MUTHAYAMMAL ENGINEERING COLLEGE

(An Autonomous Institution)

(Approved by AICTE, New Delhi, Accredited by NAAC & Affiliated to Anna University)
Rasipuram - 637 408, Namakkal Dist., Tamil Nadu

LECTURE HANDOUTS

L 1

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **I** [Introduction] **Date of Lecture:**

Topic of Lecture: Unconventional Machining Process – Introduction

Introduction :

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 work piece. In unconventional machining, a form of energy is used to remove unwanted material from a given work piece.

Prerequisite knowledge for Complete understanding and learning of Topic

- Basics about conventional machining processes

Detailed content of the Lecture:

- Modern machining methods are also named as non-conventional machining methods.
- These methods form a group of processes which removes excess material by various techniques involving mechanical, thermal, electrical chemical energy or combination of these energies.
- There is no cutting of metal with the help of metallic tool having sharp cutting edge.
- The major reasons of development and popularity of modern machining methods are listed below.

(a) Need of machine newly developed metals and non-metals having some special properties like high strength, high hardness and high toughness. A material possing the above mentioned properties are difficult to be machined by the conventional machining methods.

(b) Sometimes it is required to produce complex part geometries that cannot be produced by following conventional machining techniques. Non-conventional machining methods also provide very good quality of surface finish which may also be an encouragement to these methods.

- There can be a very long list of non-conventional machining methods.
- These methods can be classified as the basis of their base principle of working.
- The principle of working is the base of type of energy used to remove the material.
- Classification along with the principle of working is described below.

Use of Mechanical Energy

Mechanical energy is used for removing material from workpiece. In this process, cutting tool with sharp edge is not used but material is removed by the abrasive action of high velocity of stream of hard, tiny abrasive particles. The particles are kept vibrating with very high velocity and ultra high frequency to remove the material.

Electrical Energy

In this category of non-traditional machining electrical energy is used in the form of electrochemical energy or electro-heat energy to erode the material or to melt and vapourized it respectively. Electrochemical machining, electroplating or electro discharge machining are the examples work on this principle.

Use of Thermal Energy

According to this principle heat is generated by electrical energy. The generated thermal energy is focused to a very small portion of workpiece. This heat is utilized in melting and evaporating of metal. The example based o this principle is electric discharge machining.

Use of Chemical Energy

According to this principle of working chemicals are used to erode material from the workpiece. Selection of a chemical depends upon the workpiece material. Example of this type of machining is electrochemical machining. The dame principle can also be applied in reversed way in the process of electrochemical plating.

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007 P.No:2

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LECTURE HANDOUTS

L 2

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **I** [Introduction] **Date of Lecture:**

Topic of Lecture: Unconventional Machining Process – Need – Classification

Introduction :

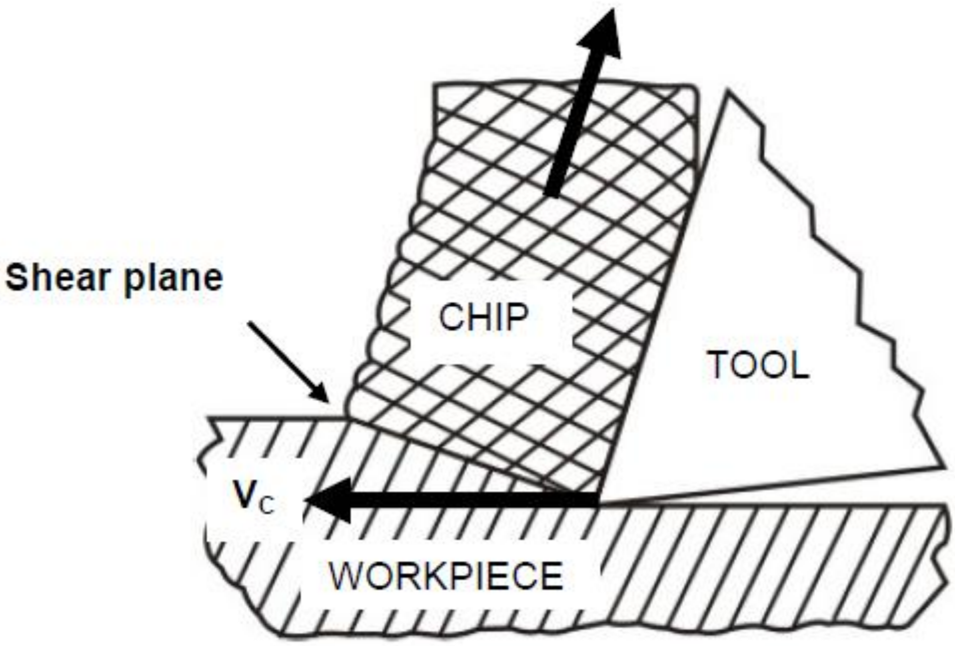
Modern machining methods are also named as non-conventional machining methods. These methods form a group of processes which removes excess material by various techniques involving mechanical, thermal, electrical chemical energy or combination of these energies. There is no cutting of metal with the help of metallic tool having sharp cutting edge.

Prerequisite knowledge for Complete understanding and learning of Topic

Thermal energy
Electrical energy
Chemical energy

Detailed content of the Lecture*:*

- To classify Non Traditional Machining Processes (NTM), one needs to understand and analyse the differences and similar characteristics between conventional machining processes and NTM processes.
- Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition.
- Such forces induce plastic deformation within the work piece leading to shear deformation along the shear plane and chip formation. Fig. depicts such chip formation by shear deformation in conventional machining.



Thus the major characteristics of conventional machining are:

- Generally macroscopic chip formation by shear deformation
- Material removal takes place due to application of cutting forces – energy domain can be classified as mechanical
- Cutting tool is harder than work piece at room temperature as well as under machining conditions

Non Traditional Machining (NTM) Processes on the other hand are characterised as follows:

- Material removal may occur with chip formation or even no chip formation may take place. For example in AJM, chips are of microscopic size and in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level
- In NTM, there may not be a physical tool present. For example in laser jet machining, machining is carried out by laser beam. However in Electrochemical Machining there is a physical tool that is very much required for machining
- In NTM, the tool need not be harder than the work piece material. For example, in EDM, copper is used as the tool material to machine hardened steels.
- Mostly NTM processes do not necessarily use mechanical energy to provide material removal. They use different energy domains to provide machining. For example, in USM, AJM, WJM mechanical energy is used to machine material, whereas in ECM electrochemical dissolution constitutes material removal.

Thus classification of NTM processes is carried out depending on the nature of energy used for material removal. The broad classification is given as follows:

- Mechanical Processes
  - – Abrasive Jet Machining (AJM)
  - – Ultrasonic Machining (USM)
  - – Water Jet Machining (WJM)
  - – Abrasive Water Jet Machining (AWJM)
- Electrochemical Processes
  - – Electrochemical Machining (ECM)
  - – Electro Chemical Grinding (ECG)
  - – Electro Jet Drilling (EJD)
- Electro-Thermal Processes
  - – Electro-discharge machining (EDM)
  - Laser Jet Machining (LJM)
  - – Electron Beam Machining (EBM)
- Chemical Processes
  - – Chemical Milling (CHM)
  - – Photochemical Milling (PCM) etc.

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007 P.No:5

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LECTURE HANDOUTS

L - 3

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **I**[Introduction] **Date of Lecture:**

Topic of Lecture: Comparison of conventional and unconventional machining process

Introduction :

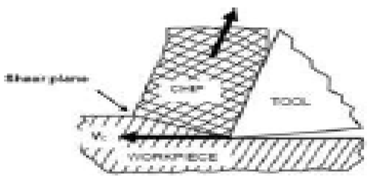
Material removal processes are mainly the secondary manufacturing processes. Material removal processes once again can be divided into mainly two groups and they are "Conventional Machining Processes" and "Non-Traditional Manufacturing Processes".

Prerequisite knowledge for Complete understanding and learning of Topic

Machining processes

Metal removal

Detailed content of the Lecture:

Conventional Manufacturing Processes	Non-Conventional Manufacturing Processes
1. Generally macroscopic chip formation by shear deformation. 	1. Material removal may occur with chip formation or even no chip formation may take place. For example in AJM, chips are of microscopic size and in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level
2. There may be a physical tool present. for example a cutting tool in a Lathe Machine,	2. There may not be a physical tool present. For example in laser jet machining, machining is carried out by laser beam. However in Electrochemical Machining there is a physical tool that is very much required for machining.
3. Cutting tool is harder than work piece at room temperature as well as under machining conditions	3. There may not be a physical tool present. For example in laser jet machining, machining is carried out by laser beam. However in Electrochemical Machining there is a physical tool that is very much required for machining.
4. Material removal takes place due to application of cutting forces – energy domain can be classified as mechanical	4. Mostly NTM processes do not necessarily use mechanical energy to provide material removal. They use different energy domains to provide machining. For example, in USM,

5. Conventional machining involves the direct contact of tool and work –piece	5. Whereas unconventional machining does not require the direct contact of tool and work piece.
6. Lower accuracy and surface finish.	6. Higher accuracy and surface finish.
7. Suitable for every type of material economically	7. Not Suitable for every type of material economically
8. Tool life is lessdue to high surface contact and wear.	8. Tool life is more
9. Higher waste of material due to high wear.	9. Lower waste of material due to low or no wear.
10. Noisy operation mostly cause sound pollutions	10. Quieter operation mostly no sound pollutions are produced.
11. Lower capital cost	11. Higher capital cost
12. Easy set-up of equipment.	12. Complex set-upequipment.
13. Skilled or un-skilled operator may required	13. Skilled operator required.
14. Generally they are manual to operate.	14. Generally they are fully automated process.
15. They cannot be used to produce prototype parts very efficiently and economically.	15. Can be used to produce prototype parts very efficientlyAnd economically.

Conventional machining usually involves changing the shape of a work piece using An implement made of a harder material. Using conventional methods to machine hard metals and alloys means increased demand of time and energy and therefore increases in costs; in some cases conventional machining may not be feasible.

Conventional machining also costs in terms of tool wear and in loss of quality in the product owing to induced residual stresses during manufacture. With ever increasing demand for manufactured goods of hard alloys and metals, such as Inconel 718 or titanium, more interest has gravitated to non-conventional machining methods.

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

1. Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007 P.No:3

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L - 4

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **I** [Introduction] **Date of Lecture:**

Topic of Lecture: Energies employed in the processes

Introduction :

Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition. Such forces induce plastic deformation within the work piece leading to shear deformation along the shear plane and chip formation

Prerequisite knowledge for Complete learning of Topic:

Mechanical energy
Electrical energy
Chemical energy

Detailed content of the Lecture:

Based on energy used, unconventional machining processes can be broadly classified into five main types. They are:

1. Mechanical Energy based Unconventional Machining Processes
2. Electrical Energy based Unconventional Machining Processes
3. Electrochemical Energy based Unconventional Machining Processes
4. Chemical Energy based Unconventional Machining Processes
5. Thermo-electrical (or Electro-thermal) Energy based Unconventional Machining Processes

Video Content / Details of website for further learning:

www.youtube.com/watch?v=-fLz4B8vg20&list=PLGU2NEype87r1ruQLwb08_ShRXT5AxyBn

Important Books/Journals for further learning:

1. Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007 P.No:4

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L - 5

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

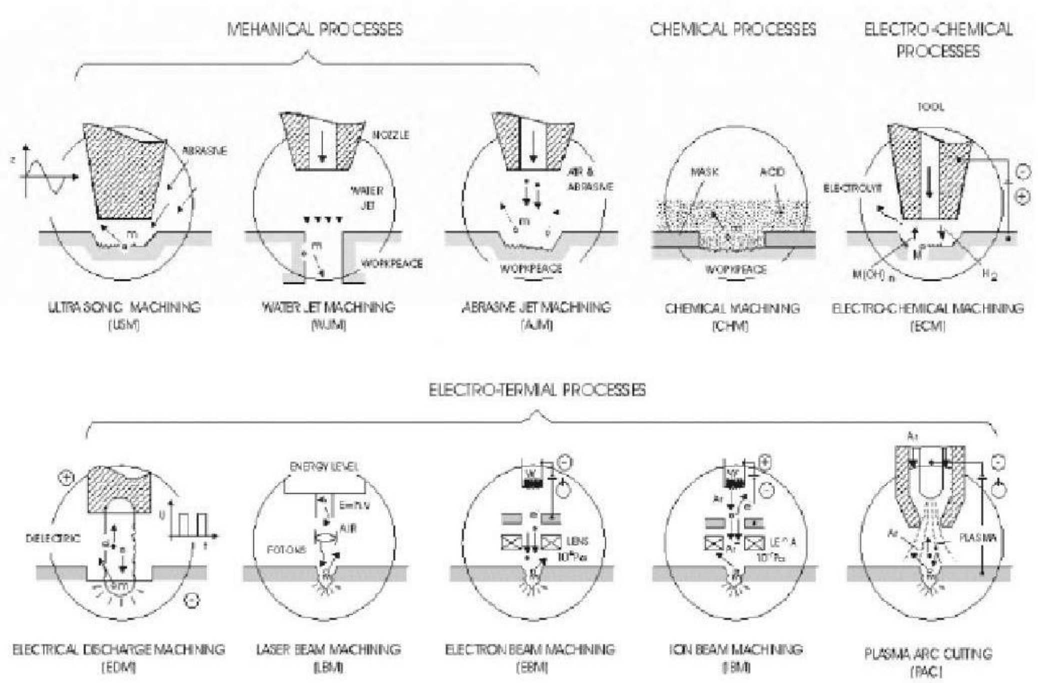
Unit : **I** [Introduction] **Date of Lecture:**

Topic of Lecture: Brief overview of various techniques.

Introduction :
Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition.

Prerequisite knowledge for Complete understanding and learning of Topic
Basics of conventional machining processes

Overview of basic non-conventional machining processes



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LECTURE HANDOUTS

L - 6

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **I**[Introduction] **Date of Lecture:**

Topic of Lecture: Brief overview of various techniques.

Introduction :

Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition.

Prerequisite knowledge for Complete understanding and learning of Topic

Basics of conventional machining processes

Process Selection

In order to make use of the non-traditional machining processes efficiently, it is necessary that the exact nature of the machining problem must be known. The points which should be looked into before the selection of these processes are;-

Physical parameters

Properties of the work material and the shape to be machined

Process capability or machining characteristics

Economic considerations

Parameters	ECM	EDM	EBM	LBM	PAM	USM	AJM
Potential, V	5 – 30	50 – 500	200 x 10^3	4.5 x 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	Electrolyte	Dielectric Fluid	Vacuum	Air	Argn 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	Hard and brittle materials

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

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L - 7

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **I** [Introduction] **Date of Lecture:**

Topic of Lecture: Brief overview of various techniques.

Introduction :

Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition.

Prerequisite knowledge for Complete understanding and learning of Topic

Basics of conventional machining processes

Shapes to be machined

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
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

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

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L - 8

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **I**[Introduction] **Date of Lecture:**

Topic of Lecture: Brief overview of various techniques.

Introduction :
Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition.

Prerequisite knowledge for Complete understanding and learning of Topic
Basics of conventional machining processes

Process capability

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

Video Content / Details of website for further learning:
www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

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L - 9

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **I** [Introduction] **Date of Lecture:**

Topic of Lecture: Brief overview of various techniques.

Introduction :

Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition.

Prerequisite knowledge for Complete understanding and learning of Topic

Basics of conventional machining processes

Process economy

Process	Capital Cost	Tooling and	Power requirement	Efficiency	Total Consumption
EDM	Medium	High	Low	High	High
CHM	Medium	Low	High	Medium	Very low
ECM	Very High	Medium	Medium	Low	Very Low
AJM	Very Low	Low	Low	High	Low
USM	High	High	Low	High	Medium
EBM	High	Low	Low	Very High	Very Low
LBM	Medium	Low	Very Low	Very High	Very Low
PAM	Very Low	Low	Very Low	Very Low	Very Low
Conventional Machining	Very low	Low	Low	Very Low	Low

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

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L - 10

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II** [Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: Abrasive Jet Machining –Working Principles , equipment used

Introduction :

- Abrasive Jet Machining (AJM), also known as micro-abrasive blasting, is a mechanical energy based unconventional machining process used to remove unwanted material from a given work piece.

Prerequisite knowledge for Complete understanding and learning of Topic

Abrasives
Metal cutting
Compressor
Nozzle

Detailed content of the Lecture:

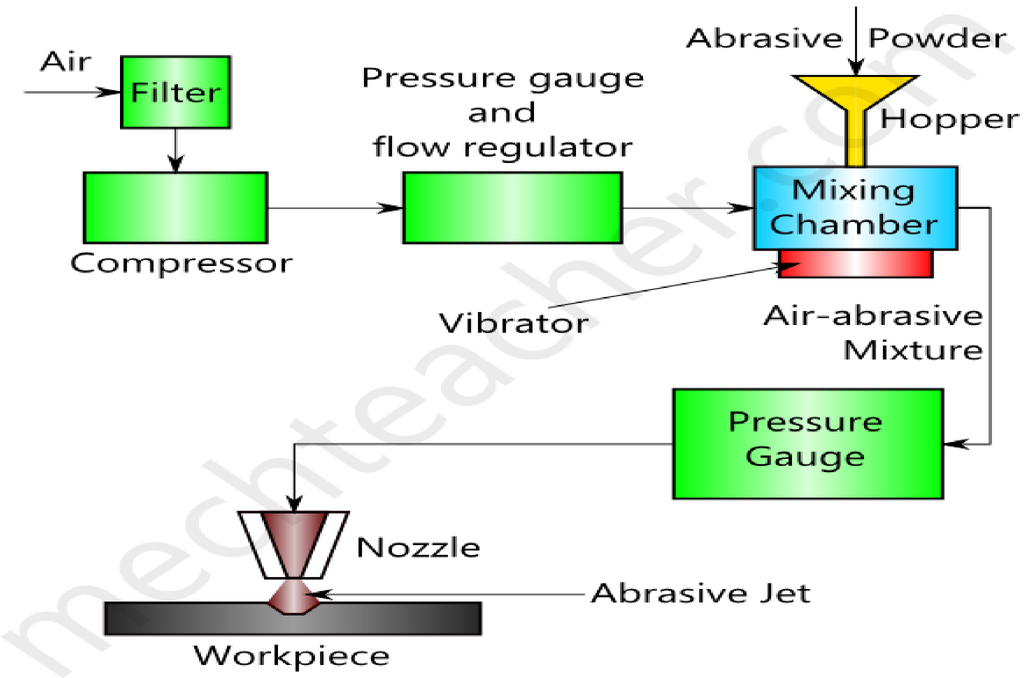
The working principle of abrasive jet machining process:

- Abrasive Jet Machining (AJM), also known as micro-abrasive blasting, 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. It is similar to Water Jet Machining (WJM).

Construction of Abrasive Jet Machining (AJM):

The constructional requirements of Abrasive Jet Machining (AJM) are listed and described below:

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 flow rate of abrasive jet.
7. **Vibrator:** It is provided below the mixing chamber. It controls the abrasive powder feed rate in the mixing chamber.
8. **Nozzle:** It forces the abrasive jet over the workpiece. Nozzle is made of hard and resistant material like tungsten carbide.



Working:

1. Dry air or gas is filtered and compressed by passing it through the filter and compressor.
2. A pressure gauge and a flow regulator are used to control the pressure and regulate the flow rate of the compressed air.
3. Compressed air is then passed into the mixing chamber. In the mixing chamber, abrasive powder is fed.
4. 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.
5. The nozzle increases the velocity of the mixture at the expense of its pressure. A fine abrasive jet is rendered by the nozzle. This jet is used to remove unwanted material from the workpiece.
6. For a good understanding of construction and working of AJM, refer the schematic diagram above.

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

1. Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 11

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LECTURE HANDOUTS

L - 11

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II** [Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: Process parameters – Material removal rate

Introduction :

In Abrasive Jet Machining (AJM), abrasive particles are made to impinge on the work material at a high velocity. The jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasive is generated by converting the pressure energy of the carrier gas or air to its kinetic energy and hence high velocity jet.

Prerequisite knowledge for Complete understanding and learning of Topic :

Abrasives
Pressure energy
Nozzle
Kinetic energy

Detailed content of the Lecture:

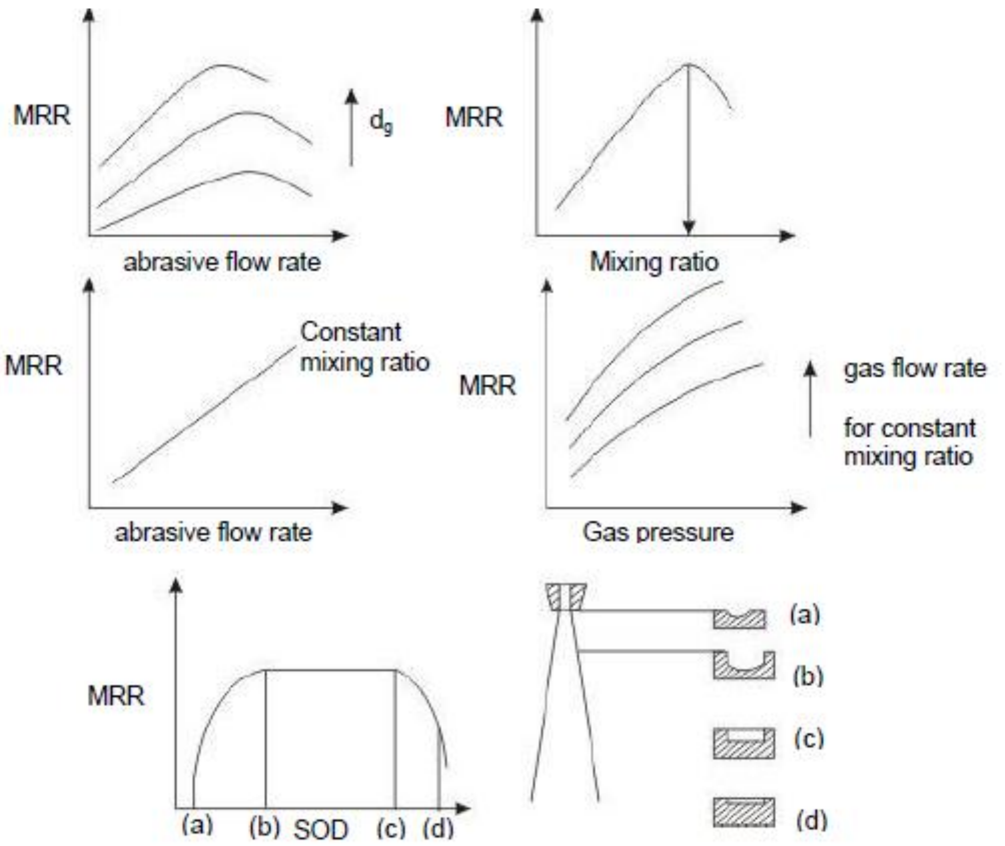
The process parameters are listed below:

- Abrasive
  - Material – Al_2O_3 / SiC / glass beads
  - Shape – irregular / spherical
  - Size – 10 ~ 50 μm
  - Mass flow rate – 2 ~ 20 gm/min
- Carrier gas
  - Composition – Air, CO_2, N_2
  - Density – Air ~ 1.3 kg/m^3
  - Velocity – 500 ~ 700 m/s
  - Pressure – 2 ~ 10 bar
  - Flow rate – 5 ~ 30 lpm
- Abrasive Jet
  - Velocity – 100 ~ 300 m/s
  - Mixing ratio – mass flow ratio of abrasive to gas
  - Stand-off distance – 0.5 ~ 5 mm
  - Impingement Angle – 60^0 ~ 90^0
- Nozzle
  - Material – WC / sapphire
  - Diameter – (Internal) 0.2 ~ 0.8 mm
  - Life – 10 ~ 300 hours

The important machining characteristics in AJM are

- The material removal rate (MRR) mm^3/min or gm/min
- The machining accuracy
- The life of the nozzle

Effect of process parameters on MRR



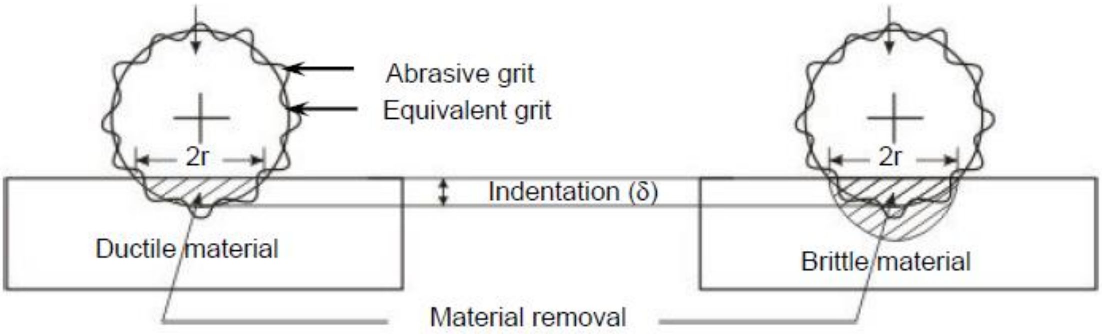
As mentioned earlier, material removal in AJM takes place due to brittle fracture of the work material due to impact of high velocity abrasive particles.

(i) Abrasives are spherical in shape and rigid. The particles are characterised by the mean grit diameter

(ii) The kinetic energy of the abrasives are fully utilised in removing material

(iii) Brittle materials are considered to fail due to brittle fracture and the fracture volume is considered to be hemispherical with diameter equal to chordal length of the indentation

(iv) For ductile material, removal volume is assumed to be equal to the indentation volume due to particulate impact



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L - 12

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II** [Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: Variation in techniques used- Applications.

Introduction : Water Jet Machining (WJM) and Abrasive Water Jet Machining (AWJM) are two non-traditional or non-conventional machining processes. They belong to mechanical group of non-conventional processes like Ultrasonic Machining (USM) and Abrasive Jet Machining (AJM). In these processes (WJM and AJWM), the mechanical energy of water and abrasive phases are used to achieve material removal or machining.

Prerequisite knowledge for Complete understanding and learning of Topic

Abrasives

Mechanical energy

Hydraulic energy

Material removal

Detailed content of the Lecture:

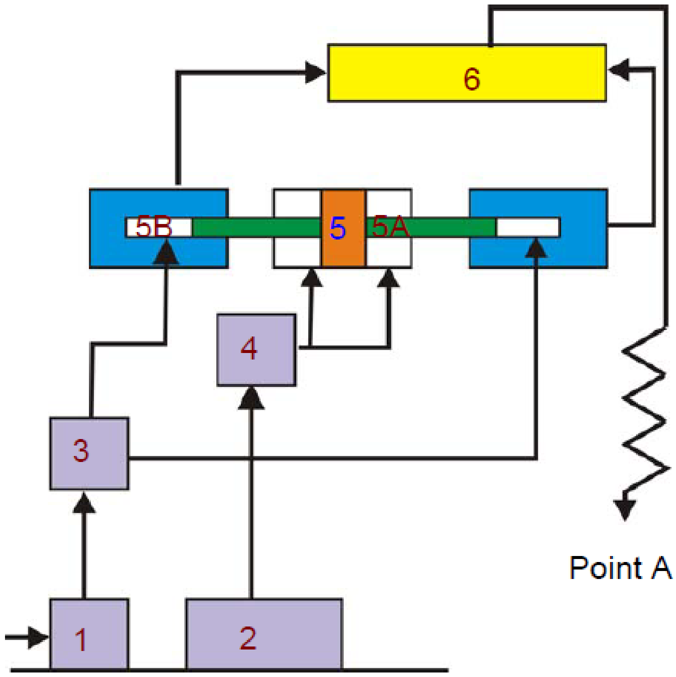
Schematic setup of Abrasive jet machining (AJM)

1. **LP Booster**
2. **Hydraulic drive**
3. **Additive mixer**
4. **Direction control**
5. **Intensifier**

5A. LP Intensifier

5B. HP Intensifier

6. **Accumulator**



WJM and AWJM can be achieved using different approaches and methodologies as enumerated below: • WJM - Pure

• WJM - with stabilizer

- AWJM – entrained – three phase – abrasive, water and air
- AWJM – suspended – two phase – abrasive and water
  - Direct pumping
  - o Indirect pumping
  - o Bypass pumping

The applications and materials, which are generally machined using WJM and AWJM, are given below:

Application

- Paint removal
- Cleaning
- Cutting soft materials
- Cutting frozen meat
- Textile, Leather industry
- Mass Immunization
- Surgery
- Peening
- Cutting
- Pocket Milling
- Drilling
- Turning
- Nuclear Plant Dismantling

Materials

- Steels
- Non-ferrous alloys
- Ti alloys, Ni- alloys
- Polymers
- Honeycombs
- Metal Matrix Composite
- Ceramic Matrix Composite
- Concrete
- Stone – Granite
- Wood
- Reinforced plastics
- Metal Polymer Laminates
- Glass Fibre Metal Laminates

Applications of AJM

- For drilling holes of intricate shapes in hard and brittle materials
- For machining fragile, brittle and heat sensitive materials
- AJM can be used for drilling, cutting, deburring, cleaning and etching.
- Micro-machining of brittle materials

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 13,14,

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LECTURE HANDOUTS

L - 13

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II**[Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: Water Jet Machining –Working Principles equipment used

Introduction :

Water Jet Machining (WJM) and Abrasive Water Jet Machining (AWJM) are two non-traditional or non-conventional machining processes. They belong to mechanical group of non-conventional processes like Ultrasonic Machining (USM) and Abrasive Jet Machining (AJM). In these processes (WJM and AJWM), the mechanical energy of water and abrasive phases are used to achieve material removal or machining.

Prerequisite knowledge for Complete understanding and learning of Topic

Abrasives

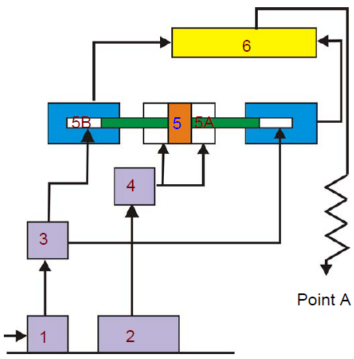
Detailed content of the Lecture:

Any standard abrasive water jet machining (AWJM) system using entrained AWJM methodology consists of following modules

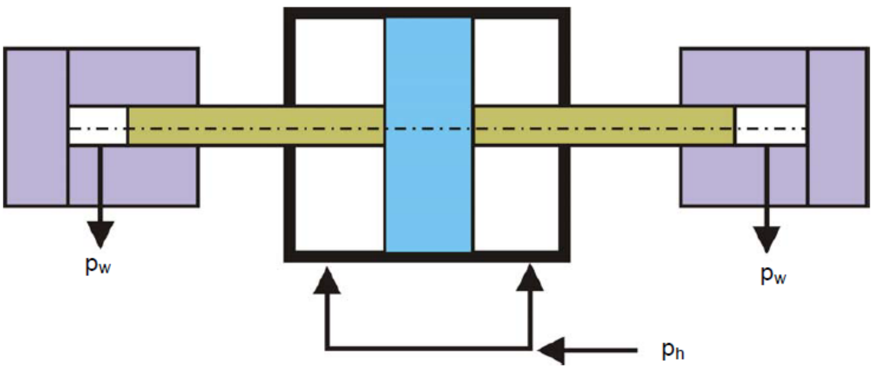
- LP booster pump
- Hydraulic unit
- Additive Mixer
- Intensifier
- Accumulator
- Flexible high pressure transmission line
- On-off valve
- Orifice
- Mixing Chamber
- Focussing tube or inserts
- Catcher
- CNC table
- Abrasive metering device
- Catcher

1. LP Booster
2. Hydraulic drive
3. Additive mixer
4. Direction control
5. Intensifier

5A. LP Intensifier
5B. HP Intensifier
6. Accumulator

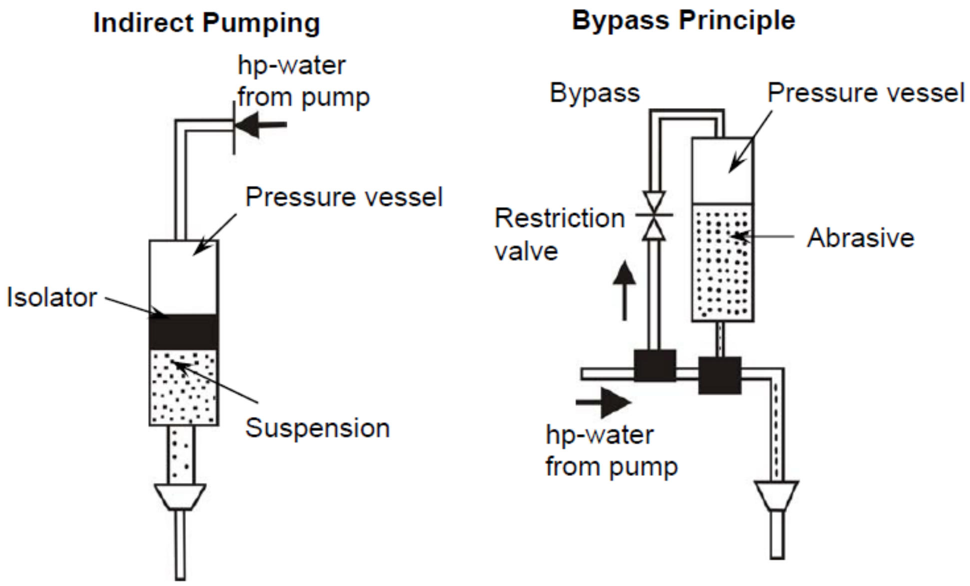


Intensifier, shown in Fig.is driven by a hydraulic power pack. The heart of the hydraulic power pack is a positive displacement hydraulic pump. The power packs in modern commercial systems are often controlled by microcomputers to achieve programmed rise of pressure etc.



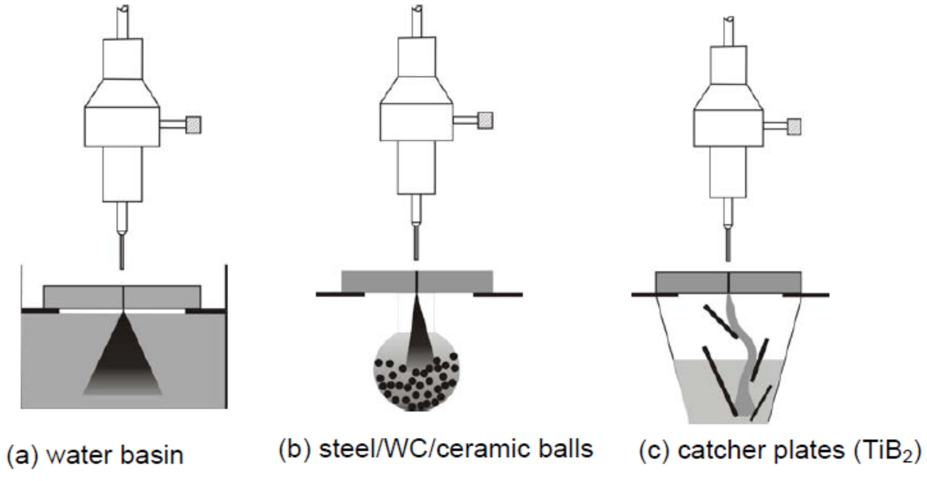
Suspension Jet

In entrained AWJM, the abrasive water jet, which finally comes from the focussing tube or nozzle, can be used to machine different materials. In suspension AWJM the abrasive water jet is formed quite differently. There are three different types of suspension AWJ formed by direct, indirect and Bypass pumping method .Fig. shows the working principle of indirect and Bypass pumping system of suspension AWJM system.



Catcher

Once the abrasive jet has been used for machining, they may have sufficiently high level of energy depending on the type of application. Such high-energy abrasive water jet needs to be contained before they can damage any part of the machine or operators. "Catcher" is used to absorb the residual energy of the AWJ and dissipate the same. Fig. 9 shows three different types of catcher – water basin type, submerged steel balls and TiB_2 plate type.



Video Content / Details of website for further learning:
www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:
Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007 P.No:202

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LECTURE HANDOUTS

L - 14

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II**[Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: Process parameters – Material removal rate

Introduction :

Water Jet Machining (WJM) and Abrasive Water Jet Machining (AWJM) are two non-traditional or non-conventional machining processes. They belong to mechanical group of non-conventional processes like Ultrasonic Machining (USM) and Abrasive Jet Machining (AJM). In these processes (WJM and AJWM), the mechanical energy of water and abrasive phases are used to achieve material removal or machining.

Prerequisite knowledge for Complete understanding and learning of Topic

Abrasives

Mechanism of material removal

The general domain of parameters in entrained type AWJ machining system is given below:

- Orifice – Sapphires – 0.1 to 0.3 mm
- Focussing Tube – WC – 0.8 to 2.4 mm
- Pressure – 2500 to 4000 bar
- Abrasive – garnet and olivine - #125 to #60
- Abrasive flow - 0.1 to 1.0 Kg/min
- Stand off distance – 1 to 2 mm
- Machine Impact Angle – 60^o to 90^0
- Traverse Speed – 100 mm/min to 5 m/min
- Depth of Cut – 1 mm to 250 mm

Mechanism of material removal in machining with water jet and abrasive water jet is rather complex.

In AWJM of ductile materials, material is mainly removed by low angle impact by abrasive particles leading to ploughing and micro cutting.

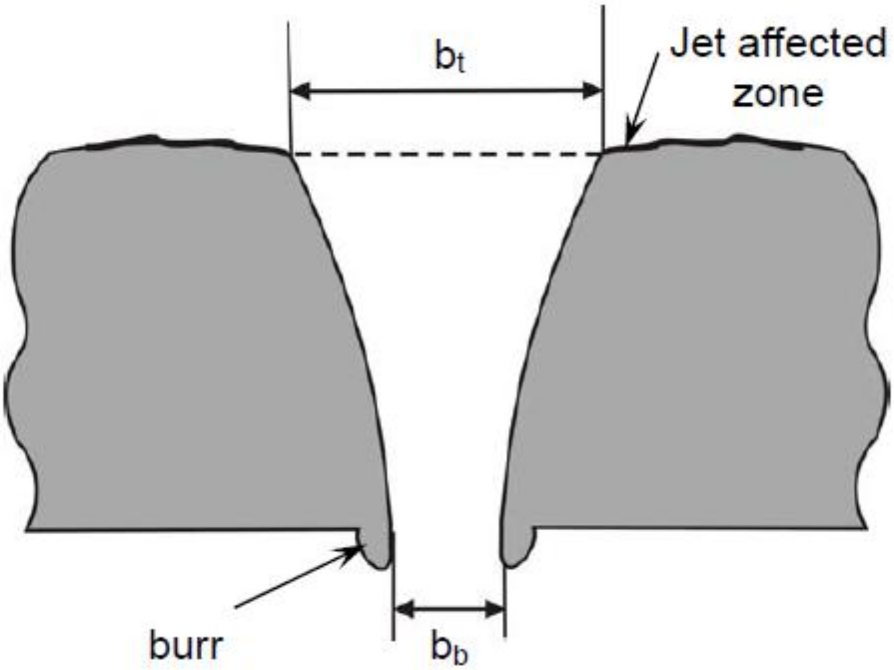
In case of AWJM of brittle materials, other than the above two models, material would be removed due to crack initiation and propagation because of brittle failure of the material.

In water jet machining, the material removal rate may be assumed to be proportional to the power of the water jet

$$MRR \propto P_{wj} \propto c_d \times \frac{\Pi}{4} d_o^{\,2} \times \sqrt{\frac{2p_w^{\,3}}{\rho_w}}$$

$$MRR = u \times c_d \times \frac{\Pi}{4} d_o^{\,2} \times \sqrt{\frac{2p_w^{\,3}}{\rho_w}}$$

In WJM and AWJM the following are the important product quality parameters.
• striation formation
• surface finish of the kerf
• tapering of the kerf
• burr formation on the exit side of the kerf



Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:
Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007 P.No:2

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L - 15

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II**[Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: Water Jet Machining – Variation in techniques used- Applications.

Introduction :

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 work piece.

Prerequisite knowledge for Complete understanding and learning of Topic

- Properties of kinetic energy of water particles.
- Functions of nozzle.

Detailed content of the Lecture:

The applications and materials, which are generally machined using WJ and AWJ, are given below:
Application

- Paint removal
- Cleaning
- Cutting soft materials
- Cutting frozen meat
- Textile, Leather industry
- Mass Immunization
- Surgery
- Peening
- Cutting
- Pocket Milling
- Drilling
- Turning
- Nuclear Plant Dismantling

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

1. Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 96

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LECTURE HANDOUTS

L - 16

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II** [Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: Ultrasonic Machining –Working Principles equipment used

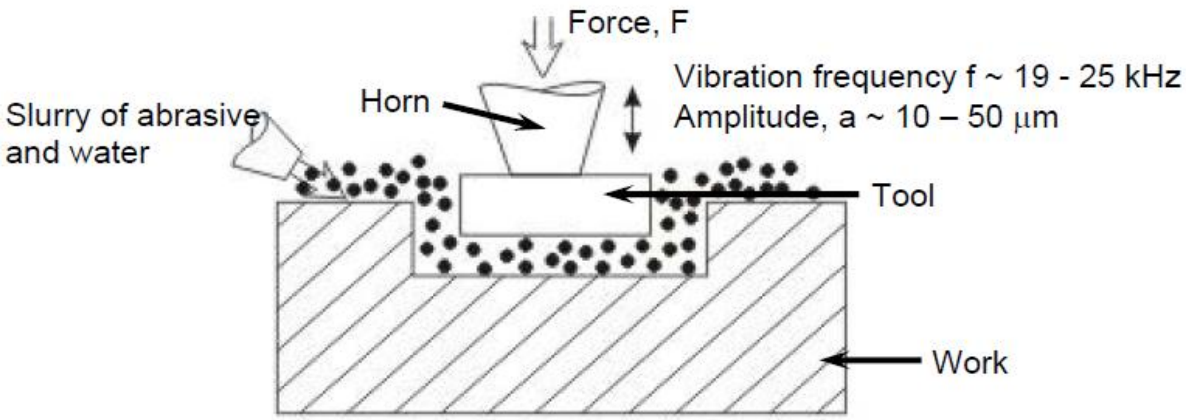
Introduction :

Ultrasonic machining (USM) is one of the non-traditional machining process. Working principle of this process resembles with conventional and metal cutting as in this process abrasives contained in a slurry are driven at high velocity against the workpiece by a tool vibrating at low amplitude and high frequency.

Prerequisite knowledge for Complete understanding and learning of Topic

- Ultrasonic waves
- Vibration
- Abrasive slurry

Detailed content of the Lecture:



Working principle of this process resembles with conventional and metal cutting as in this process abrasives contained in a slurry are driven at high velocity against the workpiece by a tool vibrating at low amplitude and high frequency.

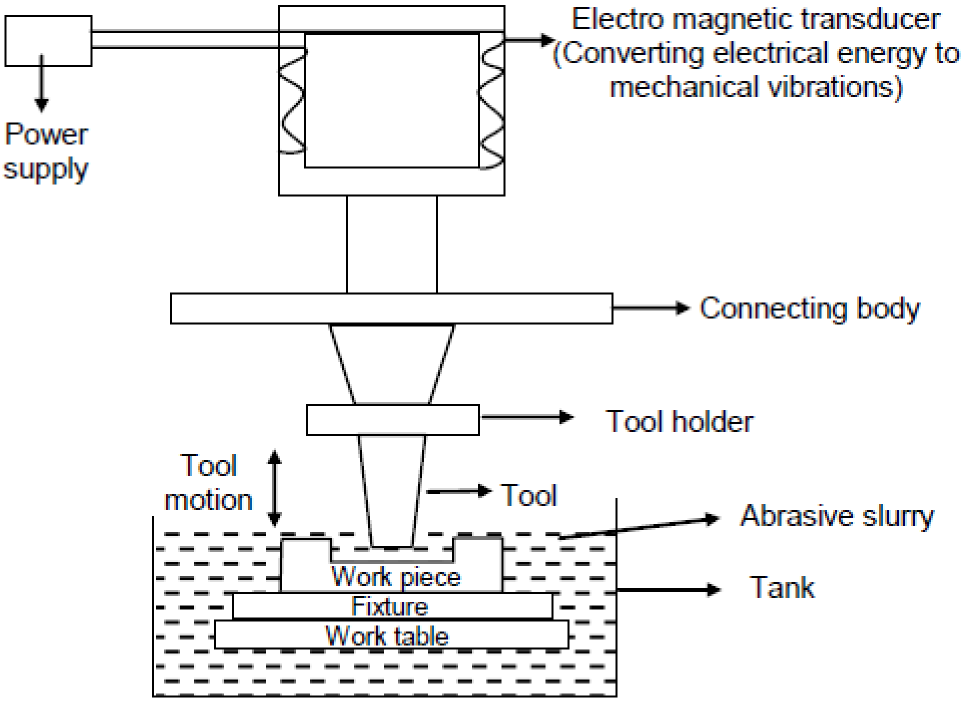
Amplitude is kept of the order of 0.07 mm and frequency is maintained at approximately 20,000 Hz.

The workpiece material is removed in the form of extremely small chips.

Normally very hard particle dust is included in the slurry like, Al_2O_2, silicon carbide, boron carbide or diamond dust.

Working principle of USM is same as that of conventional machining that is material of workpiece is removed by continuous abrasive action of hard particles vibrating in the slurry.

Abrasive slurry acts as a multipoint cutting tool and does the similar action as done by a cutting edge.



Abrasive Slurry

Abrasive slurry consists of dust of very hard particles. It is filled into the machining zone. Abrasive slurry can be recycled with the help of pump.

Workpiece

Workpiece of hard and brittle material can be machined by USM.

Workpiece is clamped on the fixture I the setup.

Cutting Tool

Tool of USM does not do the cutting directly but it vibrates with small amplitude and high frequency.

So it is suitable to name the tool as vibrating tool rather than cutting tool.

The tool is made of relatively soft material and used to vibrate abrasive slurry to cut the workpiece material.

The tool is attached to the arbor (tool holder) by brazing or mechanical means.

Sometimes hollow tools are also used which feed the slurry focusing machining zone.

Ultrasonic Oscillator

This operation uses high frequency electric current which passes to an ultrasonic oscillator and ultrasonic transducer.

The function of the transducer is to convert electric energy into mechanical energy developing vibrations into the tool.

Feed Mechanism

Tool is fed to the machining zone of workpiece.

The tool is shaped as same to the cavity of be produced into the workpiece.

The tool is fed to the machining area.

The feed rate is maintained equal to the rate of enlargement of the cavity to be produced.

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007 P.No:24

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LECTURE HANDOUTS

L - 17

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II** [Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: Ultrasonic Machining - Process parameters – Material removal rate

Introduction :
USM is mechanical material removal process or an abrasive process used to erode holes or cavities on hard or brittle work piece by using shaped tools, high frequency mechanical motion and an abrasive slurry

Prerequisite knowledge for Complete understanding and learning of Topic

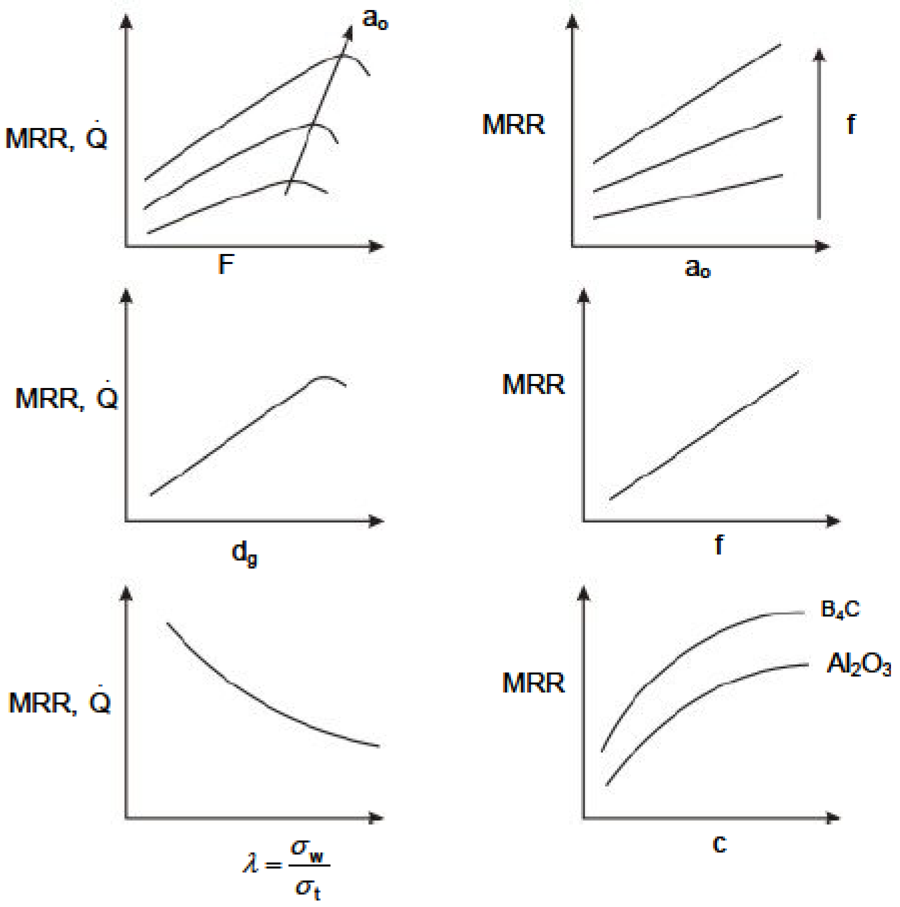
Ultrasonic waves
Vibration
Abrasive slurry

Detailed content of the Lecture:

Process Parameters and their Effects.

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 (a_o) – 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 – Al_2O_3
  - SiC
  - B_4C
  - Boronsilicarbide
  - Diamond
- Flow strength of work material
- Flow strength of the tool material
- Contact area of the tool – A
- Volume concentration of abrasive in water slurry – C



- USM is generally used for machining brittle work material.
- Material removal primarily occurs due to the indentation of the hard abrasive grits on the brittle work material.
- As the tool vibrates, it leads to indentation of the abrasive grits.
- During indentation, due to Hertzian contact stresses, cracks would develop just below the contact site, then as indentation progresses the cracks would propagate due to increase in stress and ultimately lead to brittle fracture of the work material
- under each individual interaction site between the abrasive grits and the workpiece.
- The tool material should be such that indentation by the abrasive grits does not lead to brittle failure. Thus the tools are made of tough, strong and ductile materials like steel, stainless steel and other ductile metallic alloys.

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

1. Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. page No: 31

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L - 18

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **II** [Mechanical energy based processes] **Date of Lecture:**

Topic of Lecture: USM- Variation in techniques used- Applications
Introduction : USM is mechanical material removal process or an abrasive process used to erode holes or cavities on hard or brittle work piece by using shaped tools, high frequency mechanical motion and an abrasive slurry.
Prerequisite knowledge for Complete understanding and learning of Topic Ultrasonic waves Vibration Abrasive slurry

Applications

- Used for machining hard and brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.
- Used for machining round, square, irregular shaped holes and surface impressions.
- Machining, wire drawing, punching or small blanking dies.
- This process is generally applied for the machining of hard and brittle materials like carbides glass, ceramics, precious stones, titanium, etc.
- It is used for tool making and punch and die making.
- The workpeice material is normally removed in the form of very find chips so generated surface quality is extremely good.
- It is widely used for several machining operations like turning, grinding, trepanning and milling, etc.
- It can make hole of round shape and other shapes.

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning: Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 42

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LECTURE HANDOUTS

L - 19

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III** [Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: Electric Discharge Machining- working Principle-equipment

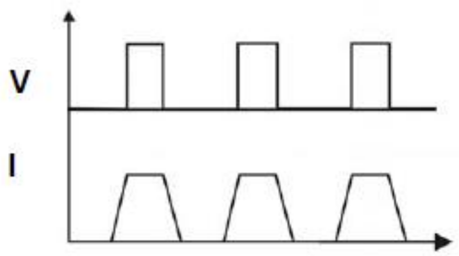
Introduction :

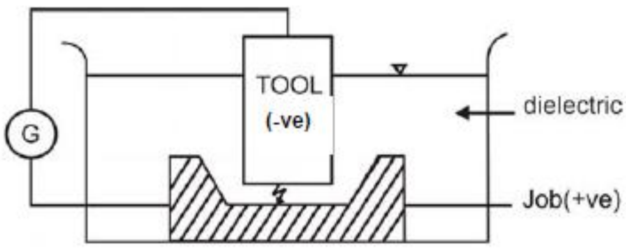
Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive.

Prerequisite knowledge for Complete understanding and learning of Topic

Thermal energy
Hardness of materials
Spark erosion
Electrical conductivity

Detailed content of the Lecture:





In EDM, a potential difference is applied between the tool and workpiece.
Both the tool and the work material are to be conductors of electricity.
The tool and the work material are immersed in a dielectric medium.
Generally kerosene or deionised water is used as the dielectric medium.
A gap is maintained between the tool and the workpiece.
Depending upon the applied potential difference and the gap between the tool and workpiece, an electric field would be established.
Generally the tool is connected to the negative terminal of the generator and the workpiece is connected to positive terminal.
As the electric field is established between the tool and the job, the free electrons on the tool are subjected to electrostatic forces.
If the work function or the bonding energy of the electrons is less, electrons would be emitted from the tool (assuming it to be connected to the negative terminal).
Such emission of electrons are called or termed as cold emission.
The "cold emitted" electrons are then accelerated towards the job through the dielectric medium.
As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons and dielectric molecules.

Such collision may result in ionisation of the dielectric molecule depending upon the work function or ionisation energy of the dielectric molecule and the energy of the electron.
Thus, as the electrons get accelerated, more positive ions and electrons would get generated due to collisions.
This cyclic process would increase the concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap.
The concentration would be so high that the matter existing in that channel could be characterised as "plasma".
The electrical resistance of such plasma channel would be very less.
Thus all of a sudden, a large number of electrons will flow from the tool to the job and ions from the job to the tool. This is called avalanche motion of electrons.
Such movement of electrons and ions can be visually seen as a spark. Thus the electrical energy is dissipated as the thermal energy of the spark.
The high speed electrons then impinge on the job and ions on the tool.
The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux.
Such intense localised heat flux leads to extreme instantaneous confined rise in temperature which would be in excess of $10,000^{o}$C.
Such localised extreme rise in temperature leads to material removal.
Material removal occurs due to instant vapourisation of the material as well as due to melting.
The molten metal is not removed completely but only partially.
As the potential difference is withdrawn as shown in Fig. 1, the plasma channel is no longer sustained.
As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark.
Thus to summarise, the material removal in EDM mainly occurs due to formation of shock waves as the plasma channel collapse owing to discontinuation of applied potential difference.
Generally the workpiece is made positive and the tool negative.
Hence, the electrons strike the job leading to crater formation due to high temperature and melting and material removal. Similarly, the positive ions impinge on the tool leading to tool wear.
In EDM, the generator is used to apply voltage pulses between the tool and the job.
A constant voltage is not applied. Only sparking is desired in EDM rather than arcing.
Arcing leads to localised material removal at a particular point whereas sparks get distributed all over the tool surface leading to uniformly distributed material removal under the tool.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=2W4xZYRkWGo

Important Books/Journals for further learning including the page nos.:
Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 130

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LECTURE HANDOUTS

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MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III** [Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: EDM Process parameters

Introduction :

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.

Prerequisite knowledge for Complete understanding and learning of Topic

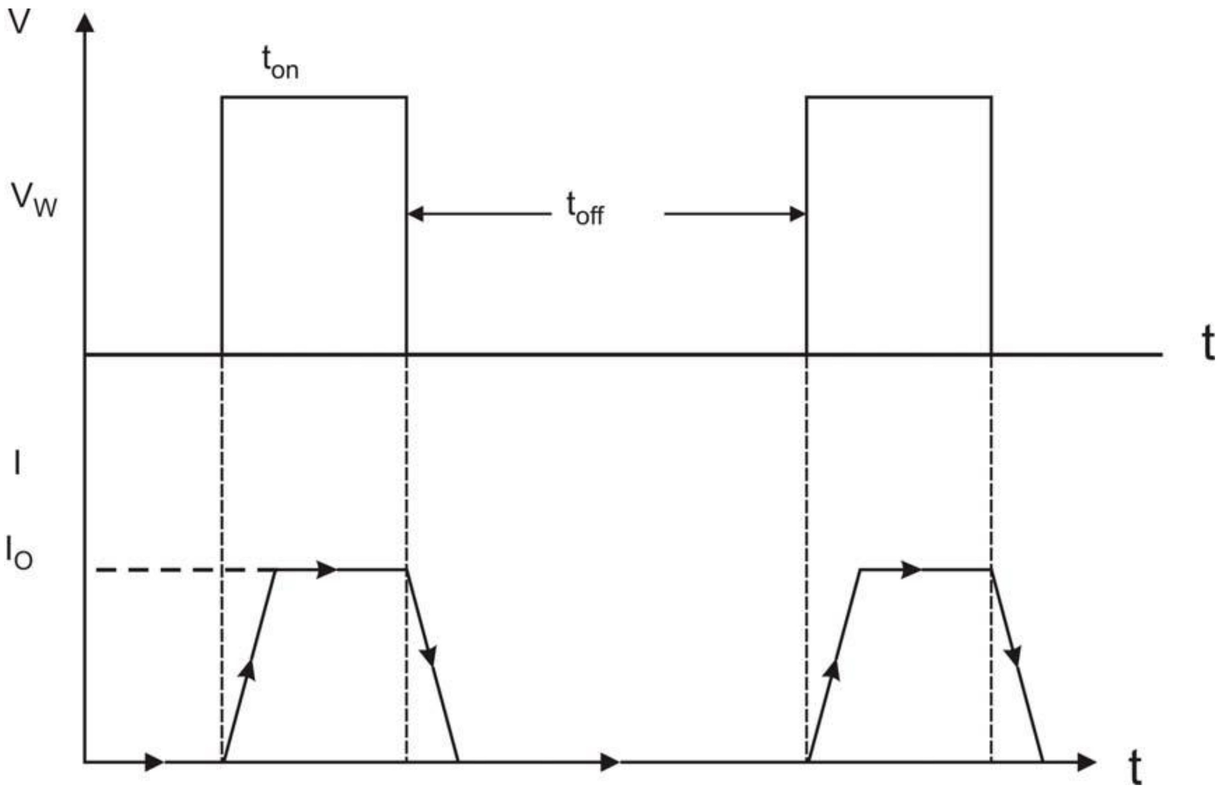
Machining processes
Electrolysis
Thermal energy
Spark erosion

Detailed content of the Lecture:

Process Parameters

The process parameters in EDM are mainly related to the waveform characteristics.

Fig.shows a general waveform used in EDM.



The waveform is characterised by the

- The open circuit voltage - V_o
- The working voltage - V_w
- The maximum current - I_o
- The pulse on time – the duration for which the voltage pulse is applied - t_{on}
- The pulse off time - t_{off}
- The gap between the workpiece and the tool – spark gap - δ
- The polarity – straight polarity – tool (-ve)
- The dielectric medium
- External flushing through the spark gap.

Characteristics of EDM

(a) The process can be used to machine any work material if it is electrically conductive

(b) Material removal depends on mainly thermal properties of the work material rather than its strength, hardness etc

(c) In EDM there is a physical tool and geometry of the tool is the positive impression of the hole or geometric feature machined

(d) The tool has to be electrically conductive as well. The tool wear once again depends on the thermal properties of the tool material

(e) Though the local temperature rise is rather high, still due to very small pulse on time, there is not enough time for the heat to diffuse and thus almost no increase in bulk temperature takes place. Thus the heat affected zone is limited to 2 – 4 μm of the spark crater

(f) However rapid heating and cooling and local high temperature leads to surface hardening which may be desirable in some applications

(g) Though there is a possibility of taper cut and overcut in EDM, they can be controlled and compensated.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=aWQsEX1TrSI

Important Books/Journals for further learning including the page nos.:
Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 160

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LECTURE HANDOUTS

L -21

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III** [Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: Material removal rate in EDM

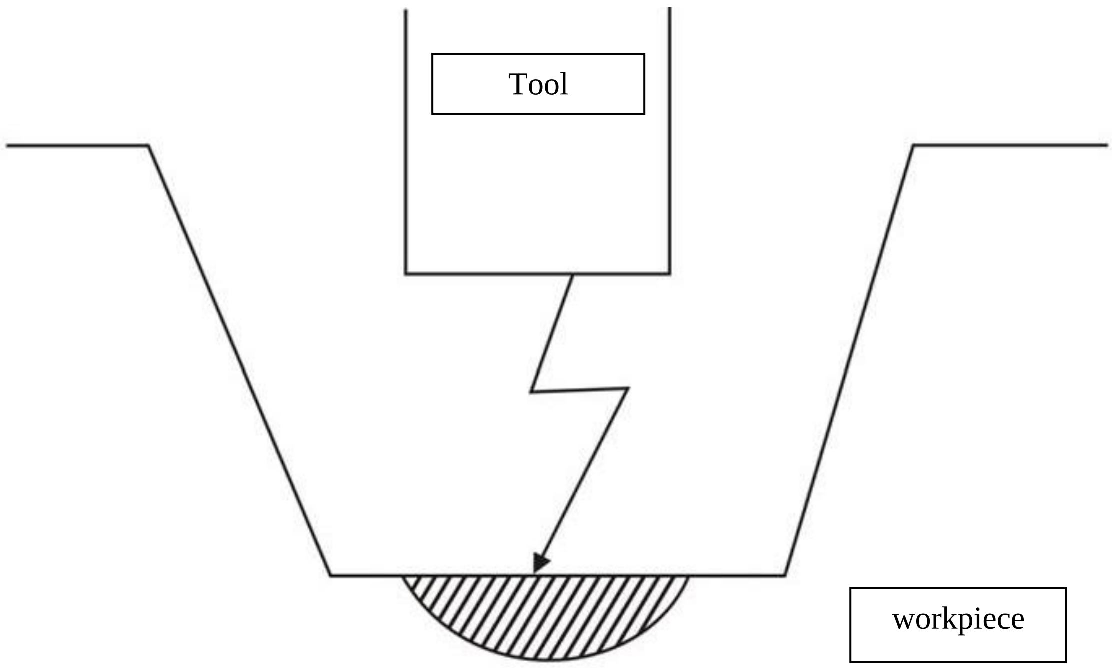
Introduction :

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology
Machining processes
Electrolysis
Thermal energy
Spark erosion

Detailed content of the Lecture:

Material removal in EDM mainly occurs due to intense localised heating almost by point heat source for a rather small time frame. Such heating leads to melting and crater formation as shown in Fig.



The molten crater can be assumed to be hemispherical in nature with a radius r which forms due to a single pulse or spark. Hence material removal in a single spark can be expressed as

$$\Gamma_s = \frac{2}{3}\pi r^3$$

Now as per Fig. 2, the energy content of a single spark is given as

$$E_s = VIt_{on}$$

A part of this spark energy gets lost in heating the dielectric, and rest is distributed between the impinging electrons and ions. Thus the energy available as heat at the workpiece is given by

$$E_w \quad \alpha \quad E_s$$

$$E_w = kE_s$$

Now it can be logically assumed that material removal in a single spark would be proportional to the spark energy. Thus

$$\Gamma_s \quad \alpha \quad E_s \quad \alpha \quad E_w$$

$$\therefore \quad \Gamma_s = gE_s$$

Now material removal rate is the ratio of material removed in a single spark to cycle time.

Thus

$$MRR = \frac{\Gamma_s}{t_c} = \frac{\Gamma_s}{t_{on} + t_{off}}$$

$$MRR = g\frac{VIt_{on}}{t_{on} + t_{off}} = g\frac{VI}{\left(1 + \frac{t_{off}}{t_{on}}\right)}$$

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=aWQsEX1TrSI

Important Books/Journals for further learning including the page nos.:
Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 169

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LECTURE HANDOUTS

L - 22

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III** [Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: EDM –Electrode/Tool

Introduction :

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.

Prerequisite knowledge for Complete understanding and learning of Topic

Machining processes
Electrolysis
Thermal energy
Spark erosion

Detailed content of the Lecture:

Electrode material should be such that it would not undergo much tool wear when it is impinged by positive ions. Thus the localised temperature rise has to be less by tailoring or properly choosing its properties or even when temperature increases, there would be less melting. Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM. Thus the basic characteristics of electrode materials are:

- High electrical conductivity – electrons are cold emitted more easily
- High thermal conductivity – for the same heat load, the local temperature rise would be less
- Higher density – for the same heat load / tool wear by weight there would be less volume removal
- High melting point – leads to less tool wear due to less tool material melting for the same heat load
- Easy manufacturability
- Cost – cheap

The followings are the different electrode materials which are used commonly in the industry:

- Graphite
- Electrolytic oxygen free copper
- Tellurium copper – 99% Cu + 0.5% tellurium
- Brass

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=aWQsEX1TrSI

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L - 23

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III**[Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: EDM –Power circuits

Introduction :

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.

Prerequisite knowledge for Complete understanding and learning of Topic

Machining processes

Electrolysis

Thermal energy

Spark erosion

Detailed content of the Lecture:

1. Several basically different electric circuits are available to provide the pulsating dc across the work-tool gap.
2. Though the operational characteristics are different, in almost all such circuits a capacitor is used for storing the electric charge before the discharge takes place across the gap.
3. The suitability of a circuit depends on the machining conditions and requirements.
4. **The commonly-used principles for supplying the pulsating dc can be classified into the following three groups:**

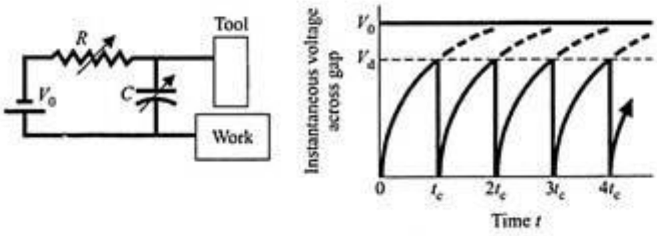
(i) Resistance-capacitance relaxation circuit with a constant dc source.

(ii) Rotary impulse generator.

(iii) Controlled pulse circuit.

(i) Resistance-Capacitance Relaxation Circuit:

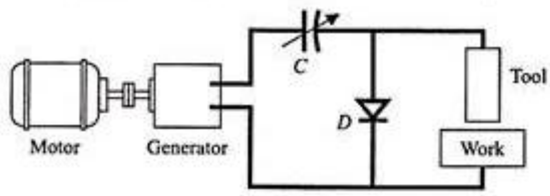
The resistance-capacitance relaxation circuit was used when the electric discharge machines were first developed. The capacitor C (which can be varied) is charged through a variable resistance R by the dc source of voltage V_0.



(a) Relaxation circuit (b) Variation of gap voltage

(ii) Rotary Impulse Generator:

For increasing the removal rate, an impulse generator is used for spark generation. The capacitor is charged through the diode during the first half cycle. During the following half cycle, the sum of the voltages generated by the generator and the charged capacitor is applied to the work-tool gap.



(iii) Controlled Pulse Circuits:

In the two systems we have discussed, there is no provision for an automatic prevention of the current flow when a short circuit is developed. To achieve such an automatic control, a vacuum tube (or a transistor) is used as the switching device. This system is known as a controlled pulse circuit. Figure 6.60 schematically shows such a system. During sparking, the current which flows through the gap comes from the capacitor.

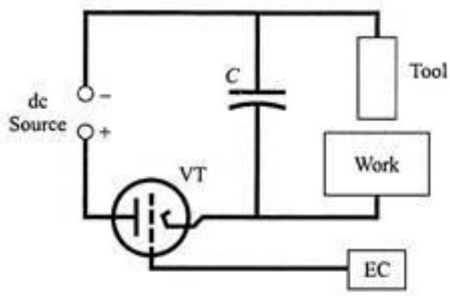


Fig. 6.60 EDM with controlled pulse circuit.

Video Content / Details of website for further learning (if any):

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L -24

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III** [Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: EDM – Tool wear

Introduction : Electrode material should be such that it would not undergo much tool wear when it is impinged by positive ions.Thus the localised temperature rise has to be less by properly choosing its properties or even when temperature increases, there would be less melting.Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM.

Prerequisite knowledge for Complete understanding and learning of Topic

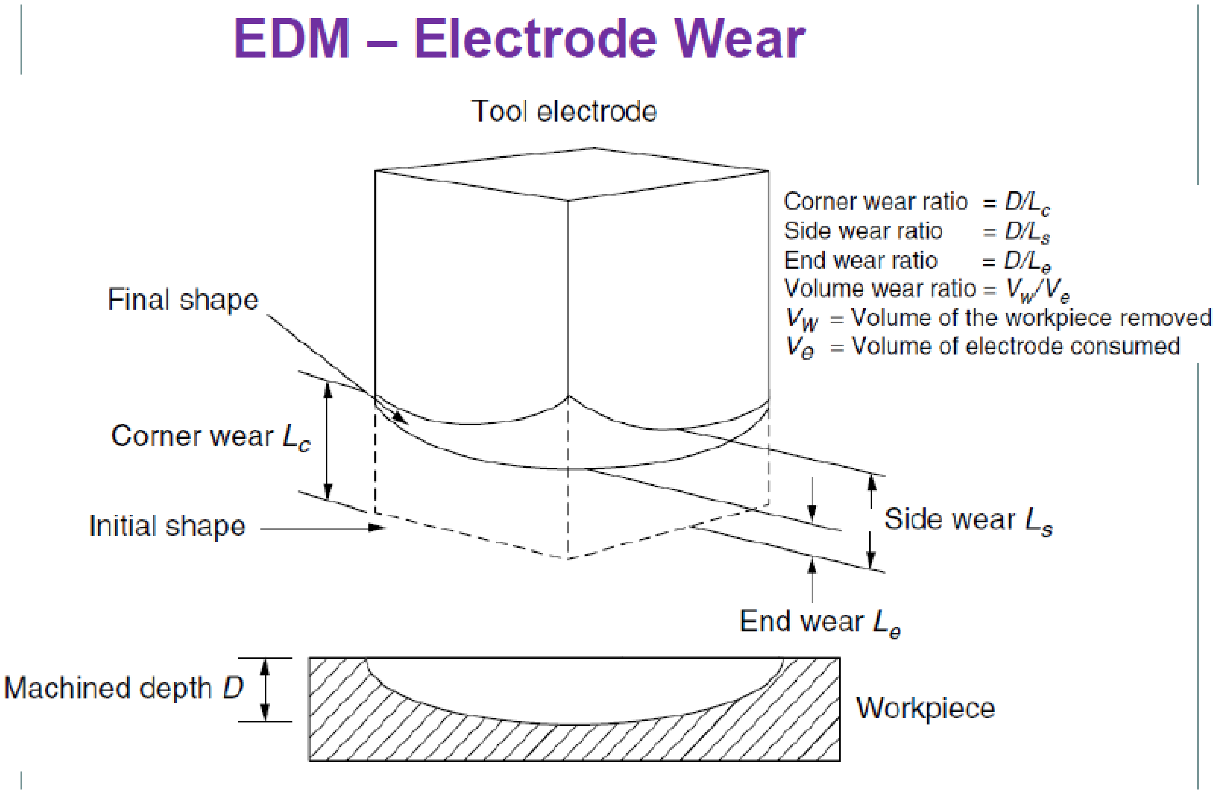
Electrical conductivity

Thermal conductivity

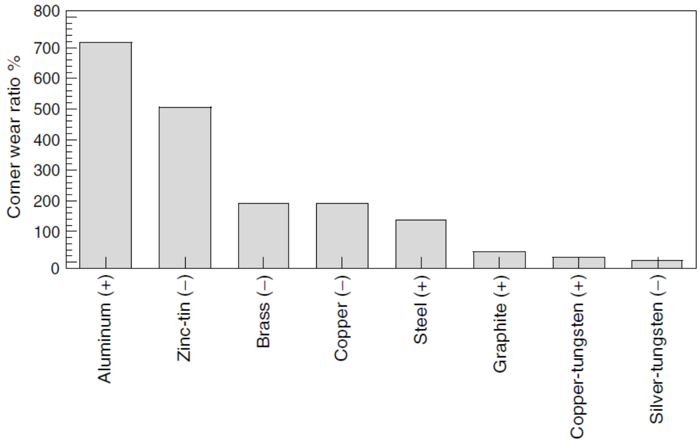
Melting point

Density

Detailed content of the Lecture:



The melting point is the most important factor in determining the tool wear.
 Electrode wear ratios are expressed as end wear, side wear, corner wear, and volume wear.
 "No wear EDM" - when the electrode-to-workpiece wear ratio is 1 % or less.
 Electrode wear depends on a number of factors associated with the EDM, like voltage, current, electrode material, and polarity.
 The change in shape of the tool electrode due to the electrode wear causes defects in the workpiece shape.
 Electrode wear has even more pronounced effects when it comes to micromachining applications.
 The corner wear ratio depends on the type of electrode.
 The low melting point of aluminum is associated with the highest wear ratio.



Graphite has shown a low tendency to wear and has the possibility of being molded or machined into complicated electrode shapes. The wear rate of the electrode tool material (Wt) and the wear ratio (Rw) are given by Kalpakjian (1997).

$$W_t = (11 \times 10^3) i T_t^{-2.38}$$

$$R_w = 2.25\ T_r^{-2.3}$$

where W_t = wear rate of the tool, mm^3/min
i = EDM current, A
T_t = melting point of the tool electrode, °C
T_r = ratio of the workpiece to tool electrode melting points

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

1. Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 11

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L - 25

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III** [Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: Dielectric – flushing .

Introduction :

Removing the microscopic particles made during the wire EDM cutting process becomes a key factor in maximizing cutting speed as well as attaining part accuracy and surface finish. Dielectric fluid is the mechanism for flushing these "chips" away.

Prerequisite knowledge for Complete understanding and learning of Topic

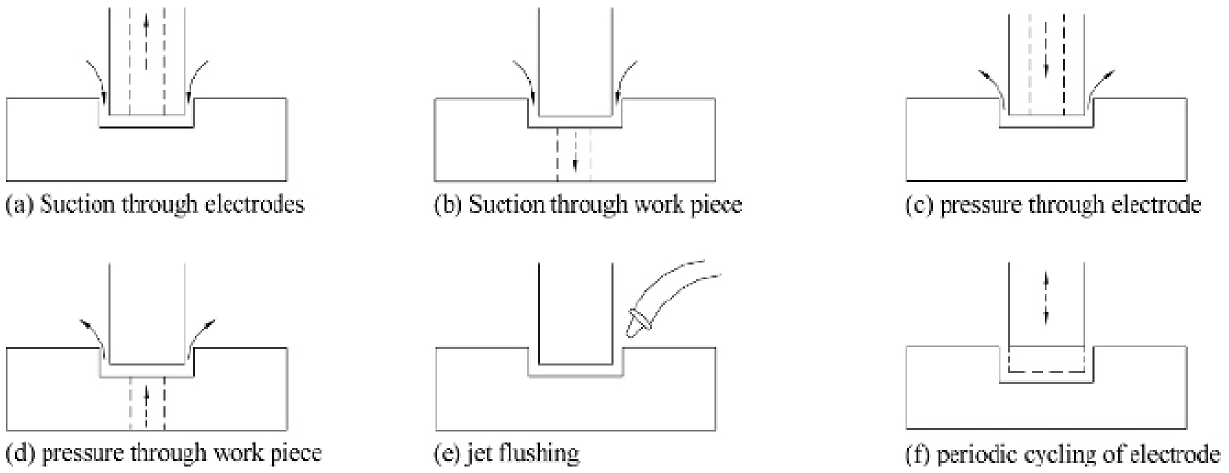
Metal cutting
Tool gap
Coolant
Surface finish

Detailed content of the Lecture:

1. In EDM, material removal mainly occurs due to thermal evaporation and melting.
2. As thermal processing is required to be carried out in absence of oxygen so that the process can be controlled and oxidation avoided.
3. Oxidation often leads to poor surface conductivity (electrical) of the workpiece hindering further machining.
4. Hence, dielectric fluid should provide an oxygen free machining environment.
5. Further it should have enough strong dielectric resistance so that it does not breakdown electrically too easily.
6. But at the same time, it should ionize when electrons collide with its molecule.
7. Moreover, during sparking it should be thermally resistant as well.
8. Generally kerosene and deionised water is used as dielectric fluid in EDM
9. Tap water cannot be used as it ionises too early and thus breakdown due to presence of salts as impurities occur.
10. Dielectric medium is generally flushed around the spark zone.
11. It is also applied through the tool to achieve efficient removal of molten material.
12. Three important functions of a dielectric medium in EDM:
    - Insulates the gap between the tool and work, thus preventing a spark to form .
    - Cools the electrode, workpiece and solidifies the molten metal particles.
    - Flushes the metal particles out of the working gap to maintain ideal cutting conditions.
13. It must be filtered and circulated at constant pressure.
14. The main requirements of the EDM dielectric fluids are adequate viscosity,high flash point, good oxidation stability, minimum odor, low cost, and good electrical discharge efficiency.
15. For most operations kerosene is used with certain additives that prevent gas bubbles and de-odoring.
16. Silicon fluids and a mixture of these fluids with petroleum oils have given excellent results.
17. Other dielectric fluids with a varying degree of success include aqueous solutions of ethylene glycol, water in emulsions, and distilled water.

EDM – Flushing

- One of the important factors in EDM operation is the removal of chips from the working gap.
- Flushing these particles prevent them from forming bridges that cause short circuits.
- Flushing – process of introducing clean filtered dielectric fluid into spark gap.
- If flushing is applied incorrectly, it can result in erratic cutting and poor machining conditions.
- Flushing of dielectric plays a major role in the maintenance of stable machining .
- Inadequate flushing can result in arcing, decreased electrode life, and increased production time.



Normal flow (Majority)

- Dielectric is introduced, under pressure, through one or more passages in the tool and is forced to flow through the gap between tool and work.
- Flushing holes are generally placed in areas where the cuts are deepest.
- Normal flow is sometimes undesirable because it produces a tapered opening in the workpiece.

Reverse flow

- Particularly useful in machining deep cavity dies.
- The gap is submerged in filtered dielectric.
- With clean fluid flowing between the workpiece and the tool, there is no side sparking.

Jet flushing

- Desired machining can be achieved by using a jet of fluid directed against the machining gap.
- Machining time is always longer with jet flushing than with the normal and reverse flow modes.

Immersion flushing

- For many shallow cuts of thin sections, simple immersion of the discharge gap is sufficient.
- Ddebris removal can be enhanced by providing relative motion between the tool and workpiece.
- Vibration comprises periodic reciprocation of the tool relative to the workpiece to effect a pumping action of the dielectric.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=pBueWfzb7P0

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Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 165

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L - 26

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III** [Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: Wirecut EDM

Introduction :

This is a special type of electric discharge machining that uses a small diameter wire as a cutting tool on the work. Working a principle of wire cut electric discharge machining is same as that of electric discharge machining.

Prerequisite knowledge for Complete understanding and learning of Topic

Cutting tool
Metal cutting
Kerf
Cutting fluid

Detailed content of the Lecture:

Process Details of WCEDM

Process details of WCEDM are almost similar to EDM with slight difference. The details of the process are indicated in the line diagram shown in Figure Its major difference of process details with EDM process details are described below.

Tool Details

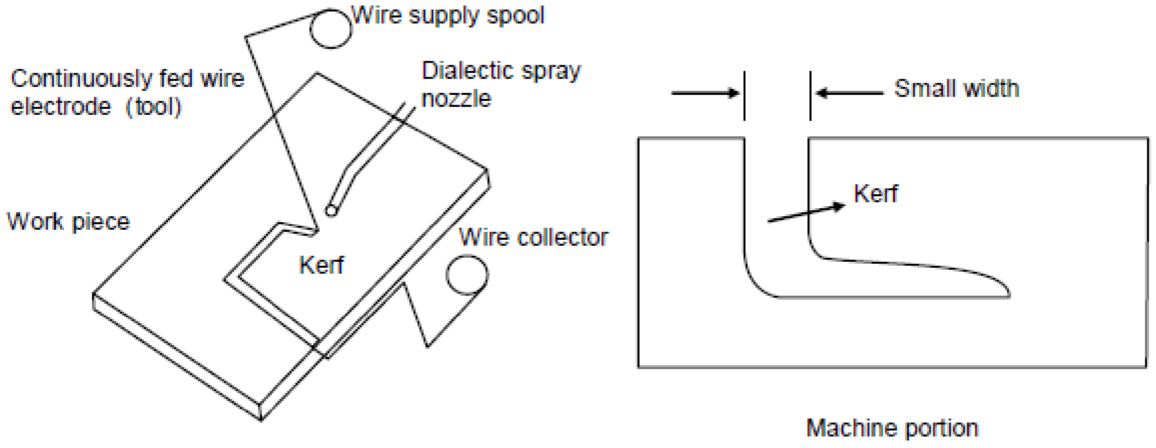
The tool used in WCEDM process is a small diameter wire as the electrode to cut narrow kerf in the workpiece. During the process of cutting the wire is continuously advanced between a supply spoil and wire collector. This continuous feeding of wire makes the machined geometry insensitive to distortion of tool due to its erosion. Material of wire can be brass, copper, tungsten or any other suitable material to make EDM tool. Normally, wire diameter ranges from 0.076 to 0.30 mm depending upon the width of kerf.

Tool Feed Mechanism

Two type of movements are generally given to the total (wire). One is continuous feed from wire supply spoal to wire collector. Other is movement of the whole wire feeding system, and wire along the kerf to be cut into the workpiece. Both movements are accomplished with ultra accuracy and pre-determined speed with the help of numerical control mechanism.

Dielectric Fluid and Spray Mechanism

Like EDM process dielectric fluid is continuously sprayed to the machining zone. This fluid is applied by nozzles directed at the tool work interface or workpiece is submerged in the dielectric fluid container. Rest of the process details in case of WCEDM process are same as that in case of EDM process.



Application of WCEDM

- WCEDM is similar to hand saw operation in applications with good precision.
- It is used to make narrow kerf with sharp corners.
- It does not impose any force to workpiece so used for very delicated and thin workpieces.
- It is considered ideal for making components for stamping dies.
- It is also used to make intricate shapes in punch, dies and other tools.

Advantages of WCEDM

Advantages are listed below :

(a) Accuracy and precision of dimensions are of very good quality.

(b) No force is experienced by the workpiece.

(c) Hardness and toughness of workpiece do not create problems in machining operation.

Disadvantages and Limitations of WCEDM

a) The major disadvantages of this process are that only electrically conducting materials can machined.

b) This process is costly so recommended for use specifically at limited operations

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

1. Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 11

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L - 27

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **III** [Electrical energy based processes] **Date of Lecture:**

Topic of Lecture: Applications Recent development in EDM

Introduction :

This process is highly economical for machining of very hard material as tool wear is independent of hardness of workpiece material. It is very useful in tool manufacturing

Prerequisite knowledge for Complete understanding and learning of Topic

Hard materials
Tool wear
Cutting tool
Die making.

Detailed content of the Lecture:

EDM is also used for broach making, making holes with straight or curved axes.

EDM is widely used for die making as complex cavities are to be made in the die making.

Drilling of micro-holes, thread cutting, helical profile milling, rotary forming, and curved hole drilling.

Delicate work piece like copper parts can be produced by EDM.

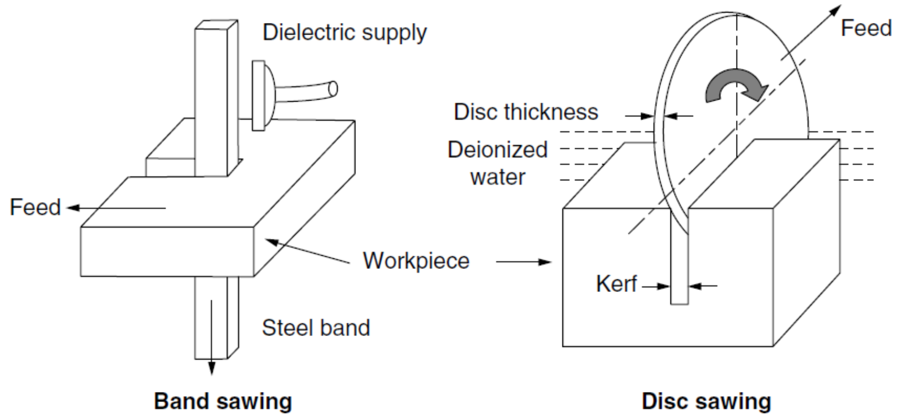
Can be applied to all electrically conducting metals and alloys.

Other applications: deep, small-dia holes using tungsten wire as tool, narrow slots, cooling holes in super alloy turbine blades, and various intricate shapes.

Recent development in EDM

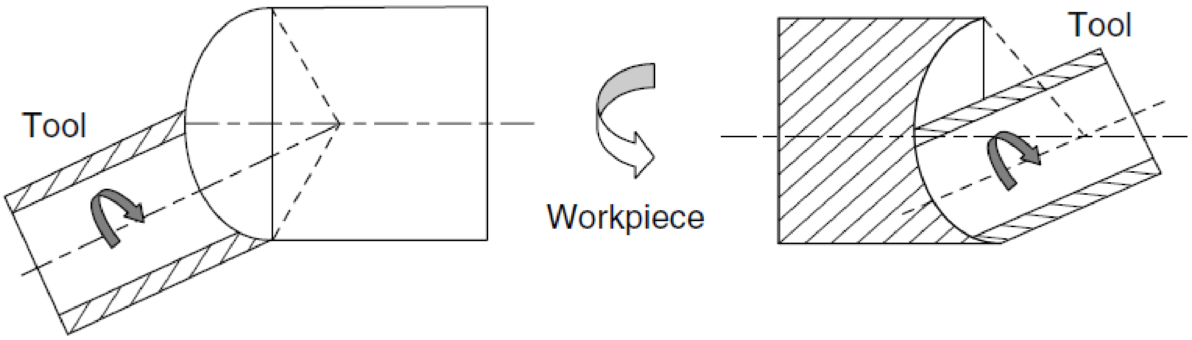
EDM Drilling
Uses a tubular tool electrode where the dielectric is flushed.
Irregular, tapered, curved, as well as inclined holes can be produced by EDM.
Creating cooling channels in turbine blades made of hard alloys.

EDM Sawing
An EDM variation - Employs either a special steel band or disc.
Cuts at a rate that is twice that of the conventional abrasive sawing method.
Cutting of billets and bars - has a smaller kerf & free from burrs.
Fine finish of 6.3 to 10 µm with a recast layer of 0.025 to 0.130 mm



Rotary EDM

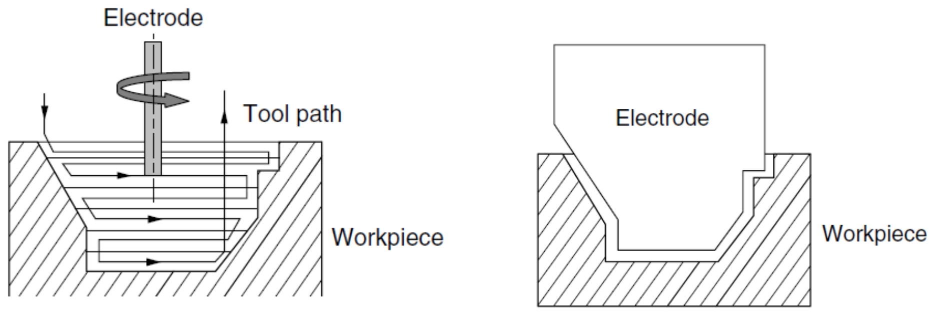
Rotary EDM is used for machining of spherical shapes in conducting ceramics using the tool and workpiece arrangement as shown below



EDM milling

EDM milling uses standard cylindrical electrodes.

Simple-shaped electrode is rotated at high speeds and follows specified paths in the workpiece



EDM milling enhances dielectric flushing due to high-speed electrode rotation.
Electrode wear can be optimized due to its rotational and contouring motions.
Complex shapes with sharp corners cannot be machined because of the rotating tool electrode.
EDM milling replaces conventional die making

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 11

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LECTURE HANDOUTS

L - 28

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV** [Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Process principles of chemical machining.

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

Prerequisite knowledge for Complete understanding and learning of Topic

Electrolysis

Electrochemical cell

Corrosion

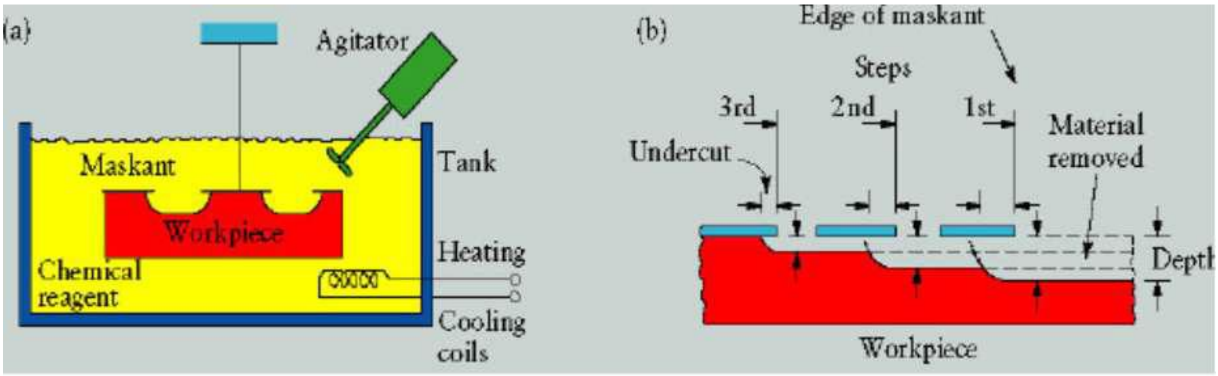
Etching

Material removal

Detailed content of the Lecture:

1. Material is removed by microscopic electrochemical cell action, as occurs in corrosion or chemical dissolution of a metal.
2. 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.
3. The basic process takes many forms:
4. chemical milling of pockets, contours,
5. overall metal removal,
6. chemical blanking for etching through thin sheets;
7. photochemical machining (pcm) for etching by using of photosensitive resists in microelectronics;
8. chemical or electrochemical polishing where weak chemical reagents are used (sometimes with remote electric assist) for polishing or
9. deburring and chemical jet machining where a single chemically active jet is used.

A schematic of chemical machining process is shown in Figure



Video Content / Details of website for further learning:

https://www.youtube.com/watch?v=NAA2E9yRRPg&feature=emb_logo

Important Books/Journals for further learning:

Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 325

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LECTURE HANDOUTS

L - 29

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV**[Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Process principles of Electro-Chemical machining

Introduction:

Electrochemical machining(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.

Prerequisite knowledge for Complete understanding and learning of Topic .

Electroplating
Anode
Cathode
Electrolysis
Metal rmoval

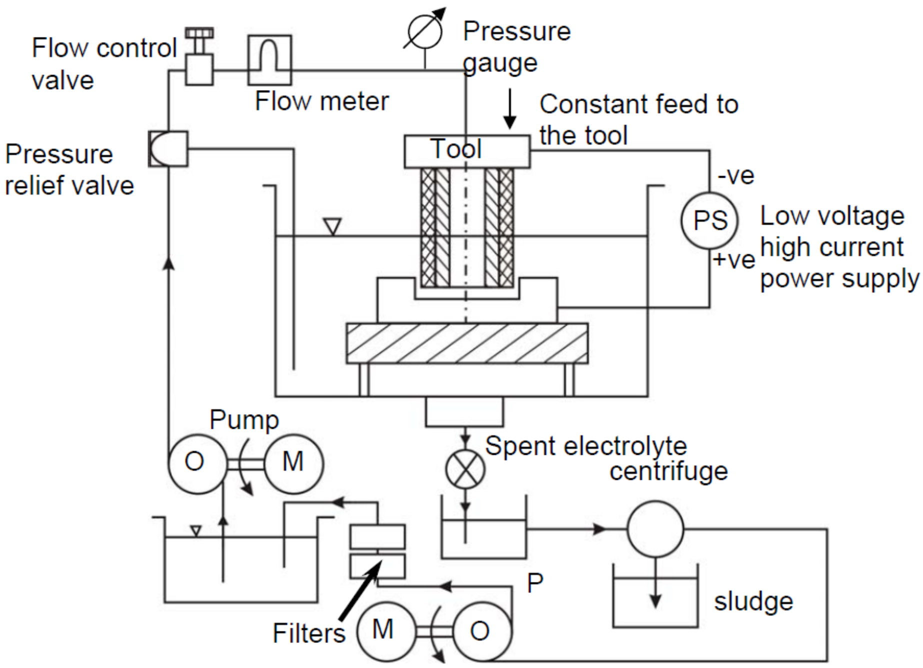
Detailed content of the Lecture:

Electrochemical machining is a metal machining technology based on electrolysis where the product is processed without contact and thermal influence. The metal work piece is partially dissolved (Machined) through electricity (Electro) and chemistry (Chemical) until it reaches the required complex 3Dend shape.

- During ECM, there will be reactions occurring at the electrodes i.e. at the anode or workpiece and at the cathode or the tool along with within the electrolyte.
- Let us take an example of machining of low carbon steel which is primarily a ferrous alloy mainly containing iron. For electrochemical machining of steel, generally a neutral salt solution of sodium chloride (NaCl) is taken as the electrolyte.
- The electrolyte and water undergoes ionic dissociation as shown below as potential difference is applied.

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

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



- As the potential difference is applied between the work piece (anode) and the tool (cathode), the positive ions move towards the tool and negative ions move towards the workpiece.
- Thus the hydrogen ions will take away electrons from the cathode (tool) and from hydrogen gas as:

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

Similarly, the iron atoms will come out of the anode (work piece) as:

$$Fe = Fe^{++} + 2e^-$$

- Within the electrolyte iron ions would combine with chloride ions to form iron chloride and similarly sodium ions would combine with hydroxyl ions to form sodium hydroxide

$$Na^+ + OH^- = NaOH$$

- In practice $FeCl_2$ and $Fe(OH)_2$ would form and get precipitated in the form of sludge. In this manner it can be noted that the work piece gets gradually machined and gets precipitated as the sludge.
- Moreover there is not coating on the tool, only hydrogen gas evolves at the tool or cathode. Fig. 2 depicts the electro-chemical reactions schematically.
- As the material removal takes place due to atomic level dissociation, the machined surface is of excellent surface finish and stress free.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=QXQOHfB0ymM&feature=emb_logo

Important Books/Journals for further learning including the page nos.:
Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 232

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LECTURE HANDOUTS | **L - 30**

MECH | **IV / VII**

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV**[Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Etchants, maskants and techniques

Introduction :

Etching is the most important stage to produce the required component from the sheet material. This stage is carried out by immerse type etching machine. The workpiece material is immersed into selected etchant and the uncovered areas were machined.Masking material which is called maskant is used to protect workpiece surface from chemical etchant

Prerequisite knowledge for Complete understanding and learning of Topic Gear terminology
Etching
Chemical reaction
Dissolution

Detailed content of the Lecture:

Etchants

- Etchants are the most influential factor in the chemical machining of any material. Various etchant are available due to workpiece material. The best possible etchant should have properties as follow

a. High etch rate

b. Good surface finish

c. Minimum undercut

d. Compatibility with commonly used maskants,

e. High dissolved-material capacity

f. Economic regeneration

g. Etched material recovery

h. Easy control of process.

i. Personal safety maintenance

- Different etchants are commercially available or the required etchant can be prepared in shop. Ferric chloride ($FeCl_3$) is the most widely used etchant in chemical machining. It is mainly used for etching iron-based alloys as well as copper and its alloys, aluminium, etc.
- Cupric chloride ($CuCl_2$) is generally applied for copper and copper based alloys in electronics industry because various regeneration systems are available for the waste etchant. Alkaline etchants

are introduced to the fabrication of electronic components such as printed circuit board.

- There are some other etchants can be named, but the industrial application of chemical machining is generally used these three etchants, even most of the companies use only ferric chloride due to economical considerations

Maskant

- Polymer or rubber based materials are generally used for masking procedure. The selected maskant material should have following properties

1. Tough enough to withstand handling
2. Well adhering to the workpiece surface
3. Easy scribing
4. Inert to the chemical reagent used
5. Able to withstand the heat used during chemical machining
6. Easy and in expensive removal after chemical machining etching.

- Multiple maskant coatings are used to provide a higher etchant resistance. Long exposure time is needed when thicker and rougher dip or spray coatings are used.
- Various maskant application methods can be used such as dip, brush, spray, roller, and electrocoating as well as adhesive tapes.
- When higher machined part dimensional accuracy is needed, spraying the mask on the workpiece through silk screen would provide a better result. Thin maskant coating would cause severe problems such as not withstanding rough handling or long exposure times to the etchant.
- The application of photoresist masks which are generally used in photocehmical machining operation, produce high accuracy, ease of repetition for multiplepart etching, and ease of modification. Possible maskaint materials for different workpiece materials were given in table.

Video Content / Details of website for further learning (if any):

Important Books/Journals for further learning including the page nos.:
Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 327

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L - 31

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV** [Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Process parameters

Introduction :

Electrochemical Machining (ECM) is a non-traditional machining (NTM) process belonging to Electrochemical category. ECM is opposite of electrochemical or galvanic coating or deposition process. Thus ECM can be thought of a controlled anodic dissolution at atomic level of the work piece that is electrically conductive by a shaped tool due to flow of high current at relatively low potential difference through an electrolyte which is quite often water based neutral salt solution

Prerequisite knowledge for Complete understanding and learning of Topic .

Electrochemical reaction

Galvanic coating

Anodic dissolution

Electrolyte

Detailed content of the Lecture:

1. During ECM, there will be reactions occurring at the electrodes i.e. at the anode or workpiece and at the cathode or the tool along with within the electrolyte.
2. Let us take an example of machining of low carbon steel which is primarily a ferrous alloy mainly containing iron.
3. For electrochemical machining of steel, generally a neutral salt solution of sodium chloride (NaCl) is taken as the electrolyte.
4. The electrolyte and water undergoes ionic dissociation as shown below as potential difference is applied

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

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

As the potential difference is applied between the work piece (anode) and the tool (cathode), the positive ions move towards the tool and negative ions move towards the workpiece.

Thus the hydrogen ions will take away electrons from the cathode (tool) and from hydrogen gas as:

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

Similarly, the iron atoms will come out of the anode (work piece) as:

$Fe = Fe^{++} + 2e$

Within the electrolyte iron ions would combine with chloride ions to form iron chloride and similarly sodium ions would combine with hydroxyl ions to form sodium hydroxide

$Na^+ + OH^- = NaOH$

In practice $FeCl_2$ and $Fe(OH)_2$ would form and get precipitated in the form of sludge.

In this manner it can be noted that the work piece gets gradually machined and gets precipitated as the sludge.

Process Parameters

Power Supply Type direct current

Voltage 2 to 35 V

Current 50 to 40,000 A

Current density 0.1 A/mm^2 to 5 A/mm^2

Electrolyte Material NaCl and $NaNO_3$

Temperature 20^o C – 50^o C

Flow rate 20 lpm per 100 A current

Pressure 0.5 to 20 bar

Dilution 100 g/l to 500 g/l

Working gap 0.1 mm to 2 mm

Overcut 0.2 mm to 3 mm

Feed rate 0.5 mm/min to 15 mm/min

Electrode material Copper, brass, bronze

Surface roughness, Ra 0.2 to 1.5 μm

Video Content / Details of website for further learning (if any):

https://www.youtube.com/watch?v=NAA2E9yRRPg&feature=emb_logo

Important Books/Journals for further learning including the page nos.:

Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 325

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LECTURE HANDOUTS

L - 32

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV** [Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Material removal rate

Introduction :

Electrochemical Machining (ECM) is a non-traditional machining (NTM) process belonging to Electrochemical category. ECM is opposite of electrochemical or galvanic coating or deposition process. Thus ECM can be thought of a controlled anodic dissolution at atomic level of the work piece that is electrically conductive by a shaped tool due to flow of high current at relatively low potential difference through an electrolyte which is quite often water based neutral salt solution.

Prerequisite knowledge for Complete understanding and learning of Topic

Electrochemical reaction

Dissolution

Detailed content of the Lecture:

Material removal rate (MRR) is an important characteristic to evaluate efficiency of a non-traditional machining process.

In ECM, material removal takes place due to atomic dissolution of work material.

Electrochemical dissolution is governed by Faraday’s laws.

The first law states that the amount of electrochemical dissolution or deposition is proportional to amount of charge passed through the electrochemical cell, which may be expressed as:

m Q∝ ,

where m = mass of material dissolved or deposited

Q = amount of charge passed

The second law states that the amount of material deposited or dissolved further depends on Electrochemical Equivalence (ECE) of the material that is again the ratio of the atomic weigh and valency.

Thus

t ν αα A ECEm

Thus ν α QA m

where F = Faraday's constant = 96500 coulombs

Fν ItA

∴ m = Fρνρ IA t m ∴ MRR

== where I = current

ρ= density of the material

The engineering materials are quite often alloys rather than element consisting of different elements in a given proportion

This equation is based on number of simplified assumption and does not account for the effect of some of significant process variables, namely, changes in valency of electrochemical EC dissolution during the operation, gas evolution and bubble formation, electrolyte electrical conductivity and temperature variation along the electrolyte fow path, over potential m presence of passivation film etc. Passivity arises as a result of chemical and electro chemical behavior of metals which results in the formation of protective film on their surfaces. Further, dissolution of iron in Nacl solution, depending upon the machining conditions, may be either in the form of ferrous hydroxide or ferric hydroxide. Mode of dissolution during machining if alloys, is still more difficult to know. The preferential valency mode of dissolution has been found to depend upon the electrolyte flow rate, IEG and length of electrolyte flow path.

Video Content / Details of website for further learning:

www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

1. Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 11

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L - 33

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV** [Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Equipments-Electrical circuits- Applications

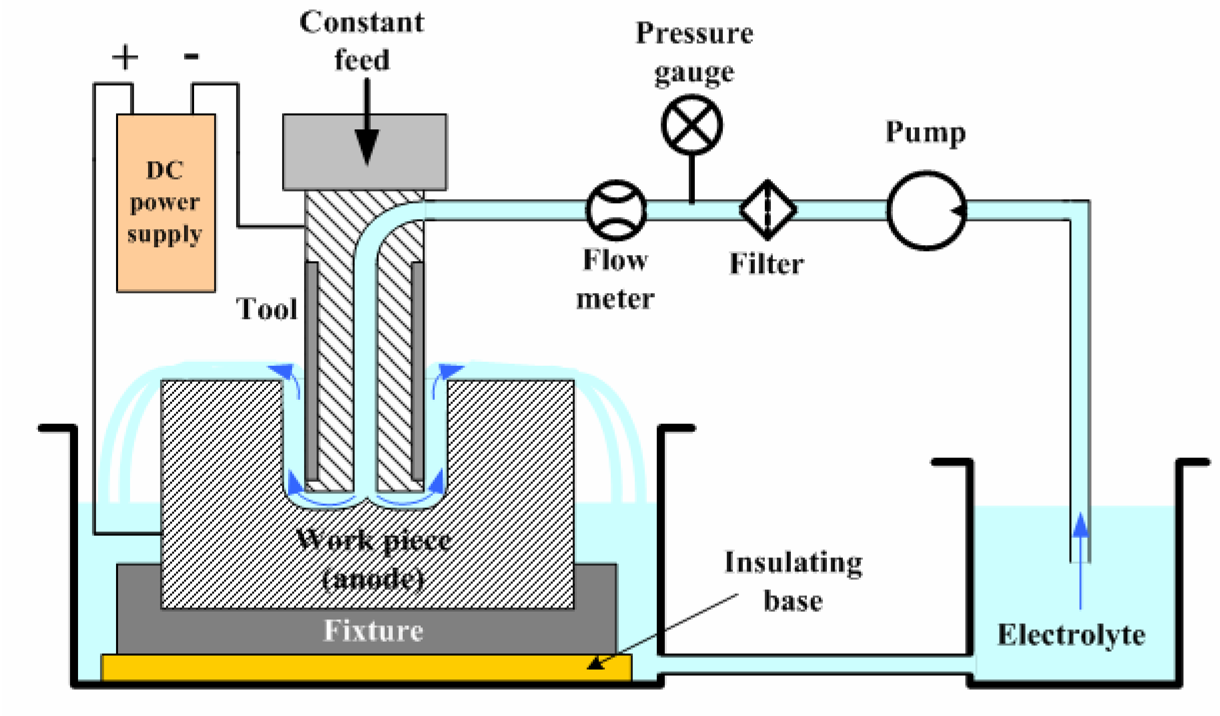
Introduction :

Electrochemical machining(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.

Prerequisite knowledge for Complete understanding and learning of Topic

Electrolyte
Dissolution
Metal removal
Electroplating

Detailed content of the Lecture:



Equipment
The electrochemical machining system has the following modules:
• Power supply
• Electrolyte supply and cleaning system
• Tool and tool feed system
• Work piece and Work holding system.

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

Applications
1. ECM can be used to make disc for turbine rotor blades made up of HSTR alloys
2. ECM can be used for slotting very thin walled collets
3. ECM can be used for copying of internal and external surfaces, cutting of curvilinear slots, machining of intricate patterns, production of long curved profiles, machining of gears and chain sprockets, production of integrally bladed nozzle for use in diesel locomotives, production of satellite rings and connecting rods, machining of thin large diameter diaphragms.
4. ECM principle has be employed for performing a number of machining operations namely, turning, treplaning, broaching, grinding, fine hole drilling, die sinking, piercing, deburring,plunge cutting etc.
5. ECM can also be used to generate internal profile of internal cams.

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=fOc65syJvDM
Important Books/Journals for further learning including the page nos.: Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 244

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LECTURE HANDOUTS

L - 34

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV** [Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Electro chemical grinding - Applications.

Introduction :

Electrochemical grinding is a modification of both the grinding and electrochemical machining. In this process, machining is affected both by the grinding action and by the electrochemical process. Hence, in the true sense, it may be called 'mechanically assisted electrochemical machining.

Prerequisite knowledge for Complete understanding and learning of Topic

Electrolysis

Dissolution

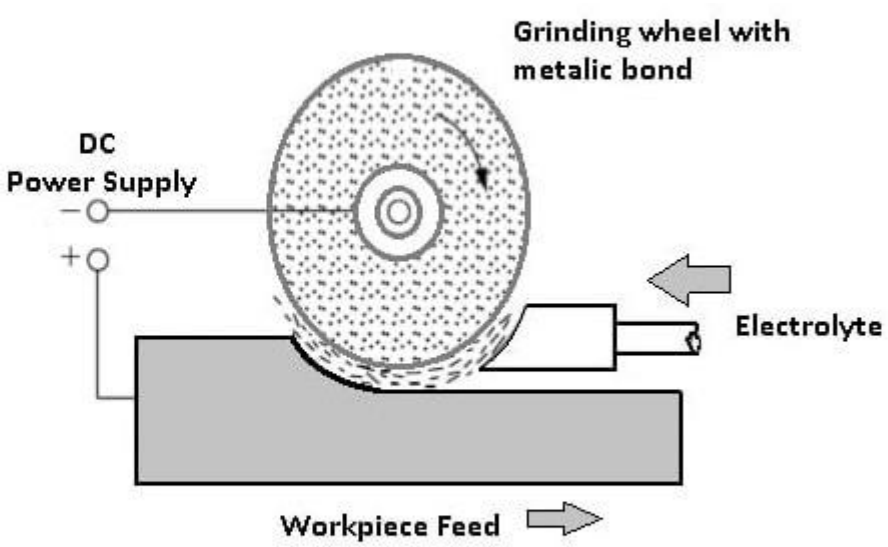
Mechanical grinding

Metal removal

Detailed content of the Lecture:

In **Electrochemical grinding**, the metal bonded **grinding** wheel filled with a non-conductive abrasive. The grinding wheel act as a **cathode** and the workpiece is act as an anode.

The **electrolyte**, which is usually sodium nitrate, sodium chloride, potassium nitrite, with a concentration of 0.150 to 0.300 kg/litre of water.



It is passed through a nozzle in the machining zone to complete the electrical connection between the anode and the cathode.

The work and wheel do not make contact with each other. Both are kept apart by the insulating abrasive particles which protrude from the face of the grinding wheel. A constant gap of 0.025 mm is maintained into which a stream of electrolyte is directed.

The electrolyte is carried past the work surface at high speed by the rotary action of the grinding wheel. With the rotation of the grinding wheel, metal is removed from the workpiece by the simultaneous electrolytic and abrasive action.

Abrasive grains on the surface of the wheel serve to act as a paddle which picks up the electrolyte and cause pressure to a build at the work area.

Applications of Electrochemical Grinding:

- Any material which is conductive may be ground by the electrolytic process. But its most useful application is concerned with hardened steel, cemented carbides, and similar materials.
- This is mainly applied to resharpening and reconditioning of carbide tools and other materials that are difficult to grind.
- The grinding pressure is low. It is possible to grind and cut thin sections and thin-wall tubing of difficult materials without distortion or burr.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=TxTeb2f-2EA&feature=emb_logo

Important Books/Journals for further learning including the page nos.:
Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 260

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L - 35

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV** [Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Electro chemical honing - Applications.

Introduction :

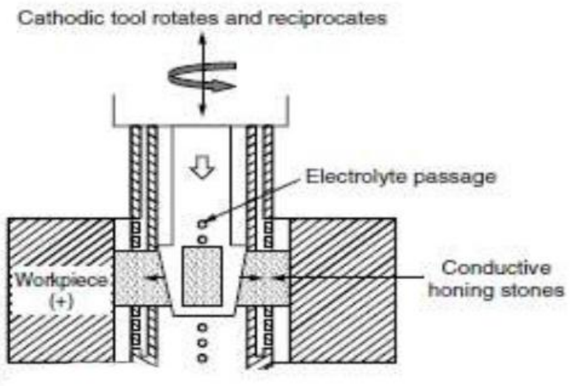
Electrochemical Honing is a process in which material is removed with help of electrical energy, chemical energy and honing process.H**oning** is an abrasive machining process that produces a precision surface on a metal workpiece by scrubbing an abrasive stone against it along a controlled path.In honing a hone tool is used. A hone tool is a tool that simultaneously rotates as well as translates.High metal removal rates are possible with ECH, with no thermal or mechanical stresses and mirror surface finish can be achieved.

Prerequisite knowledge for Complete understanding and learning of Topic .

Abrasives
Abrasive wheel
Metal removal

Detailed content of the Lecture:

In an ECH process, a DC Power Supply is used of which the tool act as the cathode and the workpiece act as anode.
The pressirized electrolyte is injected to the area being cut at a set temperature.
The feed rate is same as the rate of **liquefaction** of the material or the rate of conversion of material into a liquid state.
In this process, the gap between the tool and the workpiece varies between 80-800 micrometers (.003 in. and .030 in.).
As electrons cross the gap, material from the workpiece is dissolved as the tool forms the desired shape in workpiece.
The metal hydroxide formed during the process is carried away by the electrolytic fluid.



Electrochemical Honing

Working of Electrochemical Honing:

In electrochemical honing, **electrolyte** like sodium chloride, sodium nitrate are used.

The workpiece used in the electrochemical machining is a cylinderical workpiece which has to be cleaned from inside using electrochemical honing process.

At first, the abrasive tool is inserted into the cylindrical workpiece.

The abrasive tool which is inserted into the workpiece rotates inside it as well as have up and down resiprocatory motion.

Electrolyte is supplied to this process inside the cylindrical workpiece using a nozzle.

In this process, the workpiece acts as anode and the tool acts as cathode. In this process, a constant DC current is supplied.

The metal part of the tool apart from the stone is conductive, this metal part reacts with the electrolyte.

Due to the reaction, material starts removing from the internal part of the workpiece and a surface finish is obtained in the inside surface of the cylindrical workpiece.

The final finsih is given by the abrasive tool or the honing stone.

As the abrassive tool is an insulator so it will be only used in rubbing.

The final finish provided by the abrasive tool is very neat and of high quality.

Applications :

1. ECH is widely used in power generation and power chemical industries.
2 .It is used in gear teeth error correction.
3 .It is used in increasing life span of the roller , gears, sleeves, dies, gears and internal cylinders.
4 .It is also used in processing different materials like carbide, titanium, alloys, Inconel Incoloy, Titanium alloys, etc.

Video Content / Details of website for further learning (if any):
https://www.youtube.com/watch?v=TxTeb2f-2EA&feature=emb_logo

Important Books/Journals for further learning including the page nos.:
Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 280

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LECTURE HANDOUTS

L - 36

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **IV** [Chemical & Electrochemical energy based processes]

Date of Lecture:

Topic of Lecture: Electro chemical deburring(ECD) - Applications

Introduction :

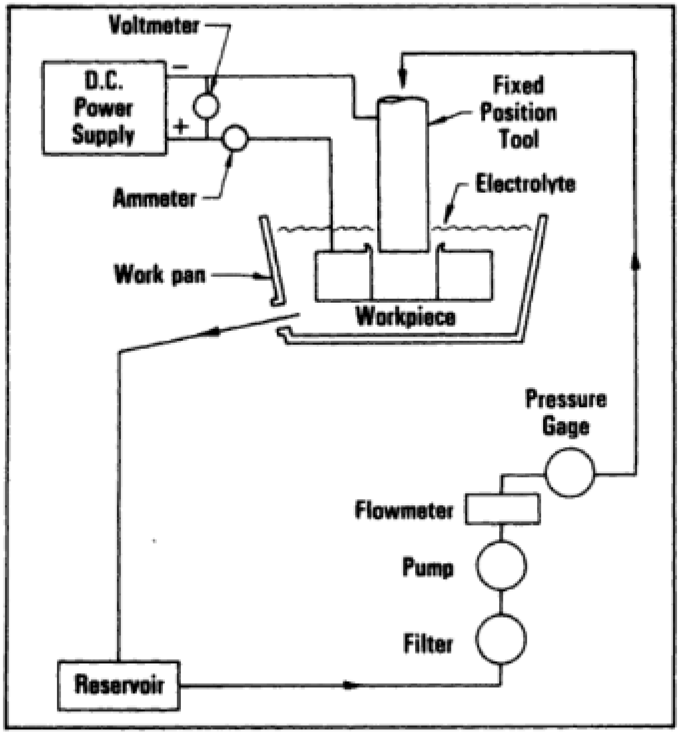
Electrochemcial deburring(ECD) is a process for the removal of metal burrs by anodic dissolution, the same principle as ECM.ECD is a special version of ECM used exclusively to deburr or radius workpieces. It differs from ECM in that the electrolyte pressure, electrolyte flow and current are all relatively low. And also the tool is usually held stationary in ECD.

Prerequisite knowledge for Complete understanding and learning of Topic

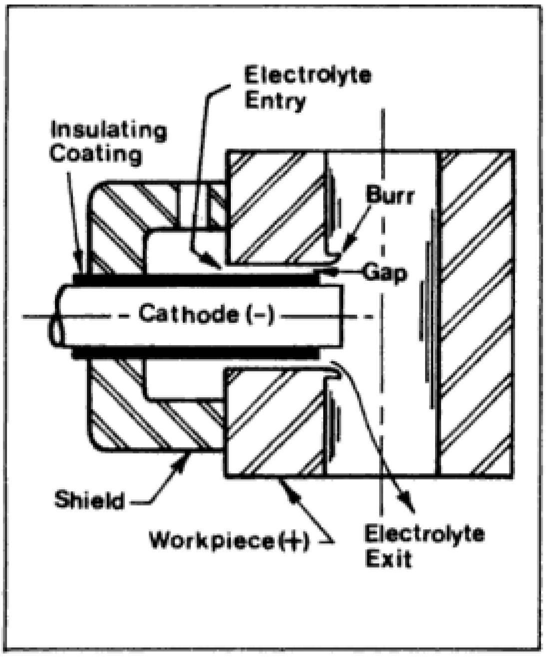
Burrs
Anodic dissolution
Electrolysis
Metal removal

Detailed content of the Lecture:

The ECD tool is insulated on all surfaces except those adjacent to the burrs. The tool is positioned to concentrate the deplating action at the root of the burrs. As in ECM, an electrolyte is introduced through the gap between the burr and the tool.



Close-up view of the ECD tool- workpiece interaction area



Process parameters

Current – 100 to 2000A

Voltage – 7 to 25 V(DC)

Electrolyte pressure – 69 to 345 KPa

Flow rate – 3.7 to 15 L/min

Gap between the tool & burr – 0.76mm

Electrodes – Brass, Copper or Stainless steel

Applications

Should be applied to selectively deburr small areas

Applied in different industries like consumer appliances, automotive,biomedical and aerospace products.

Video Content / Details of website for further learning (if any): https://www.youtube.com/watch?v=TxTeb2f-2EA&feature=emb_logo
Important Books/Journals for further learning including the page nos.: Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 007. Page No: 302

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LECTURE HANDOUTS

L - 37

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **V** [Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Laser Beam machining- principles

Introduction :

Laser Beam Machining or more broadly laser material processing deals with machining and material processing like heat treatment, alloying, cladding, sheet metal bending etc. Such processing is carried out utilizing the energy of coherent photons or laser beam,

Prerequisite knowledge for Complete understanding and learning of Topic :

- Properties of laser.
- Functions of laser beam.

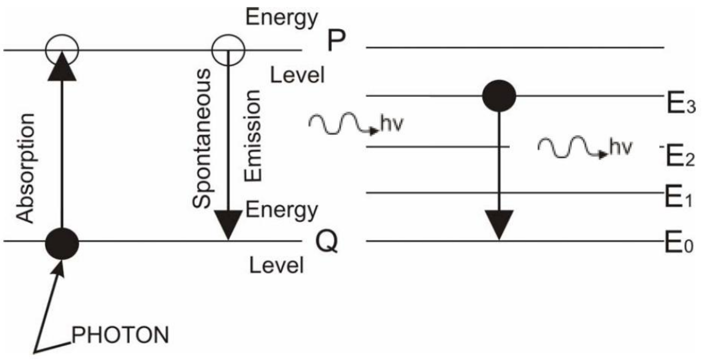
Detailed content of the Lecture:

Laser Beam – Introduction

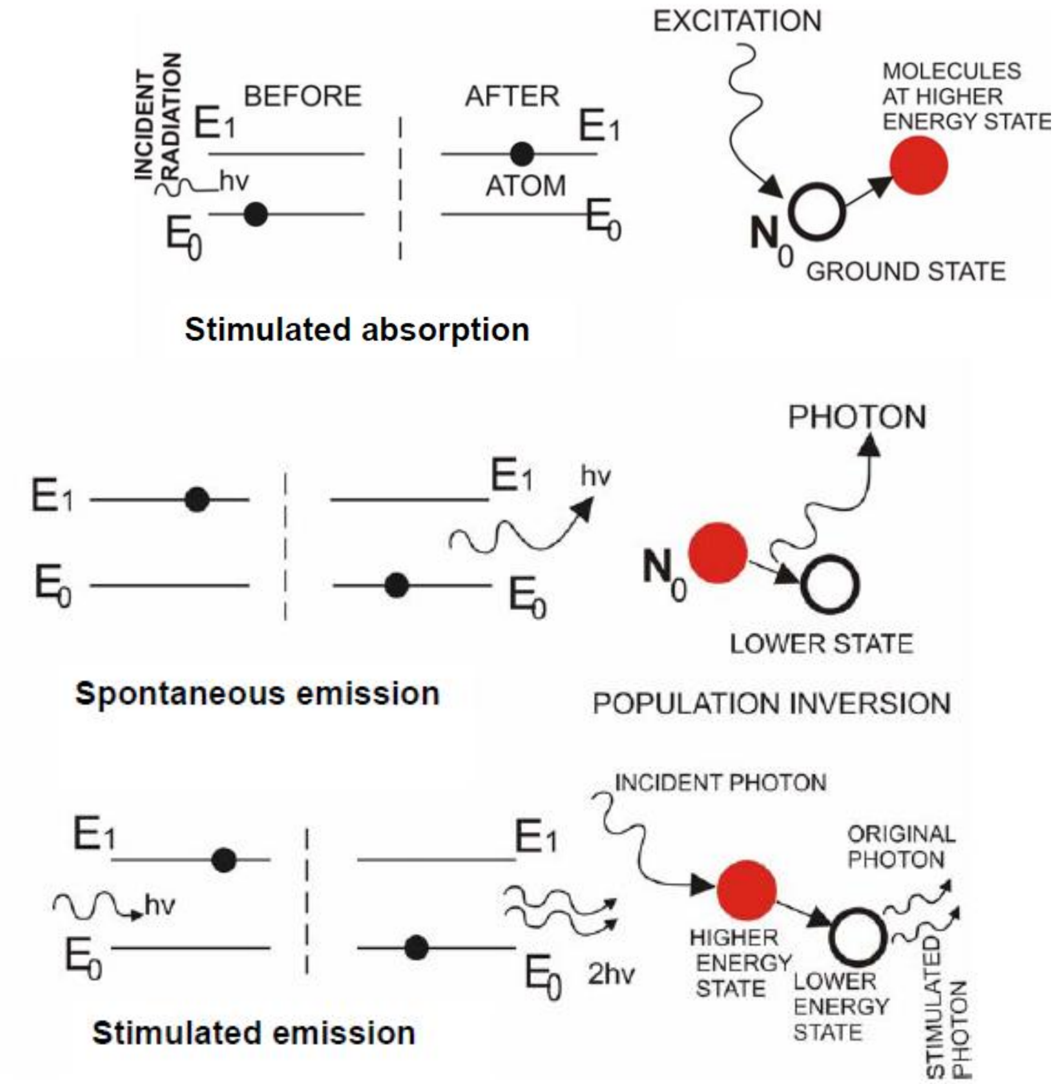
Laser Beam Machining or more broadly laser material processing deals with machining and material processing like heat treatment, alloying, cladding, sheet metal bending etc. Such processing is carried out utilizing the energy of coherent photons or laser beam, which is mostly converted into thermal energy upon interaction with most of the materials. Nowadays, laser is also finding application in regenerative machining or rapid prototyping as in processes like stereo-lithography, selective laser sintering etc.

Laser stands for light amplification by stimulated emission of radiation. The underline working principle of laser was first put forward by Albert Einstein in 1917 though the first industrial laser for experimentation was developed around 1960s.

Laser beam can very easily be focused using optical lenses as their wavelength ranges from half micron to around 70 microns. Focused laser beam as indicated earlier can have power density in excess of 1 MW/mm^2. As laser interacts with the material, the energy of the photon is absorbed by the work material leading to rapid substantial rise in local temperature. This in turn results in melting and vaporization of the work material and finally material removal.



ENERGY BANDS OF MATERIAL



Spontaneous and Stimulated emission

Video Content / Details of website for further learning:
https://www.youtube.com/watch?v=mgaukC25Hqk

Important Books/Journals for further learning:
Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 186,187

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L - 38

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **V** [Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Laser Beam machining – Equipment

Introduction : Laser Beam Machining or more broadly laser material processing deals with machining and material processing like heat treatment, alloying, cladding, sheet metal bending etc. Such processing is carried out utilizing the energy of coherent photons or laser beam, which is mostly converted into thermal energy upon interaction with most of the materials. Nowadays, laser is also finding application in regenerative machining or rapid prototyping as in processes like stereo-lithography, selective laser sintering etc.

Prerequisite knowledge for Complete understanding and learning of Topic

- Properties of Laser
- Parameters affect laser beam

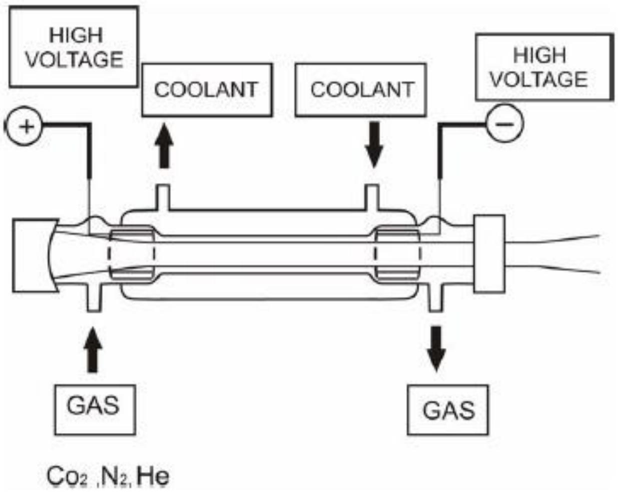
Detailed content of the Lecture:

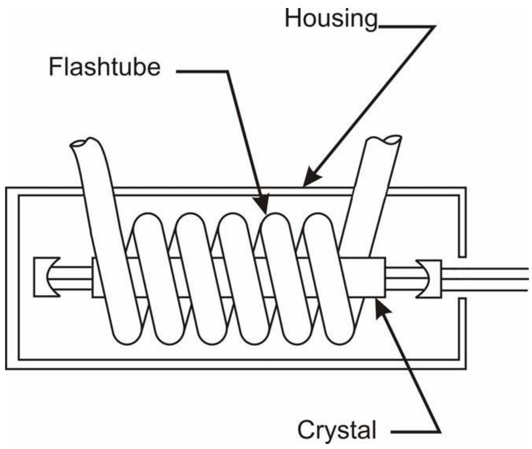
1. In a typical Nd-YAG laser,laser is pumped using flash tube.
2. Flash tubes can be helical, as shown in Fig. or they can be flat.
3. Typically the lasing material is at the focal plane of the flash tube.
4. Though helical flash tubes provide better pumping, they are difficult to maintain. Fig.shows the electrical circuit for operation of a solid-state laser.
5. The flash tube is operated in pulsed mode by charging and discharging of the capacitor.
6. Thus the pulse on time is decided by the resistance on the flash tube side and pulse off time is decided by the charging resistance.
7. There is also a high voltage switching supply for initiation of pulses.
8. Gas lasers can be axial flow, as shown in , transverse flow and folded axial flow as shown in Fig.
9. The power of a CO_2 laser is typically around 100 Watt per metre of tube length.
10. Thus to make a high power laser, a rather long tube is required which is quite inconvenient.
11. For optimal use of floor space, high-powered CO_2 lasers are made of folded design.
12. In a CO_2 laser, a mixture of CO_2, N_2 and He continuously circulate through the gas tube.

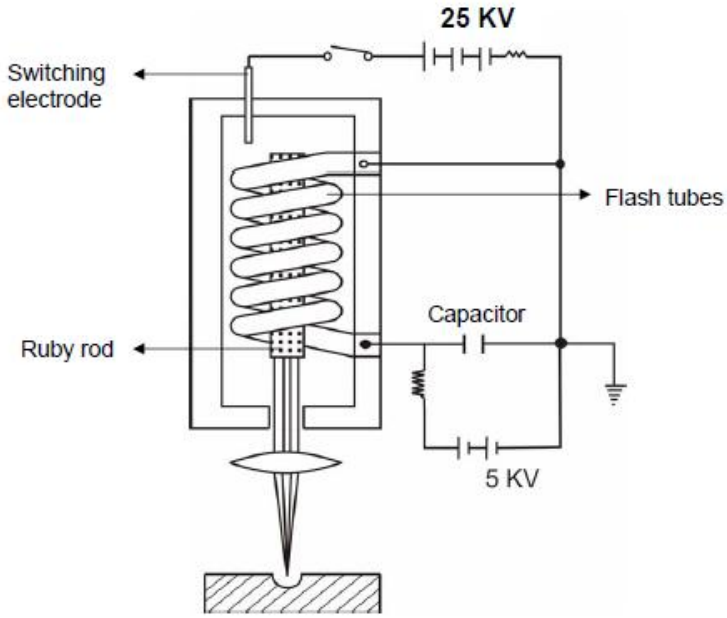
13. Such continuous recirculation of gas is done to minimize consumption of gases.

14. CO_2 acts as the main lasing medium whereas Nitrogen helps in sustaining the gas plasma.

15. Helium on the other hand helps in cooling the gases.







Video Content / Details of website for further learning:

https://www.youtube.com/watch?v=mgaukC25Hqk

Important Books/Journals for further learning:

Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 211

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LECTURE HANDOUTS

L - 39

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **V** [Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Plasma Arc Machining - Principles

Introduction :

A plasma is defined as a superheated, electrically ionized gas. Plasma Arc machining(PAM) uses a plasma stream operating at temperatures in the range from 10,000 to 14,000 ºC to cut metal by melting. However, in recent years, PAM has also been used to cut plain carbon steel, stainless steel and aluminium.

Prerequisite knowledge for Complete understanding and learning of Topic

Plasma formation

Arc cutting

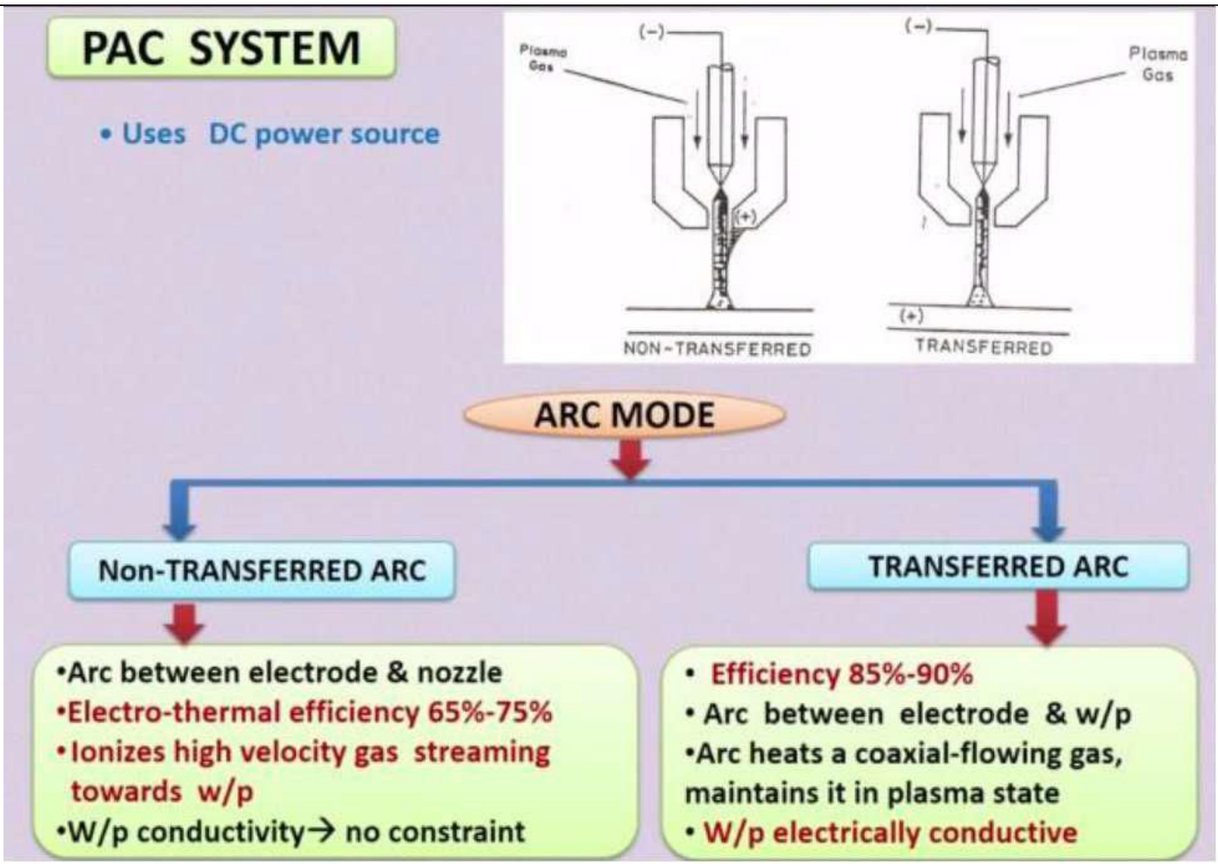
Detailed content of the Lecture:

1. When heated to elevated temperatures, gases turn into a distinctly different type of matter, which is plasma. When gases are heated by an applied electric field, an igniter supplies the initial electrons, which accelerate in the field before colliding and ionizing the atoms.
2. The free electrons, in turn, get accelerated and cause further ionization and heating of the gases.
3. The avalanche continues till a steady state is obtained in which the rate of production of the free charges is balanced by recombination and loss of the free charges to the walls and electrodes.
4. The actual heating of the gas takes place due to the energy liberated when free ions and electrons recombine into atoms or when atoms recombine into molecules

Types of Plasma Arc system:

There are different types of plasma arc cutting operations are here. So there are 2 main configurations are there.

1. non-transferred mode,
2. transfer mode



Video Content / Details of website for further learning:

https://www.youtube.com/watch?v=Xdu4bSSIi5A

Important Books/Journals for further learning:

1. Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 11

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L - 40

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **V**[Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Plasma Arc Machining - Equipment

Introduction :

A plasma is defined as a superheated, electrically ionized gas. Plasma Arc Cutting(PAC) uses a plasma stream operating at temperatures in the range from 10,000 to 14,000 ºC to cut metal by melting. The cutting action takes place by directing the high velocity plasma stream at the work, thus melting it and blowing the molten metal through the kerf.

Prerequisite knowledge for Complete understanding and learning of Topic

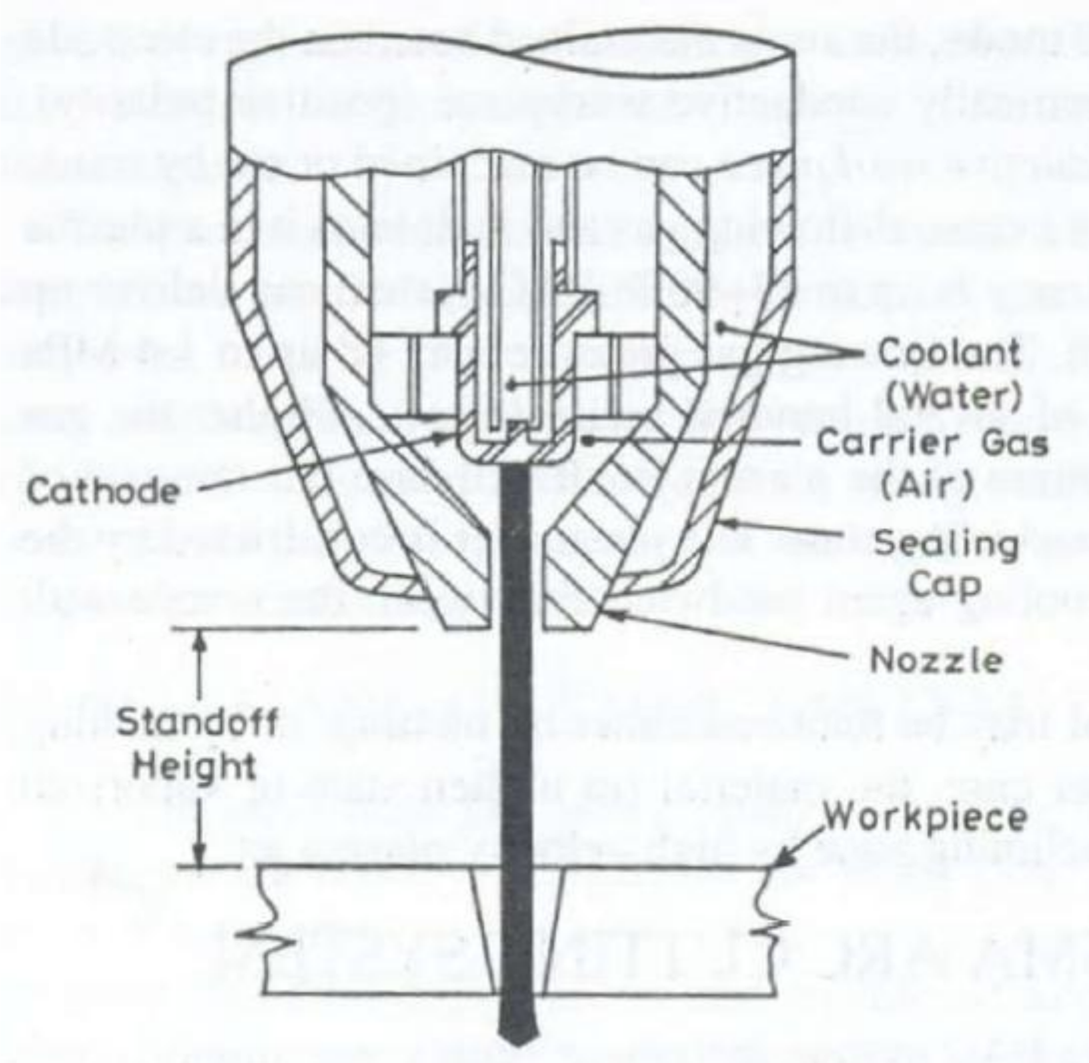
- Plasma arc
- Cathode and anode

Detailed content of the Lecture:

Elements of Plasma Arc system are

- power supply
- Gas supply
- Cooling water system
- Control console
- Plasma tourch

So first one is the power supply. Second one is the gas supply, plasma gas supply system, then cooling water system. So you have to cool down this nozzle as well as the plasma jet you have to cool down and then control console. So this plasma jet can be controlled by using a CNC machining system or this working table may be controlled by using a CNC machining system, CNC system so that any complicated contour can be cut from the workpiece material and also the fifth one is the fifth one of the plasma arc system, plasma arc cutting system is the plasma torch.



The metal removal in PAM is basically due to the high temperature produced. The heating of the work piece is, as a result of anode heating, due to direct electron bombardment plus convection heating from the high temperature plasma that accompanies the arc. The heat produced is sufficient to raise the work piece temperature above its melting point and the high velocity gas stream effectively blows the molten metal away.

Video Content / Details of website for further learning:

https://www.youtube.com/watch?v=Xdu4bSSIi5A

Important Books/Journals for further learning:

1. Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 11

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LECTURE HANDOUTS

L - 41

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **V** [Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Electron Beam Machining (EBM).– Principles

Introduction :

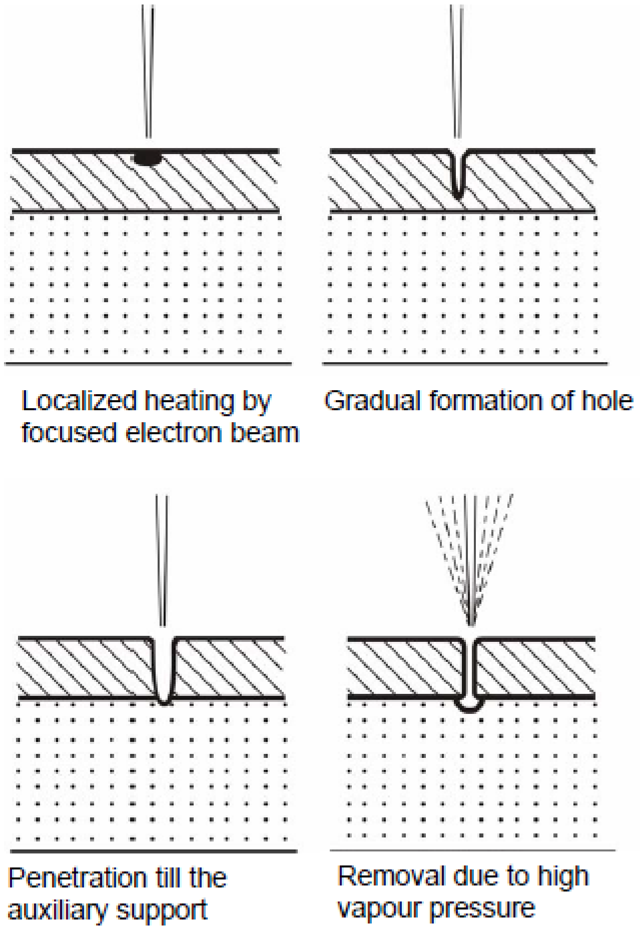
Electron Beam Machining (EBM) and Laser Beam Machining (LBM) are thermal processes considering the mechanisms of material removal. However electrical energy is used to generate high-energy electrons in case of Electron Beam Machining (EBM) and high-energy coherent photons in case of Laser Beam Machining (LBM). **Thus these two processes are often classified as electro-optical-thermal processes.**

Prerequisite knowledge for Complete understanding and learning of Topic

- Discharge of electrons
- Scattering of electrons.

Detailed content of the Lecture:

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



Video Content / Details of website for further learning

https://www.youtube.com/watch?v=jbY-tOcI2tM

Important Books/Journals for further learning:

Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 221-222

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L - 42

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **V** [Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Electron Beam Machining. – Equipment

Introduction :

Electron beam machining is a thermal process used for metal removal during the machining process. In the electrical beam machining, electrical energy is used to generate the electrons with high energy. In the Electron Beam Machining process, a high velocity focused beam of electrons are used to remove the metal from the workpiece. These electrons are traveling at half the velocity of light i.e., 1.6 x 10^8 m / s. This process is best suited for the micro-cutting of materials.

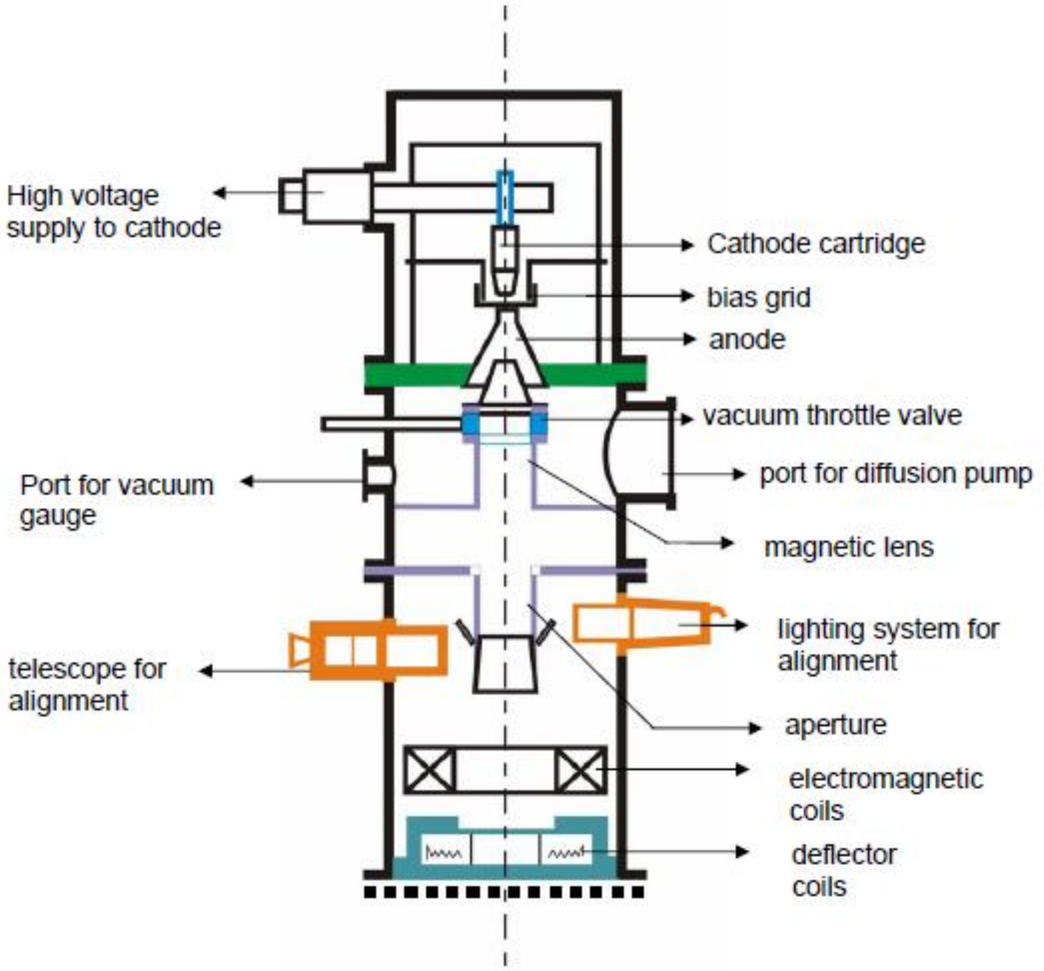
Prerequisite knowledge for Complete understanding and learning of Topic

Cathode
Anode
Generation of electrons
Heat energy
Metal cutting.

Detailed content of the Lecture:

1. An electron beam gun, is the heart of any electron beam machining facility.
2. The basic functions of any electron beam gun are to generate free electrons at the cathode, accelerate them to a sufficiently high velocity and to focus them over a small spot size.
3. The cathode is generally made of tungsten or tantalum.
4. Such cathode filaments are heated, often inductively, to a temperature of around 2500^{0}C.
5. Such heating leads to thermo-ionic emission of electrons, which is further enhanced by maintaining very low vacuum within the chamber of the electron beam gun.
6. Moreover, this cathode cartridge is highly negatively biased so that the thermo-ionic electrons are strongly repelled away form the cathode.
7. Just after the cathode, there is an annular bias grid.
8. A high negative bias is applied to this grid so that the electrons generated by this cathode do not diverge and approach the next element, the annular anode, in the form of a beam.
9. The annular anode now attracts the electron beam and gradually gets accelerated.
10. As they leave the anode the electrons may achieve a velocity as high as half the velocity of light.
11. The nature of biasing just after the cathode controls the flow of electrons.
12. After the anode, the electron beam passes through a series of magnetic lenses and apertures.
13. The magnetic lenses shape the beam and try to reduce the divergence.
14. Apertures allow only the convergent electrons to pass .

15. This way, the aperture and the magnetic lenses improve the quality of the electron beam.
16. Then the electron beam passes through the electromagnetic lens and deflection coil.
17. The electromagnetic lens focuses the electron beam to a desired spot.
18. The deflection coil can manoeuvre the electron beam,to improve shape of the machined holes.
19. Electron beam guns are also provided with illumination facility and a telescope for alignment of the beam with the workpiece.



Video Content / Details of website for further learning:
www.youtube.com/watch?v=Jg6YXvTO5FE&list=PLZ5p3dhcXgHKX5kw7ZJ5fyxWK9lgExhXm

Important Books/Journals for further learning:

1. Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 11

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L - 43

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **V** [Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Electron Beam Machining.- Types., Beam control techniques

Introduction :

Electron beam machining is a thermal process used for metal removal during the machining process. In the electrical beam machining, electrical energy is used to generate the electrons with high energy. In the Electron Beam Machining process, a high velocity focused beam of electrons are used to remove the metal from the workpiece. These electrons are traveling at half the velocity of light i.e., 1.6 x 10^8 m / s. This process is best suited for the micro-cutting of materials.

Prerequisite knowledge for Complete understanding and learning of Topic

- Electron beam
- Beam density
- Beam current
- Metal cutting

Detailed content of the Lecture:

Types :

The process of Electron Beam Machining (EBM) can be divided into two categories : 'Thermal type' and 'Non-thermal type'.

In non-thermal EBM process, the electron beam is used to cause a chemical reaction.

In the thermal type EBM process, a thermoelectronic cathode is heated to a very high temperature resulting into the release of electrons from the cathode surface.

Beam control techniques:

The electron beam is controlled with optical precision

The beam consists of negatively charged particles whose energy content is determined by the mass and velocity of the individual particles.

The negatively charged particles can be accelerated in an electrostatic field to extreme high velocities. During the process, the specific energy content of the electron beam can be increased beyond the emission energy, thus producing a beam of energy, the intensity of which far exceeds that obtainable from light.

Due to the precise electron optics, large amounts of energy can be manipulated with optical precision.

1. Electromagnetic lens:

   Before the electrons collide with the workpiece, a variable strength electromagnetic lens is used to refocus the beam to any desired diameter down to less than 0.025 mm at a precise location on the workpiece and thus attains an extremely high power density.

   This extremely, high power density immediately vaporizes any material on which the beam impinges.

2. Magnetic deflection coil:

   Mounted below the magnetic lens, is used to bend the beam and direct it over the desired surface of the workpiece.

   This deflection system permits programming of the beam in any specific geometrical pattern, using the proper deflection coil current input

   At the point of beam impingement, the kinetic energy in the beam is converted to thermal energy in workpiece.

   Another interesting deflection control technique is the flying spot scanner or optical tracing device. Using this device, the electron beam can be deflected to cover almost any conceivable pattern over a 0.25 sq.in. area.

   The desired pattern is drawn, then photographed, and the photographic negative acts as the master.

   The electron beam can also be deflected in a predetermined pattern by a relay tray or a flying spot scanner mounted in a control cabinet, which consists of a saw-tooth square wave and sine wave generator. By using this process, it is possible to drill a cross-shaped hole.

Video Content / Details of website for further learning:

https://www.youtube.com/watch?v=pkikv0RHWTA

Important Books/Journals for further learning:

Vijay.K. Jain “Advanced Machining Processes” Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 212-213

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L - 44

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : .R.K.Udhayakumar

Unit : **V**[Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Electron beam machining – material removal rate

Introduction :

Electron beam machining is a thermal process used for metal removal during the machining process. In the electrical beam machining, electrical energy is used to generate the electrons with high energy. In the Electron Beam Machining process, a high velocity focused beam of electrons are used to remove the metal from the workpiece. These electrons are traveling at half the velocity of light i.e., 1.6 x 10^8 m / s. This process is best suited for the micro-cutting of materials.

Prerequisite knowledge for Complete learning of Topic:

Electron beam density

Heat generation

Metal cutting

Material removal rate (MRR)

Detailed content of the Lecture:

In this process, the material is removed with the help of a high velocity (travelling at half the speed of light, i.e. 160,000 km/sec.) focused stream of electrons which are focused magnetically upon a very small area.

These heat and raise the temperature locally above the boiling point and thus melt and vaporise the work material at the point of bombardment. This process is best suited for micro-cutting of material (in milligram/sec) because the evaporated area is a function of the beam power and the method of focusing which can be easily controlled.

Material Removal Technique – High speed electrons impinge on surface and kinetic energy of electrons produces intense heating to melt or vaporise the metal.

ii. Voltage – 150 kV iii. Electron velocity – 228 x 1000 km/sec. iv. Power density – 6500 billion W/mm^2 v. Operations performed – Annealing, welding, or metal removal by cutting narrow slots, drilling holes of 25—125 μm in 1.25 mm thick shells. Complex contours possible by deflection by coils vi. Medium – Vacuum (10^{-5} mm Hg) vii. Materials of workpiece – All materials viii. Material removal rate – 10 mm^3/min (max) ix. Specific power consumption – 500 W/mm^3 min x. Limitations – Not suitable for large workpieces. Small crates produced on beam incident side of work. A little taper produced on holes.
Video Content / Details of website for further learning: https://www.youtube.com/watch?v=pkikv0RHWTA
Important Books/Journals for further learning: Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 191

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L - 45

MECH

IV / VII

Course Name with Code : **Unconventional Machining process**

Course Faculty : R.K.Udhayakumar

Unit : **V**[Thermal energy based processes] **Date of Lecture:**

Topic of Lecture: Electron beam machining applications

Introduction :

Electron beam machining is a thermal process used for metal removal during the machining process. In the electrical beam machining, electrical energy is used to generate the electrons with high energy. In the Electron Beam Machining process, a high velocity focused beam of electrons are used to remove the metal from the workpiece. These electrons are traveling at half the velocity of light i.e., 1.6 x 10^8 m / s. This process is best suited for the micro-cutting of materials.

Prerequisite knowledge for Complete learning of Topic:

Electron beam generation

Beam density

Metal cutting operation

Detailed content of the Lecture:

1. EBM is mainly used for micro-machining operations on thin materials.
2. These operations include drilling, perforating, slotting, and scribing, etc.
3. Drilling of holes in pressure differential devices used in nuclear reactors, aircraft engines, etc.
4. It is used for removing small broken taps from holes.
5. Micro-drilling operations (up to 0.002 mm) for thin orifices, dies for wire drawing, parts of electron microscopes, injector nozzles for diesel engines, etc.
6. A micromachining technique known as "Electron beam lithography" is being used in the manufacture of field emission cathodes, integrated circuits, and computer memories.
7. It is particularly useful for machining of materials of low thermal conductivity and high melting point.
8. To make complex shape accurate workpieces, the EBM machine parameters like beam power, focus, and mechanical motions are numerically controlled.
9. This process is commonly used for making fine gas orifices in space nuclear reactors, very fine holes in dies, metering holes in injector nozzles, etc.

10. It is being used for pattern generation in case of integrated circuit fabrication.
11. This process is used for making thousands of holes (dia. < 1 mm) in very thin plates used for turbine engine combustor dome, filters used in textile and food processing industries and similar other applications.
12. This process is also used in industries like aerospace, insulation, chemical and others

Video Content / Details of website for further learning:

https://www.youtube.com/watch?v=pkikv0RHWTA

Important Books/Journals for further learning:

Vijay.K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007. Page No: 191

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