ST.ANNE'S COLLEGE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE, New Delhi. Affiliated to Anna University, Chennai)

(An ISO 9001: 2015 Certified Institution)

ANGUCHETTYPALAYAM, PANRUTI – 607 106.

DEPARTMENT OF MECHANICAL ENGINEERING

ME8073	UNCONVENTIONAL MACHINING PROCESSES	L	T	P
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OBJECTIVE:

- To learn about various unconventional machining processes, the various process parameters and their influence on performance and their applications

UNIT I INTRODUCTION AND MECHANICAL ENERGY BASED PROCESSES 9

Unconventional machining Process – Need – classification – merits, demerits and applications. Abrasive Jet Machining – Water Jet Machining – Abrasive Water Jet Machining - Ultrasonic Machining. (AJM, WJM, AWJM and USM). Working Principles – equipment used – Process parameters – MRR- Applications.

UNIT II THERMAL AND ELECTRICAL ENERGY BASED PROCESSES 9

Electric Discharge Machining (EDM) – Wire cut EDM – Working Principle-equipments-Process Parameters-Surface Finish and MRR- electrode / Tool – Power and control Circuits-Tool Wear – Dielectric – Flushing –– Applications. Laser Beam machining and drilling, (LBM), plasma, Arc machining (PAM) and Electron Beam Machining (EBM). Principles – Equipment –Types - Beam control techniques – Applications.

UNIT III CHEMICAL AND ELECTRO-CHEMICAL ENERGY BASED PROCESSES 9

Chemical machining and Electro-Chemical machining (CHM and ECM)- Etchants – Maskant - techniques of applying maskants - Process Parameters – Surface finish and MRR-Applications. Principles of ECM- equipments-Surface Roughness and MRR Electrical circuit-Process Parameters-ECG and ECH - Applications.

UNIT IV ADVANCED NANO FINISHING PROCESSES 9

Abrasive flow machining, chemo-mechanical polishing, magnetic abrasive finishing, magneto rheological finishing, magneto rheological abrasive flow finishing their working principles, equipments, effect of process parameters, applications, advantages and limitations.

UNIT V RECENT TRENDS IN NON-TRADITIONAL MACHINING PROCESSES 9

Recent developments in non-traditional machining processes, their working principles, equipments, effect of process parameters, applications, advantages and limitations. Comparison of non-traditional machining processes.

TOTAL PERIODS: 45

OUTCOMES:

Upon the completion of this course the students will be able to

CO1 Explain the need for unconventional machining processes and its classification

CO2 Compare various thermal energy and electrical energy based unconventional machining processes.

CO3 Summarize various chemical and electro-chemical energy based unconventional machining processes.

CO4 Explain various nano abrasives based unconventional machining processes.

CO5 Distinguish various recent trends based unconventional machining processes.

TEXT BOOKS:

1. Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007
2. Pandey P.C. and Shan H.S. "Modern Machining Processes" Tata McGraw-Hill, New Delhi, 2007.

REFERENCES:

1. Benedict. G.F. "Nontraditional Manufacturing Processes", Marcel Dekker Inc., New York, 1987.
2. Mc Geough, "Advanced Methods of Machining", Chapman and Hall, London, 1998.
3. Paul De Garmo, J.T.Black, and Ronald. A.Kohser, "Material and Processes in Manufacturing" Prentice Hall of India Pvt. Ltd., 8thEdition, New Delhi , 2001.

UNIT-1

INTRODUCTION AND MECHANICAL ENERGY BASED PROCESSES

An unconventional machining process (or non-traditional machining process) is a special type of machining process in which there is no direct contact between the tool and the workpiece. In unconventional machining, a form of energy is used to remove unwanted material from a given workpiece.

Need of unconventional machining processes

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.

If such materials are machined with the help of conventional machining processes, either the tool undergoes extreme wear (while machining hard workpiece) or the workpiece material is damaged (while machining brittle workpiece). This is because, in conventional machining, there is a direct contact between the tool and the workpiece. Large cutting forces are involved and material is removed in the form of chips. Ahuge amount of heat is produced in the workpiece. This induces residual stresses, which degrades the lifeand quality of the workpiece material.

Hence, conventional machining produces poor quality workpiece with poor surface finish (if the workpiece is made of hard and brittle material). To overcome all these drawbacks, we use unconventional machining processes to machine hard and brittle materials. We also use unconventional machining processesto machine soft materials, in order to get better dimensional accuracy.

Classification of unconventional machining processes:

Unconventional machining processes can be broadly classified into several types based on four main criteria.The classification of unconventional machining processes is given below:

1. **Based on the type of energy used**
   1. Mechanical Energy based Unconventional Machining Processes (e.g. Abrasive JetMachining, Water Jet Machining)
   2. Electrical Energy based Unconventional Machining Processes (e.g. Electrical DischargeMachining)
   3. Electrochemical Energy based Unconventional Machining Processes (e.g. ElectrochemicalGrinding)
   4. Chemical Energy based Unconventional Machining Processes (e.g. Chemical Machining)

5. Thermo-electrical (or Electro-thermal) Energy based Unconventional Machining Processes(e.g. Plasma Arc Machining)

2. Based on the source of energy

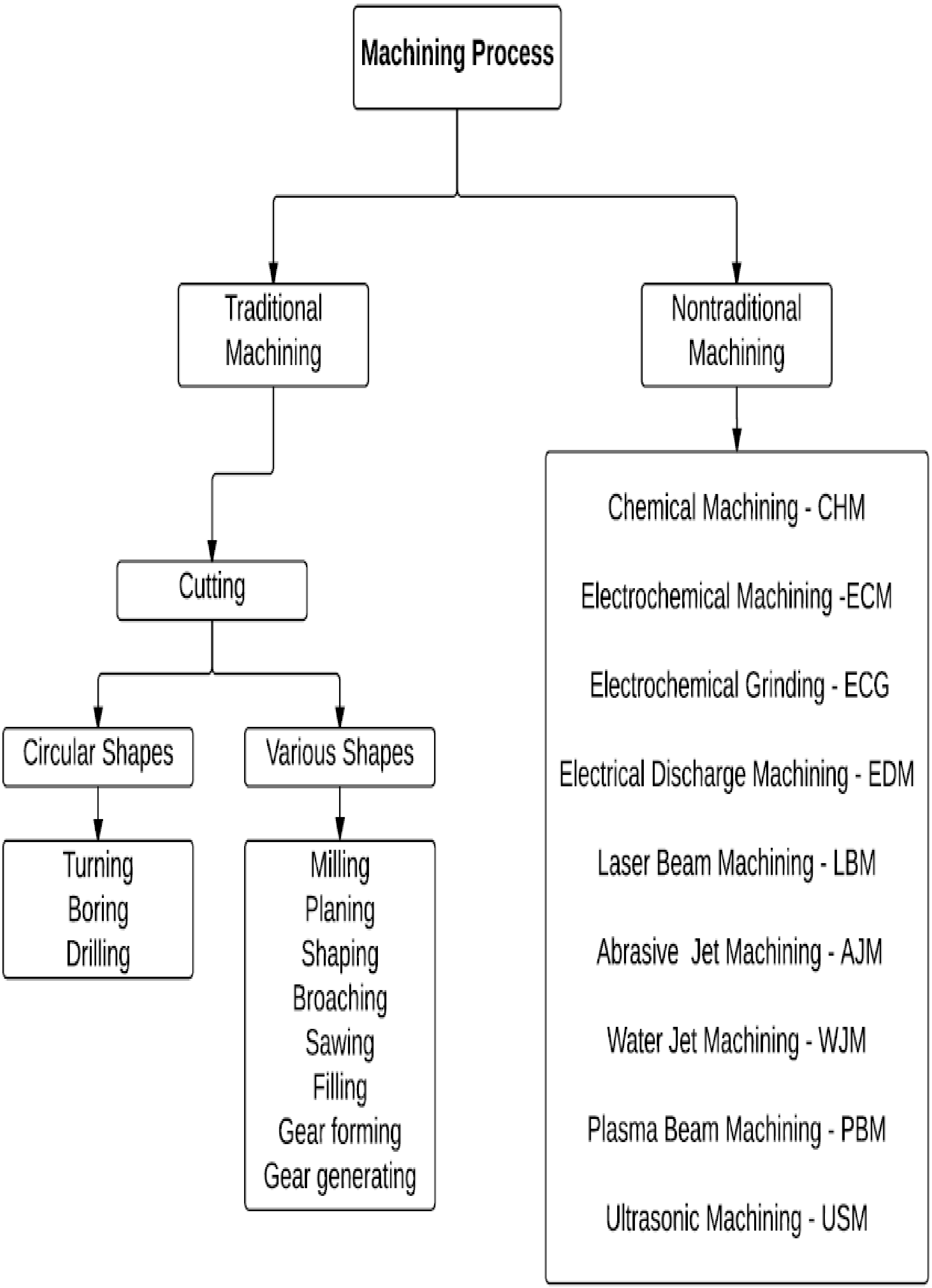
1. Current
2. Voltage
3. Hydraulic Pressure
4. Pneumatic Pressure
5. Ionized Particles
6. Light

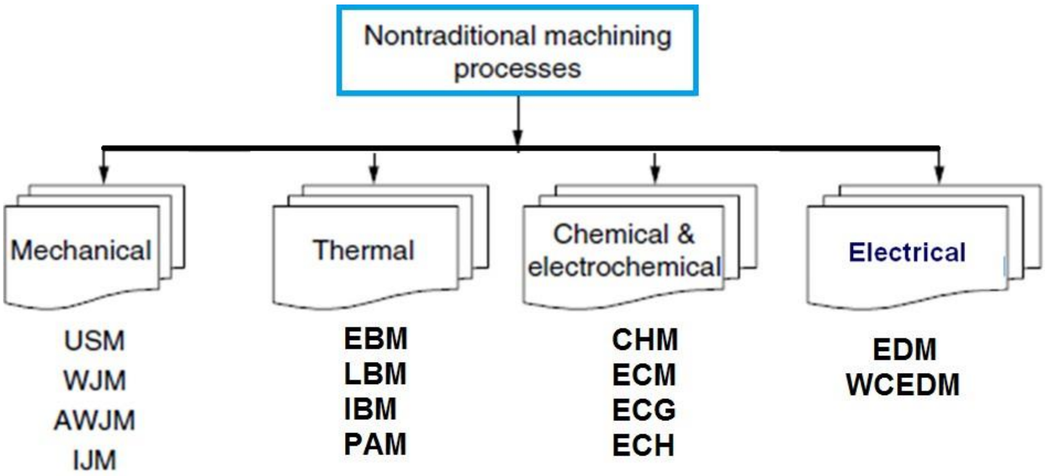
3. Based on the medium of energy transfer

1. Electrons
2. Atmosphere
3. Ions
4. Electrolyte
5. Pressurized gas
6. Water
7. Ultrasonic waves
8. Plasma
9. Laser
10. Chemical reagent
11. Radiation

4. Based on the mechanism of material removal

1. Erosion
2. Electric Discharge
3. Shear
4. Chemical Etching
5. Vaporization
6. Melting
7. Ion Displacement
8. Blasting


Machining Process
Traditional Machining
Nontraditional Machining
Cutting
Circular Shapes
Various Shapes
Turning
Boring
Drilling
Milling
Planing
Shaping
Broaching
Sawing
Filling
Gear forming
Gear generating
Chemical Machining - CHM
Electrochemical Machining -ECM
Electrochemical Grinding - ECG
Electrical Discharge Machining - EDM
Laser Beam Machining - LBM
Abrasive Jet Machining - AJM
Water Jet Machining - WJM
Plasma Beam Machining - PBM
Ultrasonic Machining - USM



1.Mechanical Energy based Unconventional Machining Processes:

In these processes, unwanted material in the workpiece is removed by mechanical erosion. The mechanical erosion can be facilitated by using any medium. For example, in abrasive jet machining, high velocity abrasive jet is used for eroding material from the workpiece. In water jet machining, high velocity water jet is used for cutting the workpiece material.

The four main mechanical energy based unconventional machining processes are:

1. Abrasive Jet Machining
2. Water Jet Machining or Water Jet Cutting
3. Abrasive Water Jet Machining
4. Ultrasonic Machining

2.Electrical Energy based Unconventional Machining Processes:

Here, electric spark discharge is used to cut and machine the workpiece. In electrical energy based processes, no arc is produced (as in arc welding). Instead, thousands of sparks are produced every second. These sparks increase the temperature of the workpiece, melt the unwanted portions and vapourise those portions. A dielectric fluid is used for cleaning the workpiece and facilitating a smooth spark discharge.

Processes that come under this category are:

5. Electrical Discharge Machining
6. Wire Cut Electrical Discharge Machining

3.Electrochemical Energy based Unconventional Machining Processes:

In these processes, unwanted portions of the workpiece are removed by electrochemical effect. The workpiece (in contact with an electrolyte) is machined by ion dissolution. Processes that come under this category are:

1. Electrochemical Machining
2. Electrochemical Grinding
3. Electrochemical Honing

4.Chemical Energy based Unconventional Machining Processes:

Here, chemical energy is used to remove material from the workpiece.

We know that metal can be easily converted to metallic salt, if suitable reagent is used. Chemical energybased processes exploit this principle.

Material is removed by controlled etching of the workpiece in the presence of a reagent known as enchant.

Chemical machining, chemical milling and photochemical milling (PCM) are the processes that come underthis category.

5. Thermo-electrical (or Electro-thermal) Energy based Unconventional Machining Processes:

Unwanted portions of a metal can be easily removed, if it is melted or vaporized. Thermo-electrical energy based unconventional machining processes make use of this principle.

In these processes, electrical energy is converted to a huge amount of heat by some means. This heat is applied on a small region of the workpiece. That particular region is either melted or vaporised. By this way, material is removed.

The following are some of the important thermo-electrical energy based unconventional machining processes:

1. Plasma Arc Machining
2. Electron Beam Machining
3. LASER Beam Machining
4. Ion Beam Machining

Material and Method of Machining

S.No.	Material	Method of Machining
1.	Non metals like ceramics, plastics and glass	USM, AJM, EBM, LBM
2.	Refractories	USM, AJM, EDM, EBM
3.	Titanium	EDM
4.	Super Alloys	AJM, ECM, EDM, PAM
5.	Steel	ECM, CHM, EDM, PAM

PROCESS SELECTION

Based on the following points:

1. Physical Parameters
2. Shapes to be machined
3. Process Capability or Machining Characteristics
4. Economic Considerations

Physical Parameters

Parameters	ECM	EDM	EBM	LBM	PAM	USM	AJM
Potential, V	5-30	50-500	200×10^3	4.5×10^3	250	220	220
Current, A	40,000	15 -500	0.001	2	600	12	1.0
Power, kW	100	2.70	0.15	20	220	2.4	0.22
Gap, mm	0.5	0.05	100	150	7.5	0.25	0.75
Medium	Electro -lyte	Dielectric Fluid	Vacuum	Air	Argon or Hydrogen or Nitrogen	Abrasive grains & water	N_2 or Co_2 or Air
Work Material	Difficult to machine materials	Tungsten carbides and electrically conductive materials	All materials	All materials	All materials which conduct electricity	Tungsten carbide, glass, quartz etc.,	Hard and brittle materials

Shapes to be machined

For Grinding

- AJM and EDM are best suited.

For deburring

- USM and AJM are well suited.

For threading

- EDM is best suited.

For clean, rapid cuts and profiles

- PAM is well suited.

For shallow pocketing

- AJM is well suited.

For producing micro holes

- LBM is best suited.

For producing small holes

- EBM is well suited.

For deep holes (L/D > 20) and contour machining

- ECM is best suited.

For shallow holes

- USM and EDM are well suited.

For Precision through cavities in work pieces

- USM and EDM are best suited.

For honing

- ECM is well suited.

For etching small portions

- ECM and EDM are well suited.

Process Capability or Machining Characteristics

1. Material Removal rate
2. Tolerance Maintained
3. Surface Finish
4. Depth of surface Damage
5. Power required for machining

Process	Process Capability			
	Metal removal Rate (mm^3/s) (MRR)	Surface Finish (μm, CLA)	Accuracy (μm)	Specific power ($kW/cm^3/min$)
LBM	0.10	0.4 -6.0	25	2700
EBM	0.15 to 40	0.4 -6.0	25	450
EDM	15 to 80	0.25	10	1.8
ECM	27	0.2-0.8	50	7.5
PAM	2500	Rough	250	0.90
USM	14	0.2-0.7	7.5	9.0
AJM	0.014	0.5-1.2	50	312.5

Process Economy

Process	Capital Cost	Tooling and fixtures	Power requirement -	Efficiency	Total consum -ption
EDM	Medium	High	Low	High	High
CHM	Medium	Low	High	Medium	V. Low
ECM	V. High	Medium	Medium	Low	V.Low
AJM	V. Low	Low	Low	High	Low
USM	High	High	Low	High	Medium
EBM	High	Low	Low	V. High	V. Low
LBM	Medium	Low	V.Low	V.High	V. Low
PAM	V.Low	Low	V.Low	V.Low	V. Low
Conventio -nal machining	V.Low	Low	Low	V.Low	Low

Advantages of UCM

- High Accuracy and surface finish in process
- Less Rejected pieces
- Increase productivity
- Tool material need not be harder than work piece material.
- Easy to machine harder and brittle materials
- There is no residual stresses in the machined material

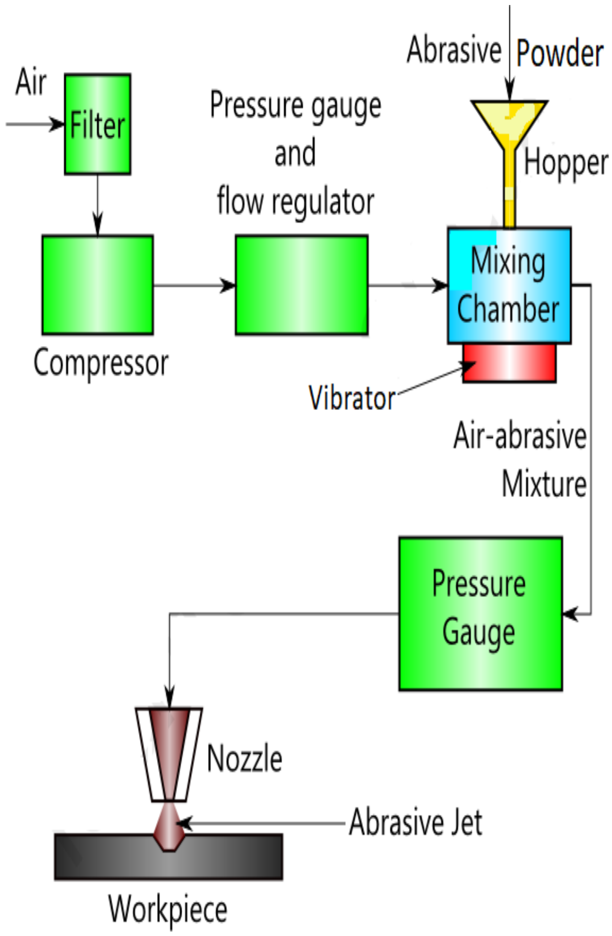
Dis-Advantages of UCM

1. More expensive process
2. Low Material Removal Rate (MRR)
3. AJM, CHM , PAM and EBM are not commercially economical Process

MECHANICAL BASED MACHINING PROCESSES

ABRASIVE JET MACHINING

Abrasive Jet Machining (AJM), is a mechanical energy based unconventional machining process used to remove unwanted material from a given work piece. The process makes use of an abrasive jet with high velocity, to remove material and provide smooth surface finish to hard metallic work pieces.



Parts & Usages

1. **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.
2. **Mixing chamber:** It is used to mix the gas and abrasive particles.
3. **Filter:** It filters the gas before entering the compressor and mixing chamber.
4. **Compressor:** It pressurizes the gas.
5. **Hopper:** Hopper is used for feeding the abrasive powder.
6. **Pressure gauges and flow regulators:** They are used to control the pressure and regulate the flowrate of abrasive jet.
7. **Vibrator:** It is provided below the mixing chamber. It controls the abrasive

powder feed rate in themixing chamber.

8. **Nozzle:** It forces the abrasive jet over the workpiece. Nozzle is made of hard and resistant materiallike tungsten carbide.

Working:

Dry air or gas is filtered and compressed by passing it through the filter and compressor. A pressure gauge and a flow regulator are used to control the pressure and regulate the flow rate of the compressed air. Compressed air is then passed into the mixing chamber. In the mixing chamber, abrasive powder is fed. A vibrator is used to control the feed of the abrasive powder. The abrasive powder and the compressed air are thoroughly mixed in the chamber. The pressure of this mixture is regulated and sent to nozzle.

The nozzle increases the velocity of the mixture at the expense of its pressure. A fine abrasive jet is renderedby the nozzle. This jet is used to remove unwanted material from the workpiece.

Operations that can be performed using Abrasive Jet Machining (AJM):

The following are some of the operations that can be performed using Abrasive Jet Machining:

1. Drilling
2. Boring
3. Surface finishing
4. Cutting
5. Cleaning
6. Deburring
7. Etching
8. Trimming
9. Milling

Advantages of Abrasive Jet Machining:

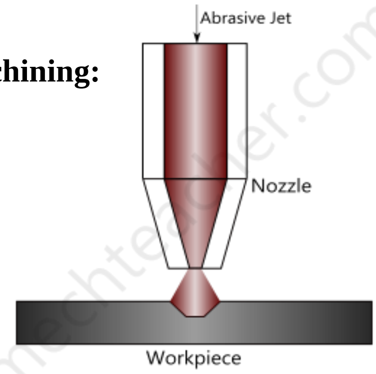
- Surface of the workpiece is cleaned automatically.
- Smooth surface finish can be obtained.
- Equipment cost is low.
- Hard materials and materials of high strength can be easily machined.

Disadvantages of Abrasive Jet Machining:

- Metal removal rate is low
- In certain circumstances, abrasive particles might settle over the workpiece.
- Nozzle life is less. Nozzle should be maintained periodically.
- Abrasive Jet Machining cannot be used to machine soft materials.

Process parameters

Process parameters of Abrasive Jet Maching (AJM) are factors that influence its Metal Removal Rate (MRR). In a machining process, Metal Removal Rate (MRR) is the volume of metal removed from a given workpiece in unit time.



Some of the important process parameters of abrasive jet machining:

1. Abrasive mass flow rate
2. Nozzle tip distance
3. Gas Pressure
4. Velocity of abrasive particles
5. Mixing ratio
6. Abrasive grain size

Abrasive mass flow rate:

Mass flow rate of the abrasive particles is a major process parameter that influences the metal removal ratein abrasive jet machining.

In AJM, mass flow rate of the gas (or air) in abrasive jet is inversely proportional to the mass flow rate of theabrasive particles. Due to this fact, when continuously increasing the abrasive mass flow rate, MetalRemoval Rate (MRR) first increases to an optimum value (because of increase in number of abrasive particles hitting the workpiece) and then decreases. However, if the mixing ratio is kept constant, Metal Removal Rate (MRR) uniformly increases with increase in abrasive mass flow rate.

Nozzle tip distance:

Nozzle Tip Distance (NTD) is the gap provided between the nozzle tip and the workpiece. Up to a certain limit, Metal Removal Rate (MRR) increases with increase in nozzle tip distance. After that limit, MRR remains constant to some extent and then decreases. In addition to metal removal rate, nozzle tip distance influences the shape and diameter of cut. For optimal performance, a nozzle tip distance of 0.25 to 0.75 mm is provided.

Gas pressure:

Air or gas pressure has a direct impact on metal removal rate. In abrasive jet machining, metalremoval rate is directly proportional to air or gas pressure.

Velocity of abrasive particles:

Whenever the velocity of abrasive particles is increased, the speed at which the abrasive particles hit the workpiece is increased. Because of this reason, in abrasive jet machining, metal removal rate increases with increase in velocity of abrasive particles.

Mixing ratio:

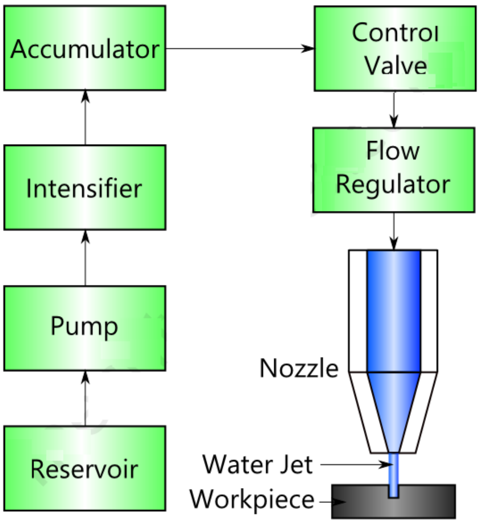
Mixing ratio is a ratio that determines the quality of the air-abrasive mixture in Abrasive JetMachining (AJM). It is the ratio between the mass flow rate of abrasive particles and the mass flow rate of air (or gas). When mixing ratio is increased continuously, metal removal rate first increases to some extent and then decreases.

Abrasive grain size:

Size of the abrasive particle determines the speed at which metal is removed. If smooth and fine surface finish is to be obtained, abrasive particle with small grain size is used. If metal has to be removed rapidly, abrasive particle with large grain size is used.

WATER JET MACHINING (WJM)

Water Jet Machining (WJM) is a mechanical energy based non-traditional machining process used to cut and machine soft and non-metallic materials. It involves the use of high velocity water jet to smoothly cut a soft workpiece. It is similar to Abrasive Jet Machining (AJM).



In water jet machining, high velocity water jet is allowed to strike a given workpiece. During this process, its kinetic energy is converted to pressure energy. This induces a stress on the workpiece. When this induced stress is high enough, unwanted particles of the workpiece are automaticallyremoved.

Reservoir: It is used for storing water that is to be used in the machining operation.
Pump: It pumps the water from the reservoir.
Intensifier: It is connected to the pump. It pressurizes the water acquired from the pump to a desired level.
Accumulator: It is used for temporarily storing the pressurized water. It is connected to the flow regulatorthrough a control valve.
Control Valve: It controls the direction and pressure of pressurized water that is to be supplied to the nozzle.
Flow regulator: It is used to regulate the flow of water.
Nozzle: It renders the pressurized water as a water jet at high velocity

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 ispressurized to 200 to 400 MPa.
- Pressurized water is then sent to the accumulator. The accumulator temporarily stores the pressurizedwater.
- 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 permissiblelimits.
- Flow regulator regulates and controls the flow rate of water.
- Pressurized water finally enters the nozzle. Here, it expands with a tremendous increase in its kineticenergy. High velocity water jet is produced by the nozzle.
- When this water jet strikes the workpiece, stresses are induced. These stresses are used to removematerial from the workpiece.
- The water used in water jet machining may or may not be used with stabilizers. Stabilizers aresubstances that improve the quality of water jet by preventing its fragmentation.
- For a good understanding of water jet machining, refer the schematic diagram above.

Advantages of Water Jet Machining (WJM):

1. Water jet machining is a relatively fast process.
2. It prevents the formation of heat affected zones on the workpiece.
3. It automatically cleans the surface of the workpiece.
4. WJM has excellent precision. Tolerances of the order of ±0.005″ can be obtained.
5. It does not produce any hazardous gas.
6. It is eco-friendly.

Disadvantages of Water Jet Machining:

1. Only soft materials can be machined.
2. Very thick materials cannot be easily machined.
3. Initial investment is high.

Applications of Water Jet Machining:

1. Water jet machining is used to cut thin non-metallic sheets.
2. It is used to cut rubber, wood, ceramics and many other soft materials.
3. It is used for machining circuit boards.
4. It is used in food industry.

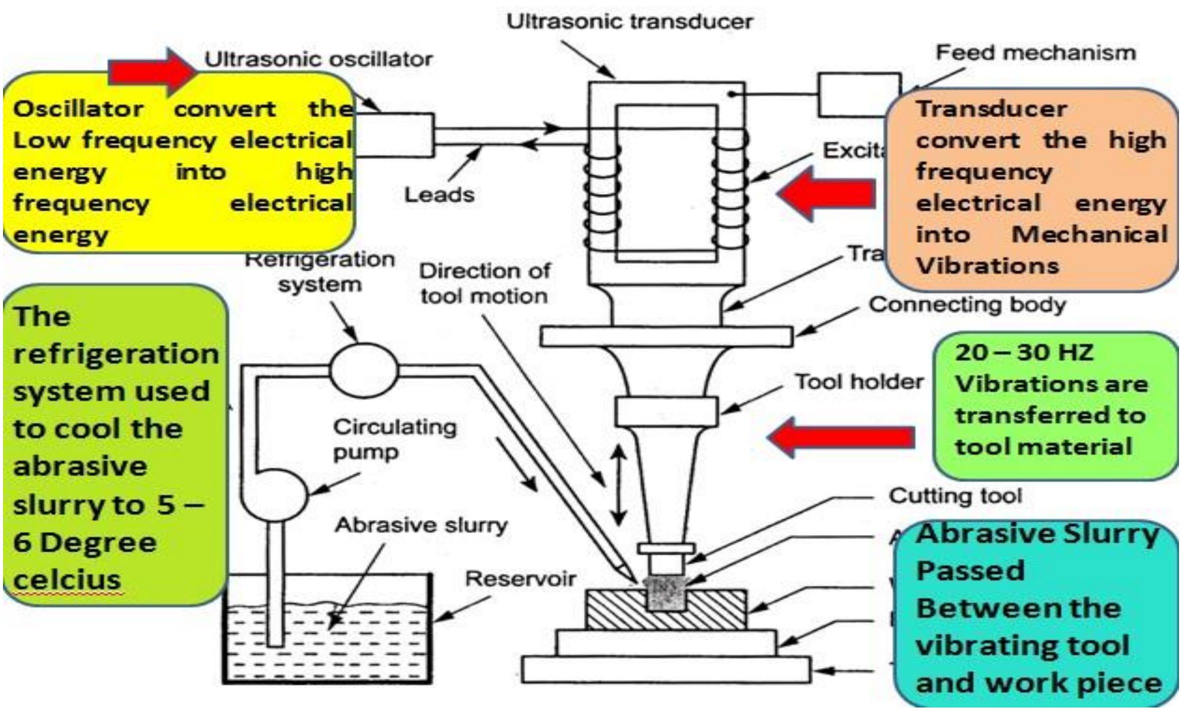
ULTRASONIC MACHINING (USM)

Principles

Working principle of Ultrasonic Machining or Ultrasonic Impact Grinding is described with the help of a schematic diagram. The shaped tool under the actions of mechanical vibration causes the abrasive particles dipped in slurry to be hammered on the stationary work piece. This causes micro-indentation fracture on the material. Small abraded particles are removed along the surface which is perpendicular to thedirection of the tool vibration. When the material is removed a cavity of the same profile of the tool face is formed. The abrasive particles gradually erode as the machining process continues. As a result fresh abrasiveparticles are needed to be supplied in the machining zone. Abrasive particles associated with the liquid are fed to the m/c zone and it ensures the removal of the worn out grains and material.

Machining Time

The machining time of the ultrasonic grinding depends on the frequency of the vibration, material properties and grain size. The amplitude of the vibration may vary from 5 to 75 µm and frequency may varyfrom 19~25 kHz. Ample static force is also required to hold the job against the machining tool. A continues flow of abrasives suspension is also mandatory.



Process parameters

1. Amplitude of vibration (15 to 50 microns), Frequency of vibration (19 to 25 kHz).

2. Feed force (F) related to tool dimensions, Feed pressure

3. Abrasive size, Abrasive material ** Al203, SiC, B4C, Boron silicon Carbide, Diamond.

4. Flow strength of the work material, Flow strength of the tool material

5. Contact area of the tool, Volume concentration of abrasive in water slurry6. Tool a. Material of tool

b. Shape

c. Amplitude of vibration

d. Frequency of vibration

e. Strength developed in tool

7. Work material -------- a. Material b. Impact strength c. Surface fatigue strength

8. Slurry --------------------a. Abrasive – hardness, size, shape and quantity of abrasive flow

b. Liquid – Chemical property, viscosity, flow rate

c. Pressure

d. Density

Advantages of USM:

1. It can be used to drill circular or non-circular holes on very hard materials like stones, carbides,ceramics and other brittle materials.
2. Non-conducting materials like glass, ceramics and semi precious stones can also be machined.

Disadvantages of USM:

1. It can be proved slower than the conventional machining processes.
2. Creating deep holes is difficult because of the restricted movement of the suspension.
3. It is arduous to select the perfect tool geometry for creating hole of certain dimension. The holes createdmay be of larger sizes because of side cutting.
4. High tool wear because of continues flow of abrasive slurry.

Applications:

1. Hard and brittle materials can be machined like tungsten carbide, diamond and glass. These are difficult tomachine in conventional m/c-ing process.
2. Wire drawing dies of tungsten carbide can be drilled by this process.
3. Circular as well as non-circular holes can be done with straight or curved axes.
4. It has been proved successful in machining geranium, silicon quartz and synthetic ruby

etc.

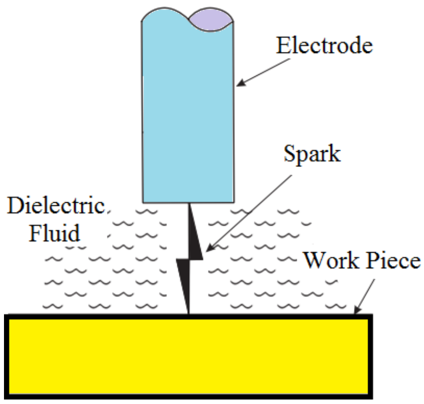
UNIT-II

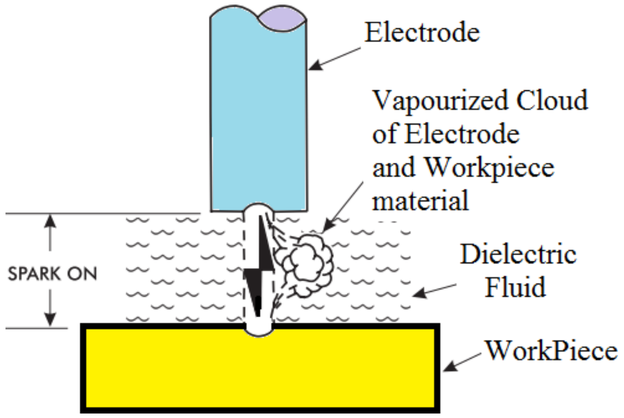
THERMAL AND ELECTRICAL ENERGY BASED PROCESSES

ELECTRICAL DISCHARGE MACHINING (EDM)

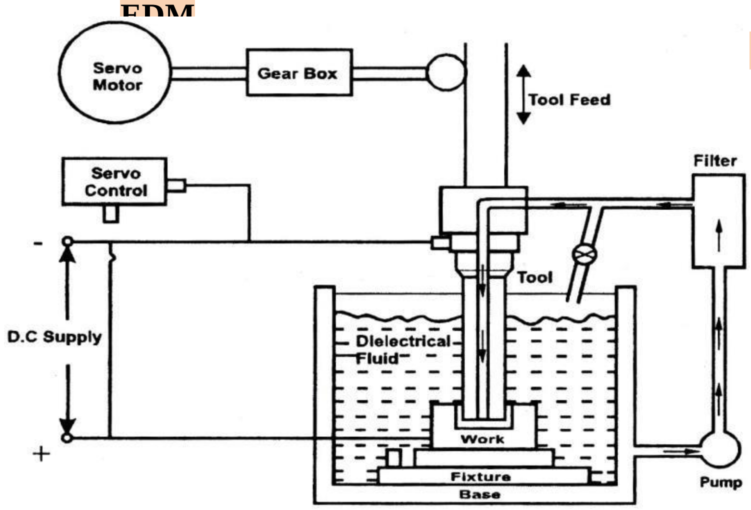
Introduction

EDM is a non-conventional machining technique uniquely used for cutting metals which are not possible to cut with traditional methods. EDM only works with materials which are electrically conductive. Delicate cavities and intricate contours which are difficult to produce with a grinder or other machines canbe done with **Electrical Discharge Machining** or EDM. The cutting tool for EDM may be made of hardened too steel, titanium carbide. EDM is also known as "Spark Machining”. Such name has been given for the fact that it removes the metal by applying a rapid series of repetitive electrical discharges. An electrode and the work piece are used for the conducting path of these electrical discharges. A continuously flowing fluid is always flowing to flush away the little amount of material that is removed. Repetitive discharge gives the work piece a desired shape.





WORKING PRINCIPLE OF EDM



Schematic layout of EDM

Working principle of EDM As shown in Figure, at the beginning of EDM operation, a high voltage is applied across the narrow gap between the electrode and the work piece. This high voltage induces an electric field in the insulating dielectric that is present in narrow gap between electrode and work piece. This cause conducting particles suspended in the dielectric to concentrate at the points of strongest electrical field. When the potential difference between the electrode and the work piece is sufficiently high, the dielectric breaks down and a transient spark discharges through the dielectric fluid, removing small amount of material from the work piece surface. The volume of the material removed per spark discharge is typically in the range of 10^{-6} to $10^{-\ 6}$ mm^3.

Advantages of EDM

The main advantages of EDM are:

By this process, materials of any hardness can be machined;

- No burrs are left in machined surface;
- One of the main advantages of this process is that thin and fragile/brittle components
- Can be machined without distortion; Complex internal shapes can be machined

Limitations of EDM

The main limitations of this process are:

This process can only be employed in electrically conductive materials;

- Material removal rate is low and the process overall is slow compared to conventional
- Machining processes; unwanted erosion and over cutting of material can occur;
- Rough surface finish obtained, when at high rates of material removal.

Specifications

Voltage = 250 V

GAP = 0.005 – 0.05 mm

Temperature = 10000 degree celcius Spark occur = 10 – 30 micro seconds

Current density = 15 – 500A

Process Parameters

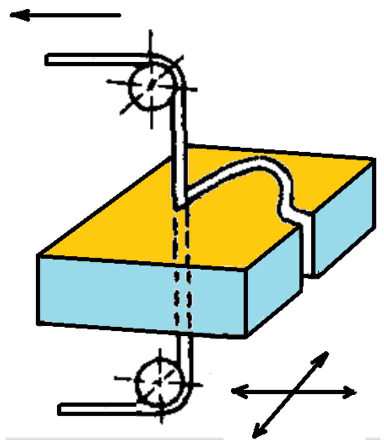
1. Operating Parameters
2. Taper

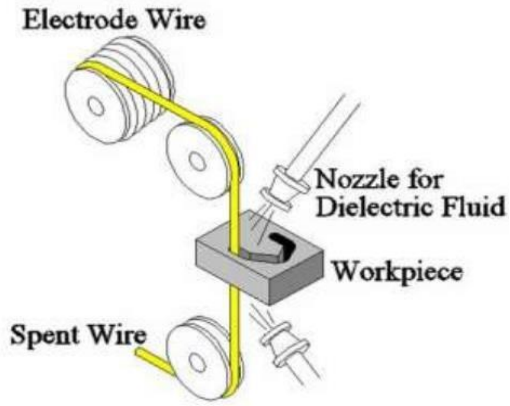
3. Surface finish

4. Current Density

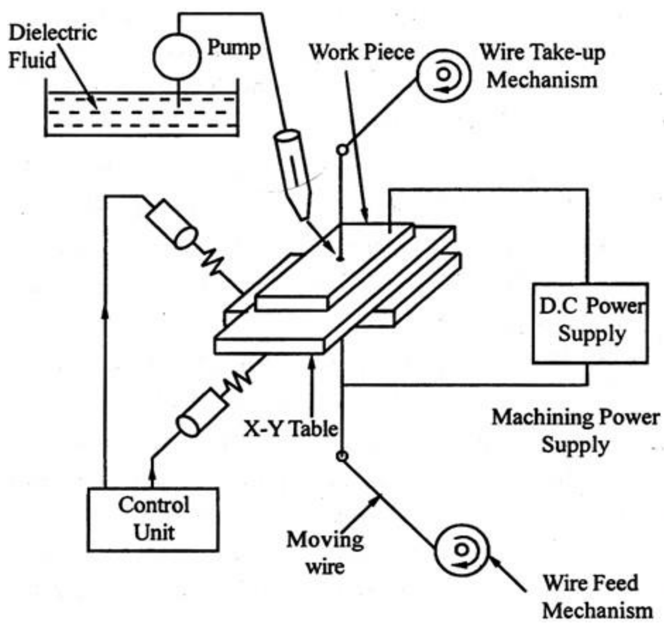
WIRE CUT EDM (WCEDM)

Wire EDM machining (Electrical Discharge Machining) is an electro thermal production process where a thin single strand metal wire, along with de-ionised water (used to conduct electricity) allows the wire to cut through metal by the use of heat from electrical sparks, while preventing rust.





A very thin wire of diameter ranging from 0.02 to 0.3 mm is used as an electrode in wire cut EDM. It cuts the work piece with electrical discharge just like a band saw. In this process either work piece or the wire is moved. The spark discharge phenomenon is used for eroding the metal which is same as the conventional EDM. In wire cut EDM the wire acts as an electrode as a result complicated shapes can be cut easily without forming electrode. Basically the wire-cut EDM consists of a machine which has a work piece contour movement control unit (NC tension: a power supply which supplies electrical energy to the wire andhas a unit).



Wire - Brass or Molybdenum

0.02 – 0.03mm dia wire

10 – 30 mm/ sec wire Feed

10 – 30 micro second sparking

15 – 500 Amp / mm2

30 - 250 V

10,000 C - Temperature

15 – 80 mm3 / sec MRR

Petroleum Based Hydrocarbon Fluids – Paraffin, white Sprit ..

It also has work piece mounting table and a wire driver section. The wire driver section is use for moving the wire accurately at a constant tension. Another important part is the dielectric fluid (distilled water) supplier having constant specific resistance. Wire EDM has the following features -

- No forming electrode is necessary, Electrode wear is very negligible.
- Smooth machined surface, Tight geometrical and dimensional tolerances.
- Extremely high tolerances between punch and die. Extended die life.
- Straight holes are possible to produce, No skill is needed to run the machine.
- Machine can be operated without any regular supervision for long time at high operating rates.

Advantages

- Because of the absence of the split lines in the die, savings of the stages in the sequential tools occurs. Itpermits more punch opening per stage.
- There will no flashes on the moulded parts because the moulds with draught can be arranged withoutvertical divisions.
- To necessity for tool manufacturing and storing.
- Work pieces are hardened before cutting, so no heat treatment distortion is present.
- Whole work is done in one machine. So die manufacturing cycle time is short.
- Lesser inspection time because of single piece construction of dies with high accuracy.

- Time is utilized perfectly as the wire cut EDM can cut throughout the day.
- Very economical even for small batch production, Low thermally affected zone. High surface finish.
- Numbers of rejected work piece are very small.

THERMAL ENERGY BASED PROCESSES

Principle

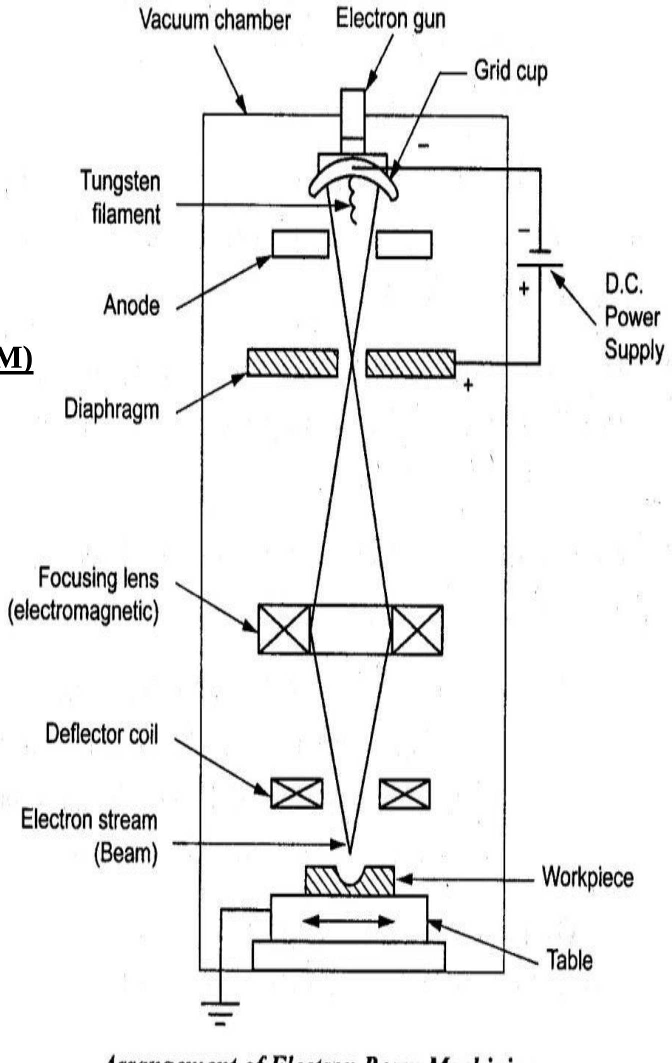
Here the machining is done by usage of heat energy.The heat energy is focused on a particularportion for melt & Vaporize the work material.

Example :

1. Electron Beam Machining (EBM)
2. Laser Beam Machining (LBM)
3. Plasma Arc Machining (PAM)

ELECTRON BEAM MACHINING (EBM)

Principle



Arrangement of Electron Beam Machining

In this, a 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 x 10^8m/sec. this process is best for micro cutting of materials.

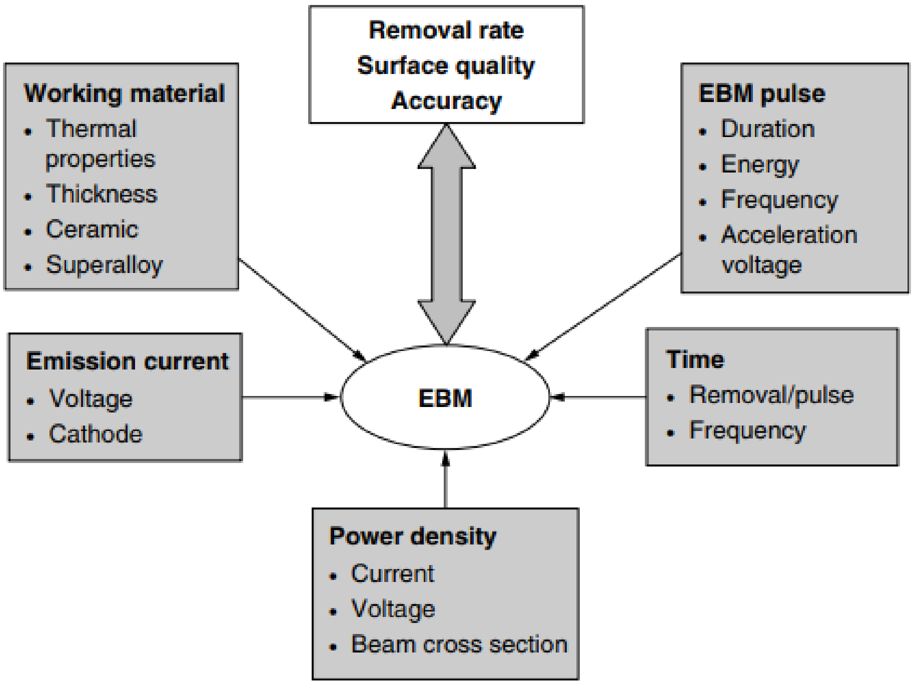
When the high velocity beam of electron strike the work piece its kinetic energy is converted into heat. This concentrated heat raises the temperature of material and vaporise a small amount of it, resulting in removal of material from the work piece.

Working

The main components

of EBM installation,shown in Fig. are housed in a vacuum chamber,
evacuated to about 10–4 torr. The tungsten filament cathode is heated to about 2500 to 3000°C in order to emit electrons. A measure of this effect is the emission current, the magnitude of which varies between 20 and 100 mA. Corresponding current densities lie between 5 and 15 A/cm^2 . Emission current depends on the cathode material, temperature, and the high voltage that is usually about 150 kV. Such a high voltage accelerates a stream of electrons in the direction of the workpiece. After acceleration, electrons, focused by the field, travel through a hole in the anode. The electron beam is then refocused by a magnetic or electronic lens system so that the beam is directed under control toward the workpiece. The electrons maintain the velocity (228 × 10^3 km/s) imparted by the acceleration voltage until they strike the workpiece, over a well- defined area, typically 0.25 mm in diameter. The kinetic energy of the electrons is then rapidly transmitted into heat, causing a corresponding rapid increase in the temperature of the workpiece, to well above its boiling point, thus causing material removal by evaporation.

Factors Affecting Performance of EBM



<u>EBM Process Parameters and Capabilities</u>

Acceleration voltage	50–60 kV
Beam current	100–100 μA
Beam power	0.5-50 kW
Pulse time	4-64,000 μs
Pulse frequency	0.1-16,000 Hz
Vacuum	0.01-0.0001 mm mercury
Spot size	0.013-0.025 mm
Deflection range	6.4 mm^2
Beam intensity	1.55×10^5–1.55×10^9 W/cm^2
Depth of cut	Up to 6.4 mm
Narrowest cut	0.025 mm in 0.025-mm-thick metal
Hole range	0.025 mm in 0.02-mm-thick metal 1.0 mm in 5-mm-thick metal
Hole taper	1°–2° typical
Hole angle to surface	20°–90°
Removal rate	40 mm^3/s
Penetration rate	0.25 mm/s
Perforation rate	Up to 5000 holes/s
Tolerance	± 10% depth of cut
Surface roughness	1 μm R_a

Advantages

■ Drilling is possible at high rates (up to 4000 holes per second).

■ No difficulty is encountered with acute angles.

■ Drilling parameters can easily be changed during machining.

■ No limitation is imposed by work piece hardness, ductility, and surface reflectivity.

■ No mechanical distortion occurs to the work piece since there is no contact.

■ The process is capable of achieving high accuracy and repeatability of 0.1 mm for position of holes and 5percent for the hole diameter.

■ The process produces the best surface finish compared to other processes.

■ The cost is relatively small compared to other processes used to produce very small holes.

Disadvantages

■ High capital equipment cost

■ Long production time due to the time needed to generate a vacuum

■ The presence of a thin recast layer

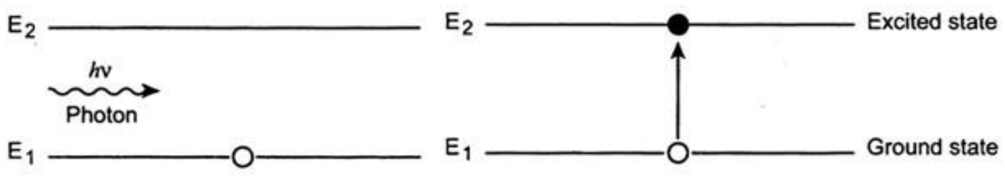
■ Need for auxiliary backing material

LASER BEAM MACHINING (LBM)

Normally, the atoms in the excited state will not stay there for a long time. It comes to the ground state by emitting a photon of energy $E = h\nu$. Such an emission takes place by one of the following two methods.

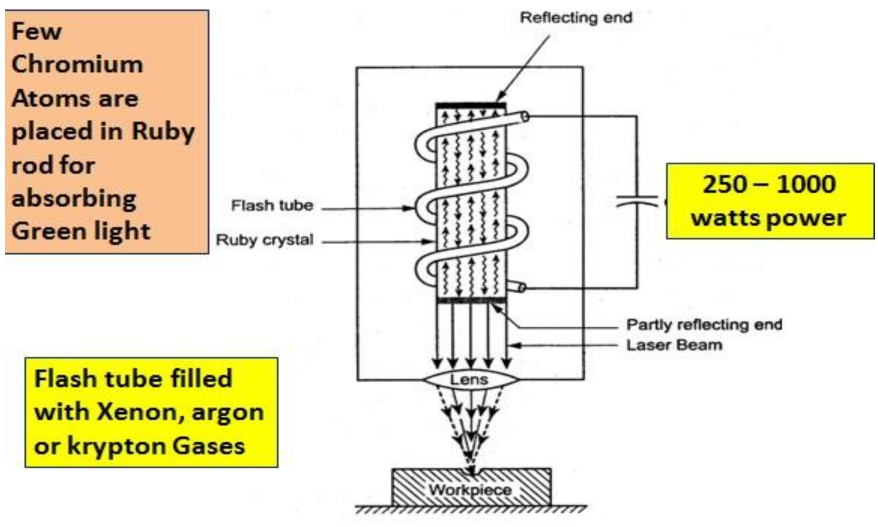
Laser works on the principle of quantum theory of radiation.

Consider an atom in the ground state or lower energy state (E_1) when the light radiation falls on the atom, it absorbs a photon of energy $h\nu$ and goes to the excited state (E_2).

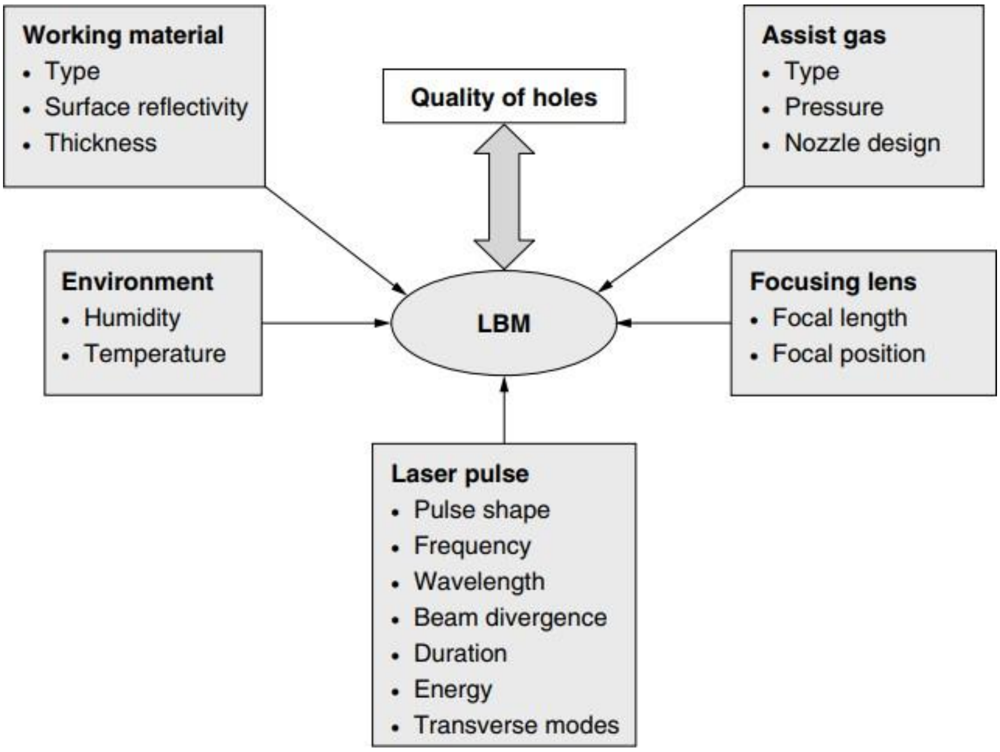


(i) Before absorption *(ii) After absorption*

1. Spontaneous Emission
2. Stimulated Emission



Schematic diagram of LBM



Working

A flash light of 1000watts wound around the ruby rod as shown in figure. When a switch is ON the light energy from the flash tube passed into the ruby rod and it triggers the chromium atom in the rod. So theexcited atoms emit photons. These photons are reflected so many times due t the presence of mirror arrangement in the construction. Due to this a powerful coherent beam of red light is obtained. This red light is focused on work piece through converging lenses. So this red light heat and vaporise the pointed metal portion in the work piece. Likewise the machining continued.

Applications of Laser

1. Laser in Metal Cutting, 2.Laser in Drilling, 3.Laser in Welding, 4.Laser in Surface Treatment

5.Trimming,6.Blanking,7.Micromachining applications

Laser in Surface Treatment

- A thin layer of cobalt alloy coating is applied on Turbine blade for heat and Wear Resistance.
- thin Ceramic coating is applied on metal Surface for heat and Wear Resistance.
- It’s also used to seal the micro cracks which are usually present in hard – Chromium electroplates

Advantages of LBM

1. All Kind of metals are machined, Micro holes are possible
2. Soft materials like rubber can be machined
3. No tool wear and contact with w/p
4. Automated process, Controlling of beam is easy

Disadvantages of LBM

1. High initial Cost, 2 . Operating cost is high, 3.required skilled labours, 4.Rate of production is low

5.Need safety equipments, 6.Life of flash lamp is low, 7.The machined holes are not straight and round

PLASMA ARC MACHINING (OR) PLASMA JET MACHINING

Introduction

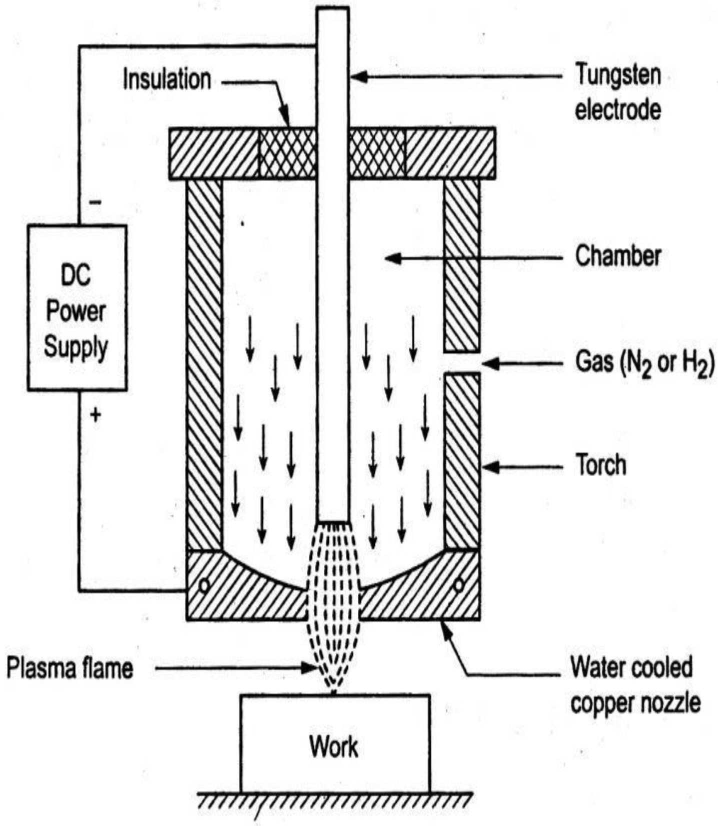
When a gas is heated to a sufficiently high temperature of the order of 11000 – 28000 degree Celsius, itbecomes partially ionized

PLASMA

It's a mixture of free electrons + partiallyionized gas and Neutral Atoms

Working Principle

The material is removed by directing a high velocity jet of high temperature (11000°C – 28000°C) ionized gas on the work piece. This high temperature plasma jet melts the material of the work piece.



Schematic arrangement of PAM

In plasma machining

continuous arc is generated between a hot tungsten cathode and the water-cooled copper anode. A gas is introduced around the cathode and flows through the anode.

The temperature, in the narrow orifice around the cathode, reaches 28,000°C, which is enough to produce a high-temperature plasma arc. Under these conditions, the metal being machined is very rapidly melted and vaporized. The stream of ionized gases flushes away the machining debris as a fine spray creating flow lines on the machined surface.

Types of Torches

1. Direct arc plasma torches (or) Transferred arc type.
2. Indirect arc plasma torches (or) Non-transferred arc type.

S.No.	Gas or Gas Mixture	Material to be machined
1.	Nitrogen – Hydrogen, Argon – Hydrogen	Stainless steel and non-ferrous metals.
2.	Nitrogen – Hydrogen, compressed air	Carbon and alloy steels, cast iron.
3.	Nitrogen, Nitrogen – Hydrogen, Argon – Hydrogen	Aluminium, Magnesium

UNIT-III

CHEMICAL AND ELECTRO-CHEMICALENERGY BASED PROCESSES

Introduction

The metal is removed from the work piece through controlled etching or chemical attack of the workpiece material in contact with a chemical solution

CHEMICAL MACHINING PROCESS

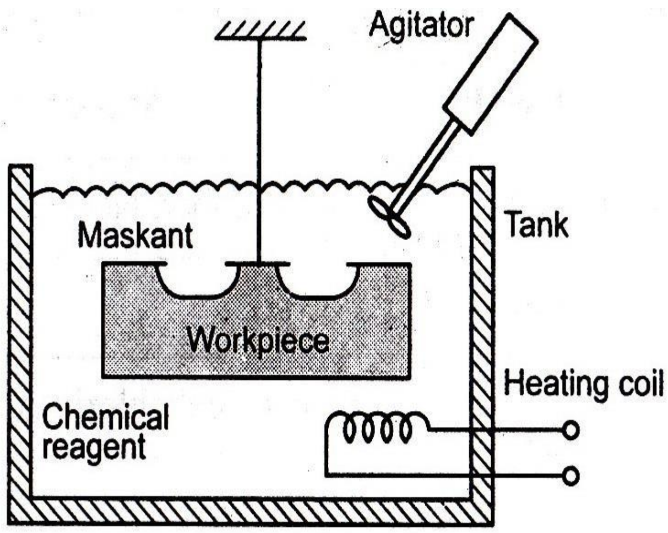
In this method, the metal is removed by ion displacement of the work piece material in contact with achemical solution.

Examples

1. Electro-chemical machining (ECM)
2. Electro-chemical Grinding (ECG)
3. Electro-chemical Honing (ECH)
4. Electro-chemical Deburring (ECD)

<u>Chemical Machining</u>

Chemical machining (CM) is the controlled dissolution of workpiece material (etching) by means of a strong chemical reagent (etchant). In CM material is removed from selected areas of workpiece by immersing it in a chemical reagents or etchants; such as acids and alkaline solutions. Material is removed by microscopic electrochemical cell action, as



occurs in corrosionor chemical dissolution of a metal. This controlled chemical dissolution will simultaneously etch all exposed surfaces even though the penetration rates of the material removal may be only 0.0025–0.1 mm/min.

Processes in Machining

- Maskant coating
- Cleaning ,Drying
- Dipping in chemical solution
    - Stirring & Heating – For uptain Uniform Depth, Washing

Steps in chemical machining

Residual stress relieving: If the part to be machined has residual stresses from the previous processing,these stresses first should be relieved in order to prevent warping after chemical milling.

Preparing: The surfaces are degreased and cleaned thoroughly to ensure both good adhesion of the maskingmaterial and the uniform material removal.

Masking: Masking material is applied (coating or protecting areas not to be etched).

Etching: The exposed surfaces are machined chemically with etchants.

Demasking: After machining, the parts should be washed thoroughly to prevent further reactions with or exposure to any etchant residues. Then the rest of the masking material is removed and the part is cleaned and inspected.

Applications:

Chemical machining is used in the aerospace industry to remove shallow layers of material fromlarge aircraft components missile skin panels, extruded parts for airframes.

Maskants

The process essentially involves bathing the cutting areas in a corrosive chemical known as an etchant, which reacts with the material in the area to be cut and causes the solid material to be dissolved;inert substances known as maskants are used to protect specific areas of the material as resists.

Sl.No.	Material	Maskant
1.	Aluminium	Butyl rubber, Neoprene rubber
2.	Magnesium	Polymers
3.	Titanium	Translucent chlorinated polymers
4.	Nickel	Neoprene
5.	Ferrous metals	Polyvinyl chloride, polyethylene

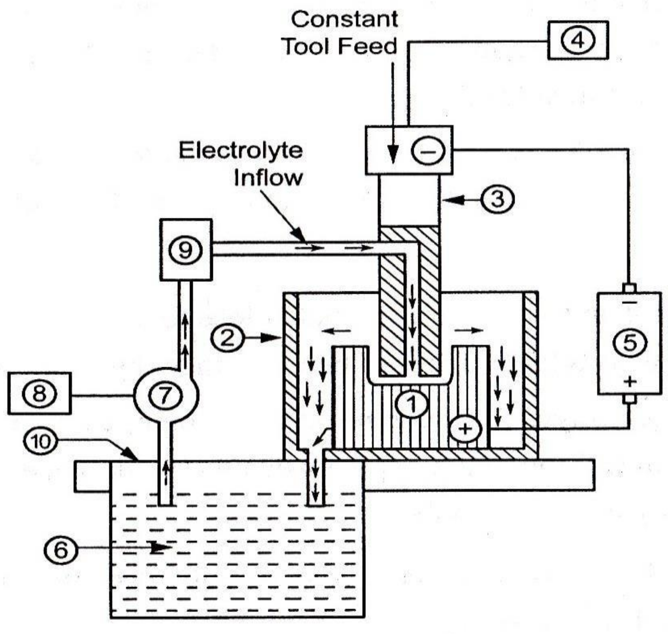
Methods of Maskants

- Scribed and Peeled Maskants
- Photo resists Maskants

Electrochemical Machining (ECM)

Introduction Electrochemicalmachining (ECM) is a metal-removal process based on the principle of reverse electroplating. In this process, particles travel from the anodic material (workpiece) toward the cathodic material (machining tool). A current of electrolyte fluid carries away the deplated material before it has a chance to reach the machining tool. The cavity produced is the female mating image of the tool shape.

Similar to EDM, the workpiece hardness is not a factor, making ECM suitable for machining



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

Arrangement of ECM Process

difficult-to –machine materials. Difficult shapes can be made by this process on materials regardless of their hardness. A schematic representation of ECM process is shown in Figure. The ECM tool is positioned very close to the workpiece and a low voltage, high amperage DC current is passed between the workpiece and electrode.

Advantages of ECM

- The components are not subject to either thermal or mechanical stress.
- No tool wears during ECM process.
- Fragile parts can be machined easily as there is no stress involved.
- ECM deburring can debur difficult to access areas of parts.
- High surface finish (up to 25 µm in) can be achieved by ECM process.
- Complex geometrical shapes in high-strength materials particularly in the aerospace industry for the mass production of turbine blades, jet-engine parts and nozzles can be machined repeatedly and accurately.
- Deep holes can be made by this process.

Limitations of ECM

- ECM is not suitable to produce sharp square corners or flat bottoms because of the tendencyfor the electrolyte to erode away sharp profiles.
- ECM can be applied to most metals but, due to the high equipment costs, is usually• usedprimarily for highly specialised applications.

Material removal rate, MRR, in electrochemical machining

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

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

I: current (amp);

h: current efficiency (90–100%).

The rates at which metal can electrochemically remove are in proportion to the current passedthrough the electrolyte and the elapsed time for that operation. Many factors other than current influence the rate of machining. These involve electrolyte type, rate of electrolyte flow, and some other process condition.

ELECTRO-CHEMICAL GRINDING (ECG) (OR) ELECTROLYTIC GRINDING

Principle

Machining operation by the combined action of Electro-chemical effect and conventional grinding operation

90 % - Metal

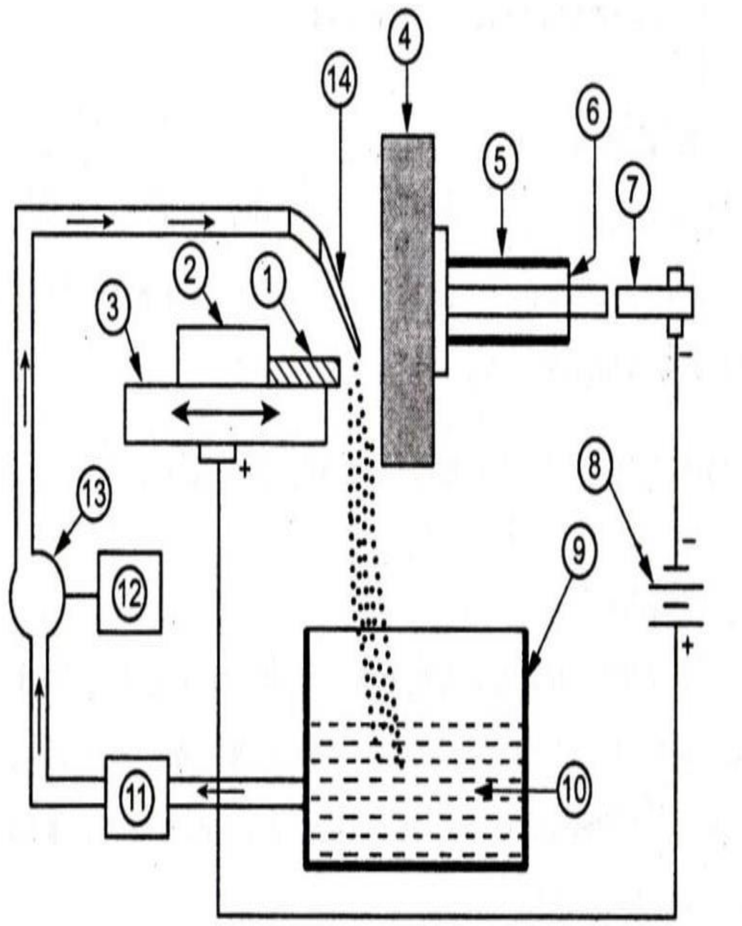
removed by chemical

Action 10 % -Metal

removed by Grinding

Action

ECG also called electrolytic grinding is similar to ECM, except that the cathode is an electrically conductive abrasive grinding wheel instead of a tool shaped like the contour to be machined • Used primarily to machine difficultto cut alloys such as stainless steel, Hastelloy, Inconel, Monel, Waspally and tungsten carbide, heat treated workpeices, fragile or therm-sensitive parts, or parts for which stress-



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

Arrangement of ECG process

free and burr-free results are required. ECG removes metal by a combination of electrochemical (responsible for 90% of material removal) and grinding actions. The grinding action removes the buildup of oxide film onthe surface of the workpiece . Less power is needed for ECG than for ECM since the machining area is smaller and the abrasive in the wheel is removing the oxide film – current ranges from 5 to 1000A are most common, with a voltage of 3 to 15V over an electrolyte gap of approximately 0.25mm or less and wheel speeds of 1100 to 1800m/min. Many similarities between ECG and conventional grinding make this one of the easiest ECM based processes to both understand and implement – grinding wheel closely resemble their conventional counterparts with the exception that ECG wheels use an electrically conductive abrasive bonding agent; electrolyte is introduced to the work area in the same manner that coolant is introduced in conventional grinding.

Process parameters

ECG exhibits MRRs that are up to 10 times faster than conventional grinding on materials harder than 60HRC; although MRRs are high, ECG cannot obtain the tolerances achieved by conventional grinding.

The removal rate for ECG is governed by the current density, just as in ECM: as with ECM, the higher the current density, the faster the removal rate and the better the resulting surface finish.

Feed rates vary with different parameters, depending on the grinding method: if the feed rate is running too slowly for the application, a large overcut will be produced that will result in poor surface finishes and tolerances and if the feed rate is too fast, the abrasive particles will be prematurely forced into the workpiece,resulting in excessive wheel wear.

Advantages

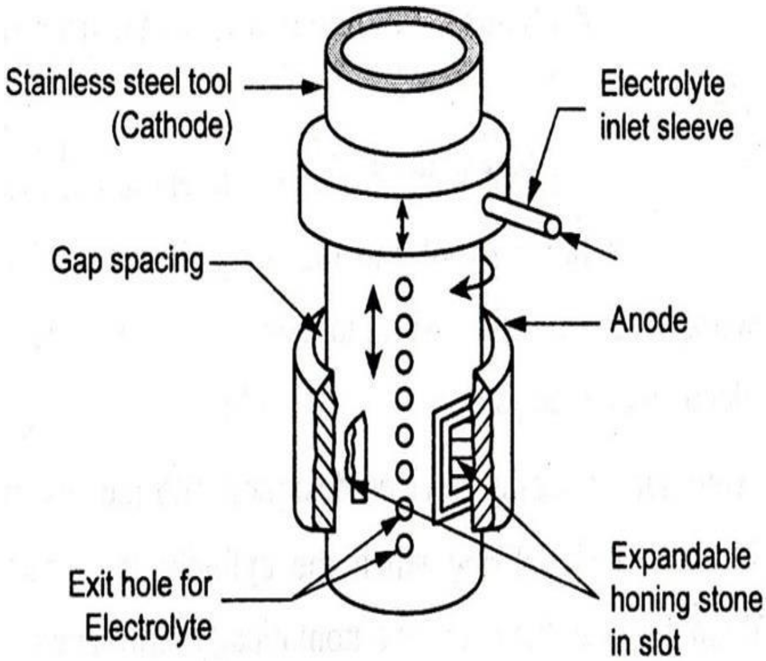
- No thermal damage to workpiece
- Elimination of grinding burn , Absence of work hardening
- Long-lasting wheels – less truing
- Higher MRR;
- Single pass grinding - reduced cost of grinding;
- Absence of burrs on the finished surface; Improved surface finish with no grinding scratches;
- Reduced pressure of work against the wheel – no distortion;
- In ECG, the ECM action is efficient

Dis advantages

- High capital cost /Higher cost of grinding wheel;
- Corrosive environment
- High preventive maintenance cost
- Tolerances achieved are low.
- Difficult to optimize due to the complexity of the process;
- Non-conductive materials cannot be machined
- Not economical for soft materials – noncompetitive removal rates compared to conventional methodsfor readily machinable metals
- Requires disposal and filtering of electrolytes

ELECTRO-CHEMICAL HONING (ECH)

It is a process in which it combines the high removal



Tool consists of a hollow stainless steel body that has expandable, nonconductive honing stones protruding from at least three locations around the circumference. The honing stones are identical with those used in conventional honing operations, except that they must resist the corrosiveness of the electrolyte. The honing stones are mounted on the tool body with a spring-loaded mechanism so that each of the stones exerts equal pressure against the workpiece.

Working

At the beginning of the ECH cycle, the stones protrude only 0.075-0.127mm from the stainless steel body, establishing the gap through which the electrolyte flows. The electrolyte enters the tool body via a sliding inlet sleeve from which it exits into the tool-workpiece gap through small holes in the tool body . After passing through the gap, the electrolyte flows from the workpiece through the gap at the top andbottom of the bore. The mechanical action of the tool is the same as with conventional honing; the tool is rotated and reciprocated so that the stones abrade the entire length of the bore. Electrolytes used in ECH are essentially the same as those used in ECM, although the control of pH, composition and sludge is less critical because the abrasive action of the stones tends to correct any resulting surface irregularities. As in ECM, the electrolytes are recirculated and reused after passing through appropriate filtration, and the most commonly used electrolytes are sodium chloride and sodium nitrate.

Process parameters

• Machines are available that deliver up to 6000 amp

• Current density at the workpiece can range from 12 to 47amp/cm2

• Working voltages are 6-30VDC

• The electrolyte is delivered to the work area at pressures of 0.5-1MPa

• ECH can remove materials at rates up to 100% faster than conventional honing, the gain being morepronounced as the material hardness increases

• Machine capacities are currently able to accommodate bore lengths up to 600mm and bore diameters from

9.5 to 150mm

Advantages

- Increased MRR particularly on hard materials
- Since most of the material is removed electrochemically, honing stone life is greatly extended
- Burr-free operation

- Unlike conventional honing, no micro-scratches are left on the work surface
- Less pressure required between stones and work
- Reduced noise and distortion when honing thin walled tubes
- Cooler action leading to increased accuracy with less material damage
- As with all ECM-based processes, ECH imparts no residual stresses in the work piece
- Capable of achieving surface finishes of 0.05μ and dimensional accuracies of ±0.012mm

Disadvantages

- More number of equipments used
- Cost of machine is high
- Required Skilled labours
- Hard materials only machined.

UNIT IV

ADVANCED NANO FINISHING PROCESSES

INTRODUCTION

In order to substitute manual finishing process and to meet the functional properties such as wear resistance, power loss, due to friction on most of the engineering components, we go for advanced machining process. This finishing process is carried out at micro and nano level. This process is called as advanced nano finishing process.

Nano finishing is the only operation which can make rough surfaces in nanometers range. The ultimate precision through finishing will be where processed where there is a change in size of sub nanometer.

It offers batter accuracy, higher efficiency, economic and consistency. Some of the nano finishing processes are

1. Abrasive flow machining
2. Chemo mechanical polishing
3. Magnetic abrasive finishing
4. Magneto rheological finishing
5. Magneto rheological abrasive flow finishing

ABRASIVE FLOW MACHINING

PRINCIPLE

In abrasive flow machining process, the semisolid abrasive media acts as deformable grading wheel; which helps to remove small amount of materials.

The abrasive media is given larger force or velocity by hydraulic or mechanical means to push the media into the areas in which conventional finishing process cannot be performed.

CONSTRUCTION AND WORKING OF AFM

The schematic arrangement of abrasive flow machining is as shown in figure.

The main elements of AFM are

(i) Machine

(ii) Tooling
(iii) Media
(iv) Workpiece.

Machine

- The machine consists of two opposing hydraulic cylinder with piston rod and base plate.
- The two opposing medium charmless are hydraulically clamped together with the workpiece in between them.
- When hydraulic pressure is applied in the media containing the abrasive particles moves over the workpiece surface and removes the peaks the surface.
- Pressure and temperature control devices are provided at appropriate setup in order to monitor the pressure and temperature of the media.
- Replaceable inserts are provided at various points in experimental setup. It is made of nylon, Teflon and other materials which is used for restricted flow of media. The inserts can be replaced on worn out conditions.

Tooling

- The tool used in AFM process is the media.
- It consists of organic polymers and special hydrocarbon gel. This gel along with the abrasives is present at the base of the setup.
- Tooling design in AFM permits or block the flow of media in or out of the work surface.
- Tooling is selectively and controllably used in areas were material in the workpiece is removed.

Media

- The media consists of the base and abrasive grits.
- The base contains organic polymers and hydrocarbon gel. It exists in semisolid form.
- The abrasive grits used along with the base are Aluminium oxide, silicon carbide, boron carbide and diamond.
- These abrasive grits are mixed with the base by mechanical means to form a semisolid laden putty.
- The abrasive grits with the base is called the media. It is used to abrade the surface of workpieces, when it moves through restricted areas and resist abrasive action.
- The composition and mechanical mixing determines the stiffness of the media.

Workpieces

- The material such as metals and metal alloys are used as workpieces. These workpieces are flat or cylindrical in shape.

Working

- The hydraulic rams are those which alternatively compress and extrude the abrasive medium from the bottom cylinder to the top through the workpiece.
- The pressure of the extruding medium is in the range of 0.70 to 0.22 MPa or 100-3200 PSI.
- Abrasive grit size are 8 to 700 mesh, which enable quick cutting action. Fine grit size are 300-700 mesh for the medium to increase the stiffness.
- The medium may be mixed with hand or cycled 20-50 times through scrap
- While tooling, maximum machining takes place when there is a maximum restriction in media or flow of abrasives.
- The media stiffness is also used to determine the stock removal. If media has high stiffness, it will result in a flow patterns of pure extrusion process.
- If the media has low stiffness, then media flow in the centre is faster than along the walls.
- The pressure and temperature inside the media is determined and controlled.
- The force acting on the media are the viscous components assist to exert axial forces and tries to move along the direction of applied extrusion pressure.
- The elastic component assists in exerting radial force which presses the active abrasive particles into the workpiece surface.
- The viscous and elastic components are used in removing the material in the form of micro nano chips.
- For effective movement of the chips, the axial force should be greater than the required force because it increases the depth of penetration and remove the material.
- The surface finish obtained by this process is 0.05 µm.
- The force and velocity diagram in AFM are as shown in figure. 4.1.

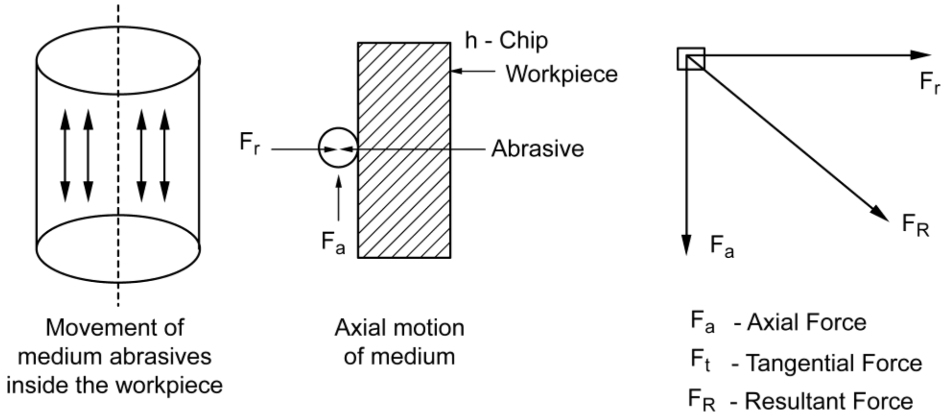


Fig. Force diagram of abrasive flow machining

TYPES OF ABRASIVE FLOW MACHINING

The types of abrasive flow machining are

1.One way abrasive flow machining

2.Two way abrasive flow machining

3.Orbital abrasive flow machining

PROCESS PARAMETERS IN ABRASIVE FLOW MACHINING

The metal removal rate depends upon the following parameters.

1. Addition of plasticizers
2. Extrusion pressure
3. Number of cycles

ADVANTAGES OF AFM

- ❖ Operations such as deburring polishing and radiusing can be done.
- ❖ This process is more suitable for batch production
- ❖ It is faster than manual finishing
- ❖ It can finish inaccessible areas in one single movement.

LIMITATIONS OF AFM

- ❖ It has low finishing rate compared to other nano finishing process.
- ❖ The process involves high production time and high production cost.
- ❖ There should be repeated replacements of poly abrasive media that is used in AFM process.

APPLICATIONS OF AFM

AFM is used in finishing of

- Extrusion dies
- Nozzle of flame cutting touch
- Air foil surfaces of impellors
- Accessory parts like fuel spray, nozzle, fuel control bodies.

CHEMO MECHANICAL POLISHING

INTRODUCTION

Chemo mechanical finishing or CMP was adopted by IBM in 80‟s for Si polishing.

Chemo mechanical polishing is a process of smoothing and planning surface with the combination of chemical etching and free abrasive polishing.

CMP of silicon wafers is a basic processing technology for production of flat, defect free, highly reflective surface.

This planarization method is a choice for < 0.5 micron technologies.

PRINCIPLE

In chemo mechanical polishing, a chemical reaction is used to soften the material and then mechanical polishing is done on the layer. The polishing action is partly mechanical and partly chemical.

Construction and Working of CMP

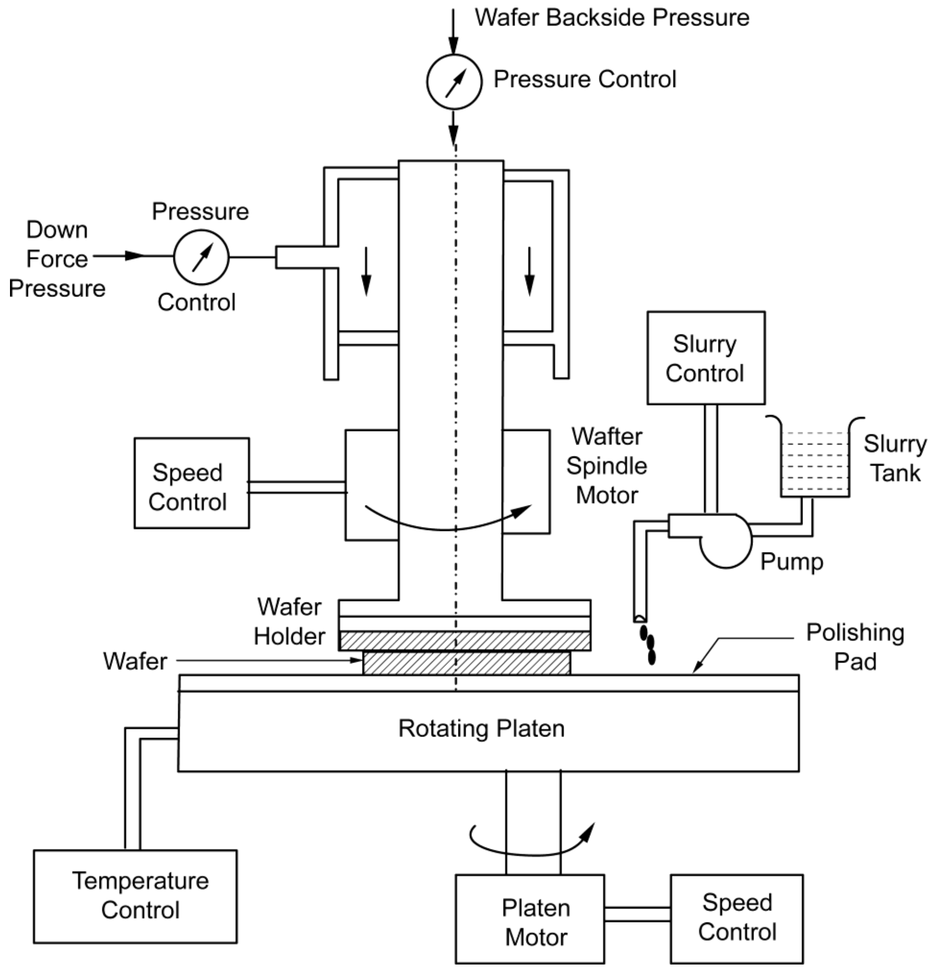


Fig. Chemo mechanical polishing

The schematic arrangement of chemo mechanical polishing is as shown in figure 4.8.

CMP consists of the rotating platen. CMP polishing pad, workpiece, CMO slurry with abrasive, speed, temperature and pressure control system.

Working

In chemo mechanical polishing, the pressure is applied by down force on the carrier. The force is transferred to the carrier through the carrier axis.

The gas pressure is loaded on the wafer. The higher points on the wafer are subjected to high pressure and the removal rate are enhanced.

The wafer face is mounted upside down.

The carrier is pressed against a moving plates containing a polishing pad. The carrier also rotates.

The slurry is supplied from above the platen. The slurry may be oxide or metal type.

An abrasive containing aqueous slurry is dripped onto the table and centrifugal force distributes the slurry across the pad.

This forms a thin colladial layer of slurry which saturates the pad.

In aqueous solution, oxide form hydroxyl and hydrogen bond between slurry particles and wafer.

The silicon dioxide bonds are formed by releasing water molecules. Thus chemical reaction occurs and the silicon bonds also brakes when the slurry particles move away.

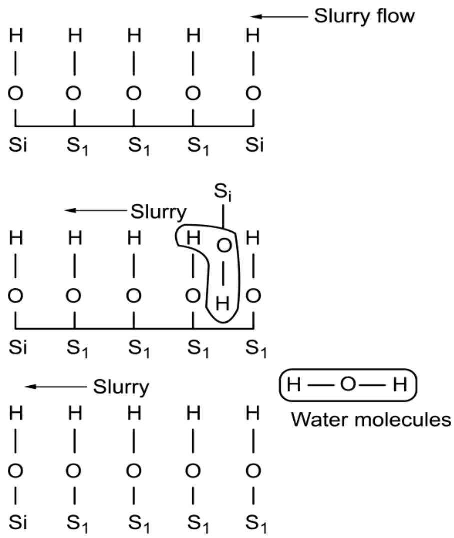
The combination of mechanical effect and chemical reaction results in material removal from the surface of the wafer.

The material removal is more or less in atomic level. The process is explained in two aspects

1. Chemical aspects of material removal
2. Mechanical aspects of material removal

Chemical Aspects of Material Removal

The process uses a chemical etching to soften the workpiece surface and the mechanical polishing off the layer takes place.



Mechanical Aspect of Material Removal

When abrasives are present in the slurry then substantial material removal takes place due to abrading, but when there is no abrasives in the slurry the material removal purely takes place due to mechanical friction and result of pressure down force applied.

The process detaches material from the surface in a relative motion caused by protrusion of fixed and free abrasives between opposing surfaces of the polishing pad and workpiece.

The process parameter involved in CMP process are

- Process : 10 to 50 kPa
- Platen / carrier rpm: 10 to 100 rpm

- Velocity – 10 – 100 cm/s
- Slurry flow rate – 50 to 500 m/min Typical material removal rate
- Oxide CMP – 2800 A^0 / min

FACTORS AFFECTING PROCESS PARAMETERS

The factors affecting process parameters are

- Temperature in the polishing pad
- Conditioning of polishing pad.

ADVANTAGES OF CMP

- It is used to polish metal like Aluminium, Copper, Silver titanium etc.
- It can also polish insulators like $SiO2$, $Si3N4$.
- Ceramics like SiC, TiN, TaN can also be polished.

LIMITATIONS OF CMP

- Cleaning of platen surface in a difficult process.
- Embedded particles, residual slurry are to be removed very carefully.
- Due to residues min scratches are also formed on the surface of the platen and the pad.
- Surface defects such riping out and dishing are formed on the surface.

APPLICATIONS OF CMP

- It is used in fabrication of semiconductor devices
- Oxides are deposited on the wafer in from of shape trenches
- Flat panel display
- Microelectronic mechanical system
- Magnetic recording head and CD writing

MAGNETIC ABRASIVE FINISHING

INTRODUCTION

Magnetic abrasive finishing process was developed in US, USSR, Bulgaria and Japan. This process is mainly used in finishing radiusing and deburring of various flat surfaces and cylindrical surfaces.

PRINCIPLE

In magnetic abrasive finishing process, the magnetic particles are joined to each

CONSTRUCTION AND WORKING OF MAF

- ❖ The schematic arrangement of magnetic abrasive finishing is shown in figure 4.11.
- ❖ MAF process consists of magnetic abrasive particles, flexible magnetic abrasive brush and workpieces.

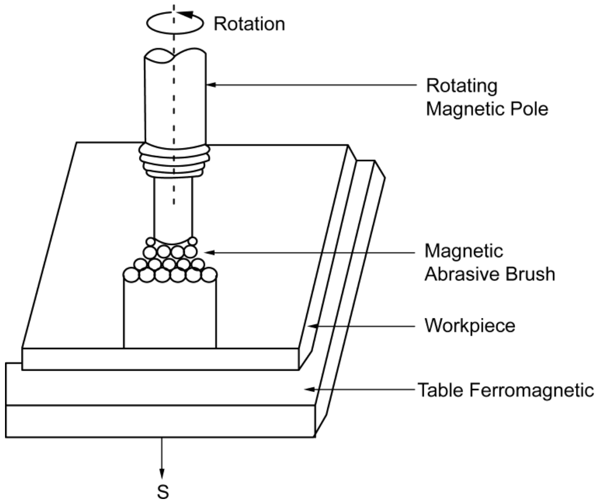


Fig. Magnetic abrasive finishing

Magnetic Abrasive Particles

- ❖ The rotating magnetic poles consist of granular magnetic abrasives composed of ferromagnetic particles and abrasives as shown in figure 4.9.

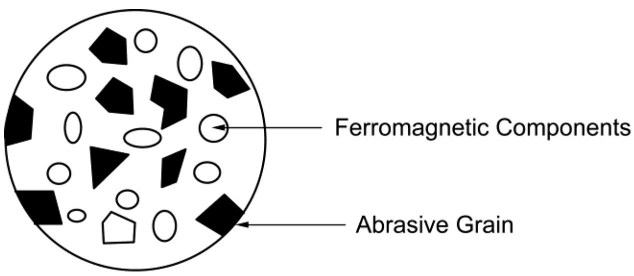


Fig. 4.12. Magnetic Abrasive Particle

- ❖ These particles acts as the multiple cutting tool.

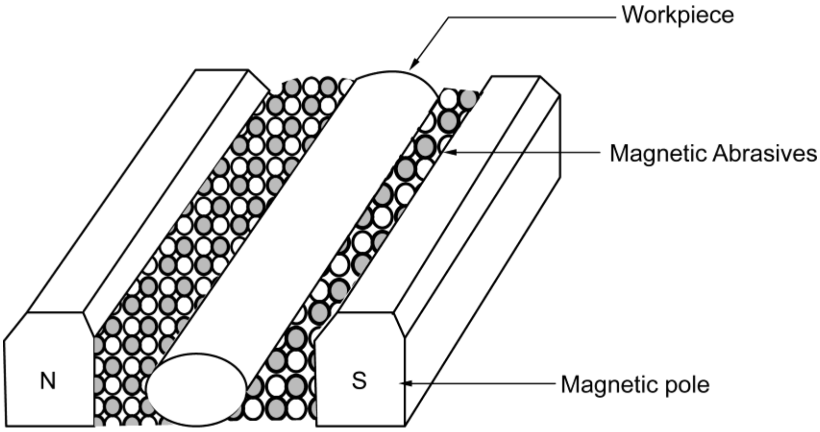


Fig. Magnetic abrasive finishing-cylindrical surface

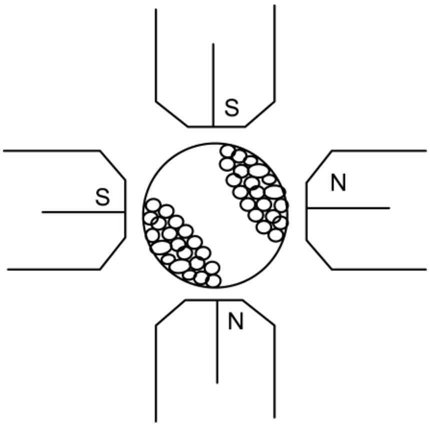


Fig. Magnetic abrasive finishing – internal surface

Flexible Magnetic Abrasive Brush

- When electromagnets generates the magnetic field, the ferromagnetic abrasives join with each other under the influence of magnetic field.
- The ferromagnetic abrasive particles join together to produce a flexible magnetic abrasive brush. This brush acts as the cutting tool.

Workpiece

- The workpiece used in MAF processis ferromagnetic or non ferromagnetic materials.
- The workpiece is placed between the poles of magnet.
- The workpiece may be flat surface, internal and external surface of cylindrical objects for finishing.

Working

- ❖ When the electromagnets generates the magnetic field. This magnetic field influence the abrasive particles.
- ❖ In presence of magnetic field, the magnetic abrasive particles join with each other to magnetic abrasive brush.
- ❖ The magnetic field produced generates the essential pressure require to move the abrasive brush.
- ❖ The magnetic field also controls and regulates the essential cutting force required to abrade the peaks on the surface of the workpiece.
- ❖ The magnetic flux density produced will rotate, vibrates and produce axial movement on the workpiece surface.
- ❖ The flexible magnetic brush receives the actions due to magnetic flux density and produces sharing action on workpiece.
- ❖ The force acting on the workpiece is exerted by the magnetic flux density through the flexible magnetic abrasive brush.
- ❖ The force acting on the workpiece are of two types (i) Normal force (ii) Tangential force.
- ❖ The normal force acting in “F” which is responsible for actuating the abrasive particles along the magnetic force, it is mainly responsible for cutting action or penetration in the workpiece. The tangential force acting
- ❖ It also improves the surface integrity by introducing the compressive residual stresses.

FACTORS AFFECTING PROCESS PARAMETERS

1. Pressure
2. Type and size of grains
3. Finishing efficiency
4. Bonded and unbounded magnetic abrasive
5. Magnetic flux density.

ADVANTAGES OF MAF

- ❖ MAF have self adaptability and easy controllability
- ❖ Surface finish is in order of nanometer.
- ❖ The device can be easily mounted on other machine without the need of high capital investment.

DISADVANTAGES OF MAF

- It is difficult to implement MAF in mass production operation.
- It is a time consuming process.
- It is not applicable for some ordinary finishing task where conventional finishing technique can be easily implemented.

APPLICATIONS OF MAF

- It is used in finishing processes such as lapping, buffing, honing and burnishing operation in surface of tubes, bearing and automobile components.
- Polishing and removal of thin oxide film from high speed rotating shafts.
- It is used in finishing operations of cutting tools, turbine blades, air foil optics and sanitary pipes.
- It is used in medical field in areas of capillary tube, needles and biopsy needles etc.

MAGNETO RHEOLOGICAL FINISHING

INTRODUCTION

A magneto rheological fluid is a layer of smart fluid in a carrier. It is a type of oil when subjected to a magnetic field, the fluid increases it apparent viscosity to the point that it becomes a viscoelastic solid.

Rheology is a science of flow and deformation study of rheological properties of the medium. The performance of the medium. The performance of the medium is given by its rheological properties.

Flow behavior of the medium is complex in nature as it is a heterogeneous mixture. Each ingredient of the mixture is responsible for its flow behavior.

PRINCIPLE

In magneto rheological finishing process under the influence of magnetic field the MR fluid (Magneto rheological fluid) becomes a viscoelastic solid. This act as the cutting tool to remove the materials from the surface of the workpiece.

CONSTRUCTION AND WORKING OF MRF

The schematic arrangement of magneto rheological polishing is as shown in figure 4.20.

The MRF experimental setup consist of electromagnets, nozzle, suction pipe, pumps and MR fluid conditioner.

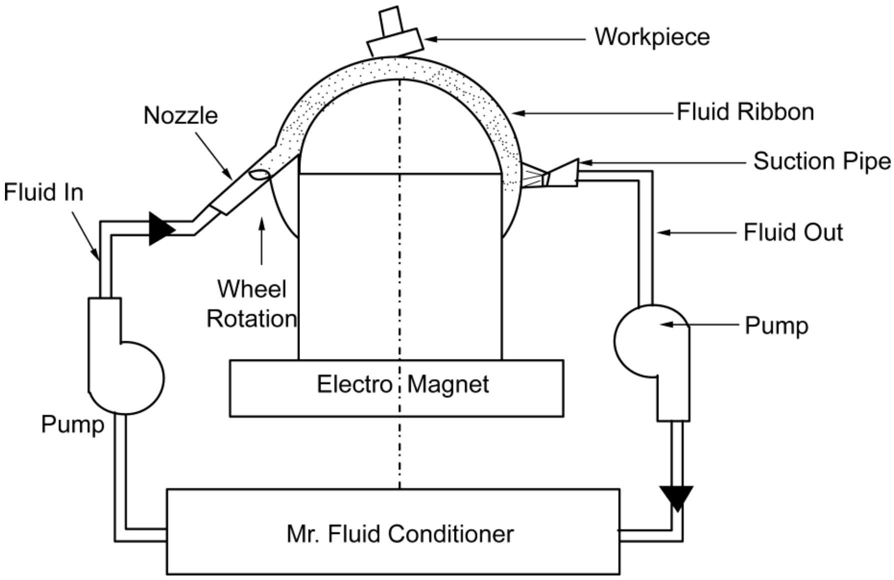


Fig. Magneto rheological finishing process

The basic components in MR fluid are

1. Magnetic dispersed phase
2. Abrasive particles
3. Stabilizers
4. Carrier fluid

Workpiece

The workpiece material used in MRF in optical lenses, glasses and ceramic.

Nozzle

Nozzle in the opening connected by the pump from the MR fluid conditioner.

Nozzle is used to deliver the MR fluid over the surface of the electromagnetic rotating wheel.

Suction

- It is a point at which the MR fluid is sucked after finishing the polishing process.
- It is sucked by this pipe and pumped into the MR fluid conditioner again.

Working

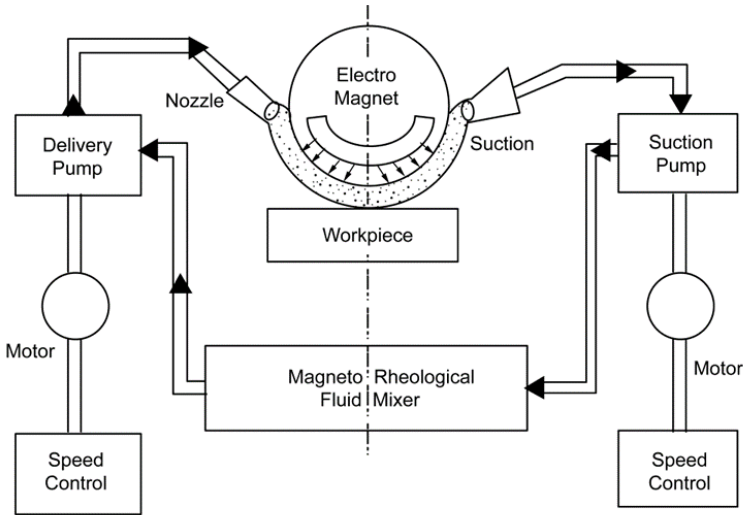


Fig. Magneto rheological fluid circulation system

- ❖ Magneto rheological fluid is delivered to the moving roller just above the electromagnetic pole through the nozzle.
- ❖ This fluid is influenced by the magnetic field. In presence of the magnetic field, the fluid becomes a thin polishing ribbon.
- ❖ This polishing ribbon contains the CI particle closed to magnetic fluid and abrasives above the CIP chain which touch the surface of workpiece to be polished. It acquire a plastic Bingham‟s property.
- ❖ MR fluid is extruded into the rotating wheel form a thin ribbon that will contact the optical surface of the workpiece.
- ❖ Electromagnets below the rotating wheel creates a strong local magnetic field gradient.
- ❖ The strength of magnetic field gradient influences the stiffness of MR fluid and pulls it. The MR fluid produces dynamic field strength of 50-100 kPa. The controlled zone magnetized fluid becomes the polishing tool.
- ❖ Material removal takes place due to shear stress. The workpiece is positioned above the abrasive involved in finishing operation. There are two types of forces acting on the roller. 1. Normal force and 2. Tangential force.
- ❖ The normal force represent as „Fn ‟ this force penetrates the abrasive inside the workpiece. Under magnetic force, the particle squeezes in the converging gap.
- ❖ The other force is the tangential force „Fxy‟ which helps in removal of material in form of micro- nano chips. This is done by shear flow of MR fluid which pushes the abrasives forward. The resultant force “Fr ” moves the chip from the workpieces.
- ❖ In absence of magnetic field the abrasive ribbon changes the viscoelastic nature into fluid. This fluid is sucked by the suction pipe.

Carbonyl iron particles in columnar and structure in presence of magnetic field get aligned along the lines of magnetic force. The abrasive floats on the outer layer of the magnetic field which is in contact with the workpieces.

When the ribbon have relative motion due to magnetic flux gradient with respect to work surface, the surface of the work[piece get abraded due to shearing plastic deformation at the tips. Thus finishing or polishing operation is carried out. MR fluid is efficient process for high precision finishing of optics. It is also used for free from shapes.

The merits of using MR polishing fluid lap are

- It is adjustable with respect to magnetic field.
- It carry away the heat and debris from the polishing zone.
- It does not produce any pressure like of grinding wheel.
- It does not lodes, it sharpness as it is self deformable.

The accuracy produced by computer controlled MRF process is in the order of 10-100 nm.

ADVANTAGES OF MRF

- High accuracy
- Enhances product quality and repeatability
- Increases production rate, productivity yield and cost effectiveness.
- Manufacture of precision optics.
- Optical glasses with roughness of less than 10 angstrom can be machined.
- Polishing tool can be easily adjusted and confines perfectly to the workpiece surface.
- Obtain high precision surfaces without any damage
- Surface finish upto nanometer level is achieved without sub surface damage.

LIMITATIONS OF MRF

- High quality fluids are expensive.
- Fluids are subject to thickening after prolonged used and need replacement.
- Settling of ferromagnetic particles can be a problem for some application
- This process is not suitable for finishing of internal and external surface of cylindrical components.

APPLICATIONS OF MRF

- Use in lens manufacturing

- Optical glasses, single crystals, calcium fluorides silicon ceramic are machined.
- Square and rectangular aperture surface such as prism, cylinder and photo blank substrates are machined
- The nano diamond doped MR fluid removes edge chips, cracks and scratches in sapphire bend bars
- Polishing of high aspect ratio optics and thin film filling and semiconductor wafers
- It is also used machining materials like glass, copper and tantalum
- It is used in automobile, electrical and manufacturing fields.

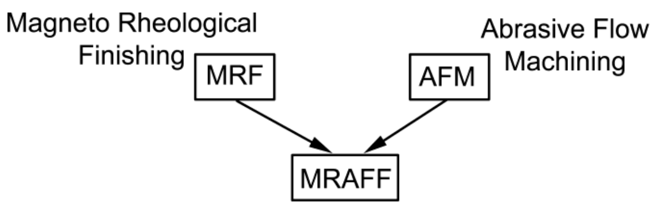
MAGNETO RHEOLOGICAL ABRASIVE FLOW FINISHING

This process is the combination of two finishing processes. They are abrasive flow machining and magneto rheological finishing. This process eliminates the limitations in AFM and MRF.

The limitations in AFM are lacks to control its properties like viscosity and wall shear stress and also difficult to mix the abrasive particles which made to think of better alternatives.

The limitations of MRF is, it is ineffective polishing hard metals and it is used for machining flat, spherical and external surfaces.

After studying these processes, it was planned to eliminate the limitations of both the processes and combine its advantages.



On combining the process, the abrasive medium in magneto rheological abrasive flow finishing can be manipulated and controlled in real time and also it helps in deterministically and selectively abrade the workpiece surfaces.

The machining setup is similar to AFM will remove the shape limitation in workpiece surface.

PRINCIPLE

Magneto rheological polishing fluid comprises of carbonyl iron powder and silicon carbide, abrasive dispersed in the viscoplastic base of grease and mineral oil.

When external magnetic field is applied these fluid exhibit change in rheological behavior. These fluids behaves smartly and does the finishing operation precisely.

CONSTRUCTION AND WORKING OF MRAFF

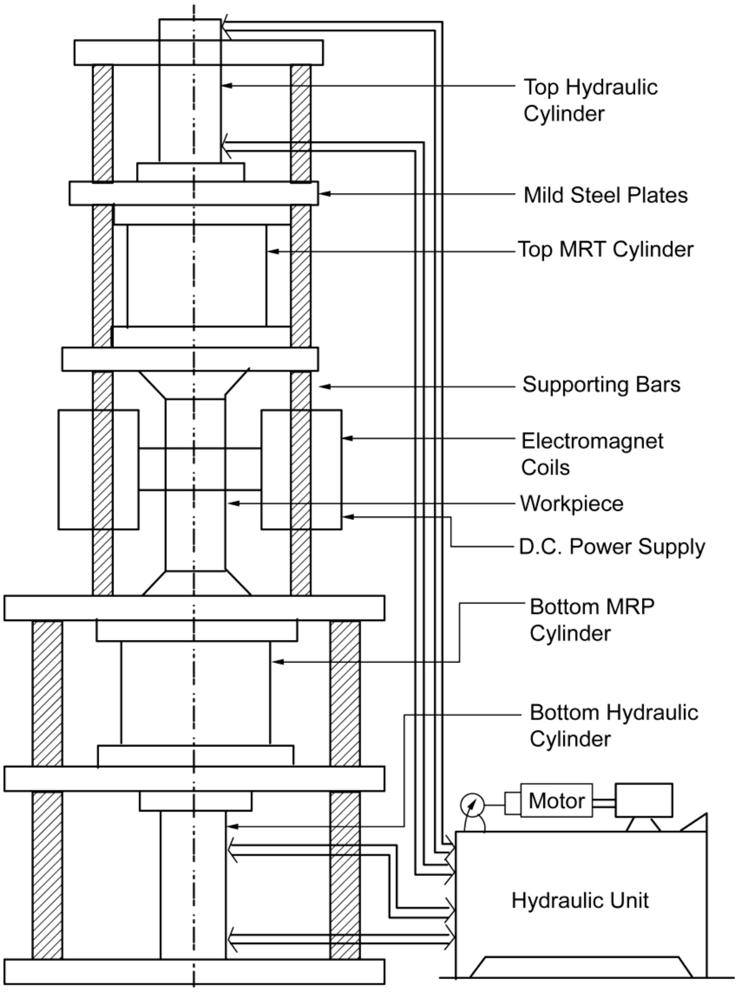


Fig. Magneto rheological abrasuive flow finishing

Magneto rheological abrasive flow finishing arrangement consists of hydraulic cylinders, MR fluid cylinder with piston, workpiece and workpiece fixtures, electromagnets.

Electromagnets

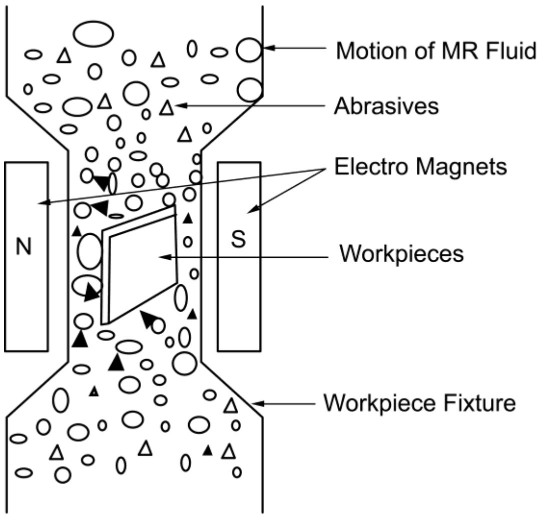
The electromagnets are placed on either side of the workpiece fixture. It consists of 2000 turns of 17 SWG copper wire.

Workpiece and Workpiece Fixtures

The workpieces are inserted in the workpiece fixtures, which are placed in between the two cylinders.

The workpiece material is metal and metal alloys.

Mechanism of Magneto Rheological Abrasive Flow Finishing



Working

- Hydraulic ram alternatively undergoes compression and extrusion in the medium cylinder and moves the MR fluid from the bottom media cylinder to the top through the workpiece.
- Appropriate pressure is applied to the hydraulic cylinder for movement of the MR fluid medium.
- When the MR fluid reaches the workpiece it is influenced by the localized magnetic field using the electro magnets.
- It develops maximum magnetic field gradient of 0.1 tesla in which the MR fluid behaves smartly and passes across the workpiece in a gap of 30 mm, the CI particles lies closer to magnetic field and abrasive particles entrap in them and lies outwards as shown in figure
- The abrasives on the MR fluid is squeezed under high pressure and viscosity around the workpiece. Thus the workpiece surface get abraded and material removal takes place.
- This compression and extrusion of the MR fluids result in finishing operation. The MR fluid media cylinder is moved from bottom to top or viceversa.
- The finishing efficiency of the MR fluids relies mainly on the rheological properties of fluid.
- The rheological properties such as yield stress and viscosity are characterized based on the specific applications.

- ❖ The property of the MR fluid is responsible for binding/bonding strength of abrasive particles surrounding CI particles or CIP chain.
- ❖ MR fluid‟s composition and volume ratio have an impact on rheological property and stability.
- ❖ Rheometer with magneto rheological devices is used to find the property analysis and temperature distribution of the fluid.

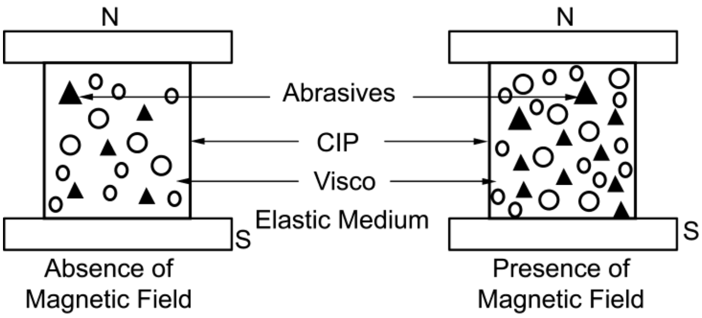


Fig. Microscopic image of MR fluid

At extrusion hydraulic pressure of 3.75 MPa, maximum improvement in surface finish is observed due to optimum concentration of magnetic field.

The best surface finish is obtained at stainless steel workpieces was 30 mm at optimum finishing condition of N-400 cycles, P = 3.75 MPa , B – 0.668 Tesla.

The maximum surface finish obtained in 0.10m at around 2000 finishing cycles.

ADVANTAGES OF MRAFF

- ❖ The viscosity of abrasives in MRAFF can be controlled in real time and also it helps in finishing the workpieces determistically.
- ❖ Complex structures can be easily machined.
- ❖ Non uniform magnetic field produces non uniform surface finish
- ❖ Required a closed environment.

APPLICATIONS OF MRAFF

- ❖ Used in investment cast milled parts, airfoil, cast aluminum automobile turbo components
- ❖ Complex piping for values, fittings, tubes and flow meter

- Finishing of automotive gears in a single pass, heart values, exhaust manifold and high pressure holes.
- Used in finishing of heart valves, exhaust manifold and high pressure holes.

UNIT V

RECENT TRENDS IN NON-TRADITIONAL MACHINING PROCESSES

INTRODUCTION

Recent developments in nontraditional machining process are the hybrid process. This process was developed by combining the advantages of two nontraditional machining processes and eliminating the limitations of those processes.

The various types of hybrid process are

1. Electric discharge diamond grinding (EDDG)
2. Electro chemical spark machining (ECSM)
3. Magneto rheological abrasive flow finishing (MRAFF)

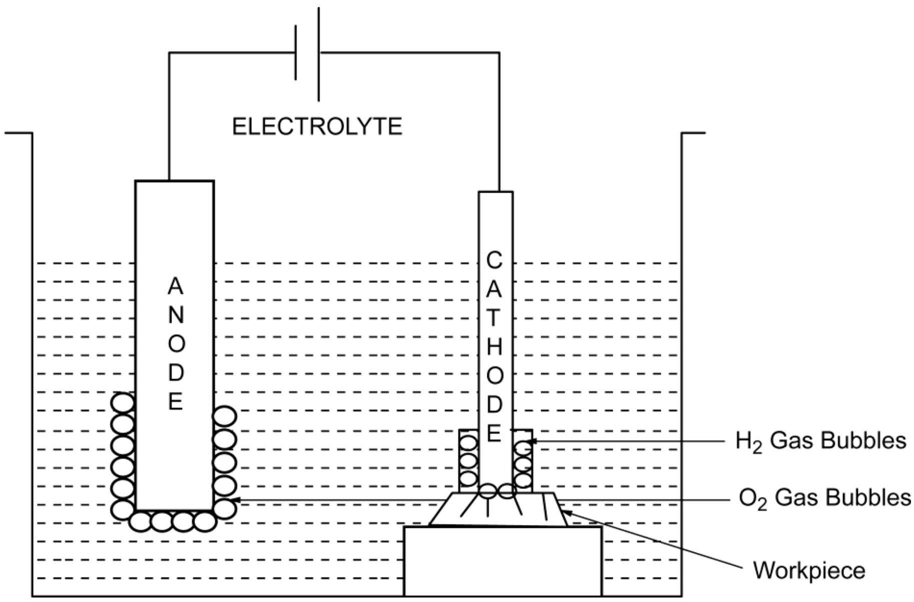


Fig. Electro chemical spark machining process

The main purposes of implementing hybrid process are

- ❖ It enhances volumetric material removal rate.
- ❖ Computer controls of the processes have good results and better performance.
- ❖ Awareness of capabilities will resolve many problems in machining.

❖ Application of adaptive control machining becomes easier.

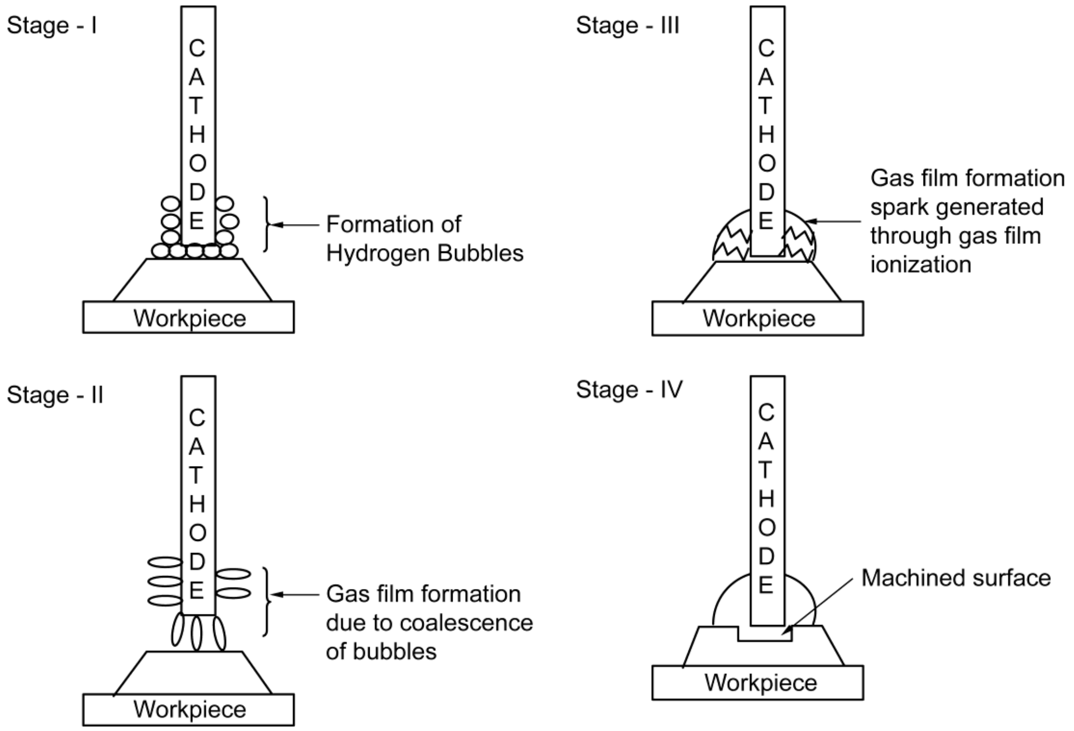


Fig. Stages in electro chemical spark machining

ELECTRO CHEMICAL SPARK MACHINING

INTRODUCTION

Electro chemical spark machining is a hybrid process of electro chemical machining and electric discharge machining. This process is Unique because it is suitable for both conducting and non conducting material. It is used for selective deposition, microwelding and machining of special non conductive material.

PRINCIPLE

The anode and the cathode are immersed inside the electrolyte. Due to potential difference developed, hydrogen bubbles are generated and thus spark is created between the cathode and workpiece. This produces high energy that helps in material removal or vapourization of material take place as shown in figure

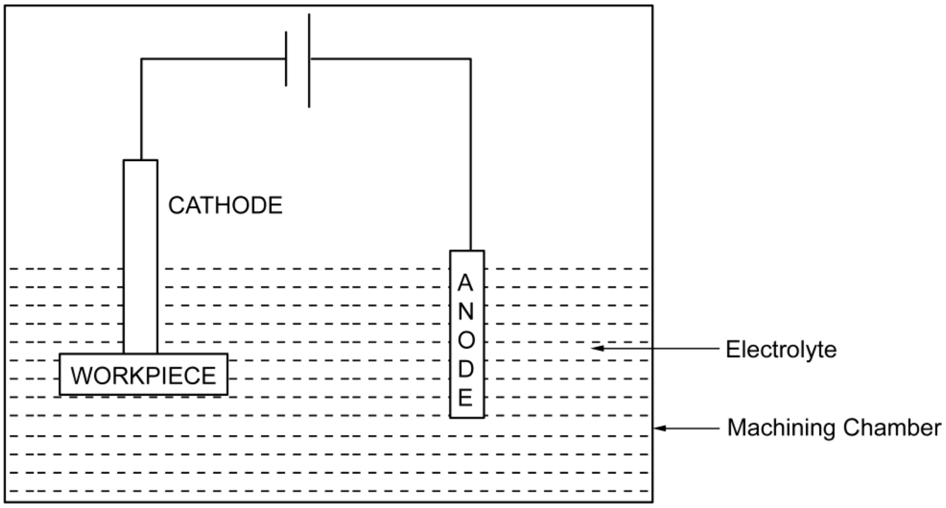


Fig. Principle of ECSM

CONSTRUCTION AND WORKING OF ECSM

- ❖ The schematic arrangement of electro chemical spark machining process is as shown in figure 5.1.
- ❖ The electro chemical spark machining process consists of an anode, cathode, electrolyte, workpiece table controlled servometer, exhaust pipes and PC control system.
- ❖ In ECSM process the anode used in graphite and it is immersed in the electrolyte. The anode larger in size compared to cathode.
- ❖ The cathode used in ECSM process is smaller in size. It is placed just above the workpiece at a distance of 500 m. The cathode and anode with the workpiece are maintained at same distance of 500 m.
- ❖ The electrolyte connected with this process may be a combination of water, hydrochloric acid with sodium chloride.
- ❖ The table in ECSM process has three types of rotation x, y and z axis. The whole experimental setup is placed in the table.

- ❖ Exhaust pipes are provide above the arrangement, which is used in removing poisonous fumes that are released during electrolysis and sparking. As these fumes are harmful to the operator and also corrosive in nature.

Working

- ❖ The anode and cathode which are connected to the power supply are immersed inside the electrolyte.
- ❖ When the supply is ON, potential difference is created in the area and hydrogen bubbles are produced near the bubble in between the workpiece as shown in figure 5.2.
- ❖ A huge number of electrons are generated due to discharge accelerated towards the workpiece kept near the cathode tip. The former being at a relatively high potential.
- ❖ The flow of huge number of electrons is seen as a current spike for a short duration of a milli seconds.
- ❖ The bombardment of electron raises the temperature of the workpieces giving rise to a sharp temperature pulse. This removes the material and vapourise it.
- ❖ The material removal in ECSM process is in the form of circular pits.
- ❖ The chemical reaction involved in this process are
- ❖ At cathode, reduction reaction takes place

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

- ❖ At anode, oxidization reaction takes place

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

- ❖ The material removal in ECSM process takes place through
  - Melting and vapourisation
  - Chemical reaction when proper electrolyte is not selected.
  - Cracks propagate through random thermal stresses.
  - Due to mechanical shock and cavitations effect.
- ❖ As the material removal is due to the heat energy produced by the spark, the workpiece used can be a conductive material or a non conductive material.

THE PROCESS PARAMETERS INVOLVED IN ECSM PROCESS

- ❖ A supply voltage ranges between 35 – 50 V.
- ❖ Cutting tool has a wire diameter of 200 μm.
- ❖ The workpiece used here is soda lime glass.
- ❖ The gap to be maintained between the cathode and workpiece is around 50 – 500 μm depending on the type of application.
- ❖ The electrolyte solution is 14 – 20% of water and sodium chloride.

ADVANTAGES OF ECSM

- ❖ No need for vacuum
- ❖ Cost effective
- ❖ Material removal is in the form of circular pits.

DISADVANTAGES OF ECSM

- ❖ The fumes produced due to chemical reaction is harmful to the operator.
- ❖ The fumes are more corrosive in nature.

APPLICATION OF ECSM

- ❖ It is used in machining materials like Alumina, Quartz and composites.
- ❖ It is used in preparation of blind holes in quartz material.
- ❖ It is used in machining materials like glass, copper, tantalum etc.
- ❖ It is used in automobile, electrical and manufacturing fields.

ELECTRICAL DISCHARGE DIAMOND GRINDING (EDDG)

INTRODUCTION

Electric discharge diamond grinding process is a hybrid process of electric discharge machining and diamond grinding. This process eliminates the limitations of EDM and diamond grinding process. The limitations of EDM are low material removal rate and resolidified white layer infected with micro cracks are produced. The limitations of diamond grinding are high cost, high specific material removal energy, due to high temperature strength degradation takes place and due to wheel wear, dressing becomes a problem.

This hybrid process takes the advantages of EDM and diamond grinding such as grinding of hard materials, increases thermal softening of the workpiece which requires less force and better accuracy with surface dressing.

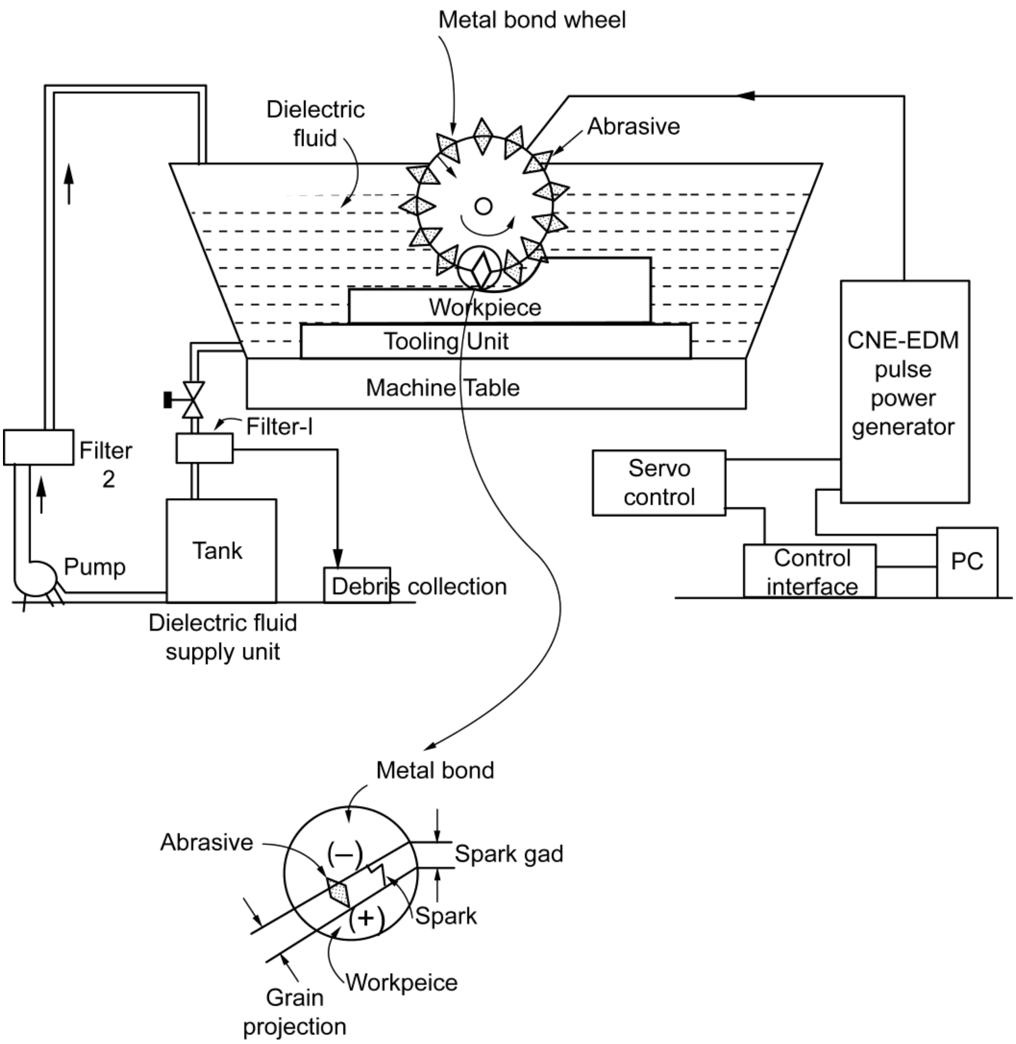


Fig. Schematic Arrangement of Electric Discharge Diamond Grinding

5.3.1. PRINCIPLE

Electric discharge diamond grinding process is a spark erosion process used for precision grinding. Spark is produced between metal bonded grinding wheel and workpiece. Heat generated during sparking softens the workpieces surface and grinding process is easily abraded using diamond abrasive particles.

CONSTRUCTION AND WORKING OF EDDG

The schematic arrangement of electric diamond grinding process is as shown in figure 5.4.

EDDG process consists of dielectric fluid, metal bonded diamond grit wheel, workpiece, servo control system and CNC-EDM controlled pulse power generator.

Dielectric Fluid: The dielectric fluid used in EDDG may be water or water based cutting fluid such as kerosene, paraffin oil and hydrocarbon oil. The arrangement consists of a tank which receives the dielectric fluid from the bottom of EDDG setup. This fluid is filtered twice and pumped into the arrangement again by using motor. This fluid filtration is done in order to remove the chips and debris formed during grinding.

Tool

The alumina metal bonded diamond grit wheel is used as a tool. This tool is an electrically conductive material. This tool is connected to negative terminal of pulse power generator. The abrasives in the wheel are diamond grits which are arranged on outer surface of grinding wheel which is used for material removal.

Workpiece

The workpiece used in EDDG process is hard material. It is electrically conductive material. The workpiece is connected to the positive terminal of the pulse power generator. The workpiece materials used are high speed steel and cemented carbides.

Servo Control System

The servo control system used in EDDG is used to maintain in a constant gap between the grinding wheel and workpiece during active feeding of the wheel into the workpiece. The system monitors the desire gap distance in such a way that the wheel feeds into the workpiece will be equal to the rate at which material is being removed. The circuit senses the gap distance effectively, if the gap is sensed block with particles they get melted out due to high generated.

Pulse Power Generator

The pulse power generator generates the DC power supply to the tool and workpieces. The whole setup in CNC EDM controlled using computer arrangement.

Working

- ❖ An electrically conductive rotating, grinding wheel is used as the electrode and workpiece is used as the anode.
- ❖ The wheel and the workpiece are connected –ve and +ve terminal of pulse power generator.
- ❖ This pulse power generator is in turn connected to the CNC computer.
- ❖ The arrangement is submerged in a big tank filled with dielectric fluid.
- ❖ The pulse power generator generates pulse electrical energy at rates upto 250000 pulse/second.
- ❖ The dielectric fluid flows through a small gap that is maintained continuously and uniformly at the rotational motion of grinding wheel.

- ❖ When the power supply discharges, DC pulse power to the wheel and workpiece, the insulative property of dielectric fluid is broken down and a small spark is produced between the gap as shown in figure 5.5. Due to this heat is generated between the gap and the material removal takes place.
- ❖ A small pool of molten metal is formed in the tool as well as the workpieces. The tool has a smaller pool than the workpiece. Large amount of heat energy is released and forms the pool. This softens the workpieces.
- ❖ The diamond abrasive grits attached an alumina wheel pushes the material in the workpiece surface.

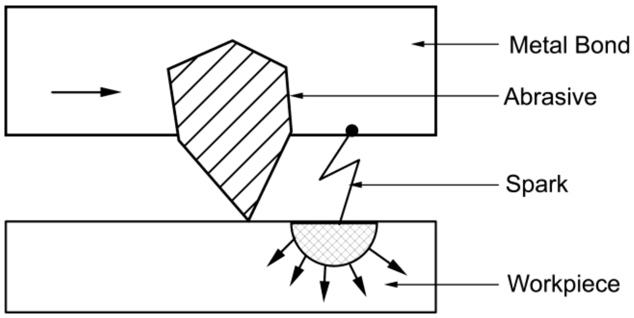


Fig. Formation of Spark in an Abrasive

Thus dressing and declogging of the wheel is maintained. The forces acting in this process are normal and tangential force.

Normal force acts on the grinding wheel helps in penetration of the wheel into the workpiece.

Tangential forces are used to remove the material from the workpieces.

FACTORS AFFECTING PROCESS PARAMETERS OF EDDG

1.Wheel speed

2.Current

3.Pulse on time

ADVANTAGES OF EDDG

- ❖ It can grind any conductive and non conductive materials.
- ❖ Less corrosive effect is produced.
- ❖ This process involves continuous dressing and declogging of the abrasive wheel and thus increases the wheel life to 25%.

APPLICATION OF EDDG

- ❖ It is used in grinding of thin sections
- ❖ Grinding of high hardness materials such as cermates, super alloys and metal matrix composites.