are to be adopted in sequence while applying the linear programming technique to optimize the metal removal rate in EDM process ?