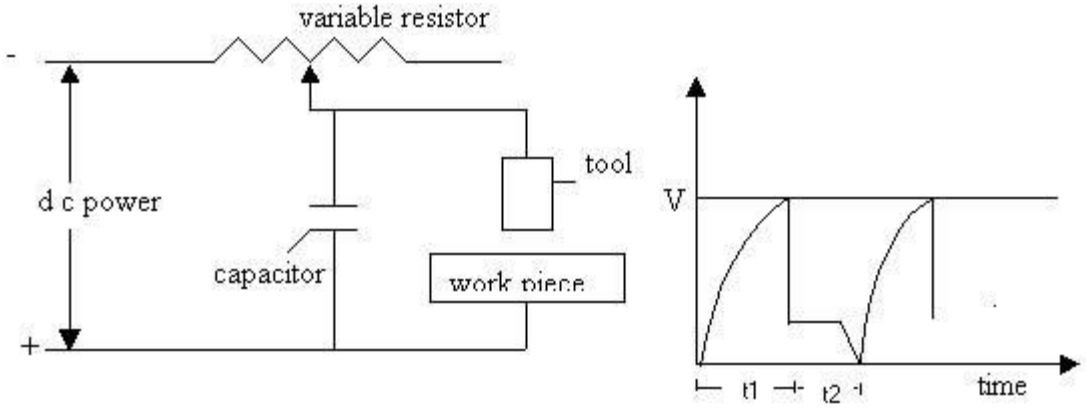
UNIT –III
ELECTRICAL ENERGY BASED PROCESSES
PART - A (2 MARKS)

1. **Sketch the relaxation circuit of EDM.**



2. **State the principle of EDM.**

In Electrical discharge Machining process, metal is removed by producing powerful electric spark between the tool and the work piece i.e. the tool is connected with cathode and the work piece is connected with anode.

3. **List out importance of EDM process.**
   - It gives high surface finish
   - Complicated shapes can be effectively machined
   - Tool manufacturing and storage is avoided
   - It is economical for small batch production.
4. **What are the functions of dielectric fluid used in EDM?**
   - It acts as an insulating medium
   - It cools the spark region
   - It carries away the eroded metal particles
   - It remains electrically non-conducting until the required breakdown voltage has been reached.
5. **Name some of the tool materials used in EDM.**

   The following are the commonly used tool material for EDM,
   - Copper
   - Graphite
   - Copper-Tungsten
6. **What is the necessity of maintaining a constant gap in EDM process?**

   The following are the reasons for maintaining a gap in EDM,
   - Spark discharge frequencies range from 200-500kHz pulses per sec at voltage level of 30-250V
   - The current density in the discharge of the channel is 10,000A/cm^2
7. **List the applications of EDM?**
   - Production of complicated and irregular shaped profiles.
   - Thread cutting in jobs.
   - Drilling of micro holes.
   - Helical profile drilling
8. **List recent developments in EDM process.**
   - Electrical discharge machines change from using relaxation circuits to faster and more efficient impulse circuits.
   - Instead of using copper as electrode, harder tungsten copper is preferred.
9. **List out the limitations of EDM.**
   - It is suitable only for machining small work pieces.

- Electrode wear and over cut are serious problems.
- Metal removal rate is slow.
- Power requirement is very high.

10. What is the function of servo control system in EDM?

The function of servo mechanism is to maintain very small gap, known as 'spark gap' in the ranges of 0.005 to 0.05 mm between the work piece material and the tool.

11. List the process capabilities of EDM process.

- Operating parameters.
- Surface finish.
- Current Density.

12. State the functions of dielectric medium used in EDM.

- It acts as an insulating medium.
- It cools the spark region and helps in keeping the tool and work piece cool.
- It carries away the eroded metal particles along with it.

13. What are the types of power generator circuits used in EDM?

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

14. What are the desirable properties for dielectric fluid?

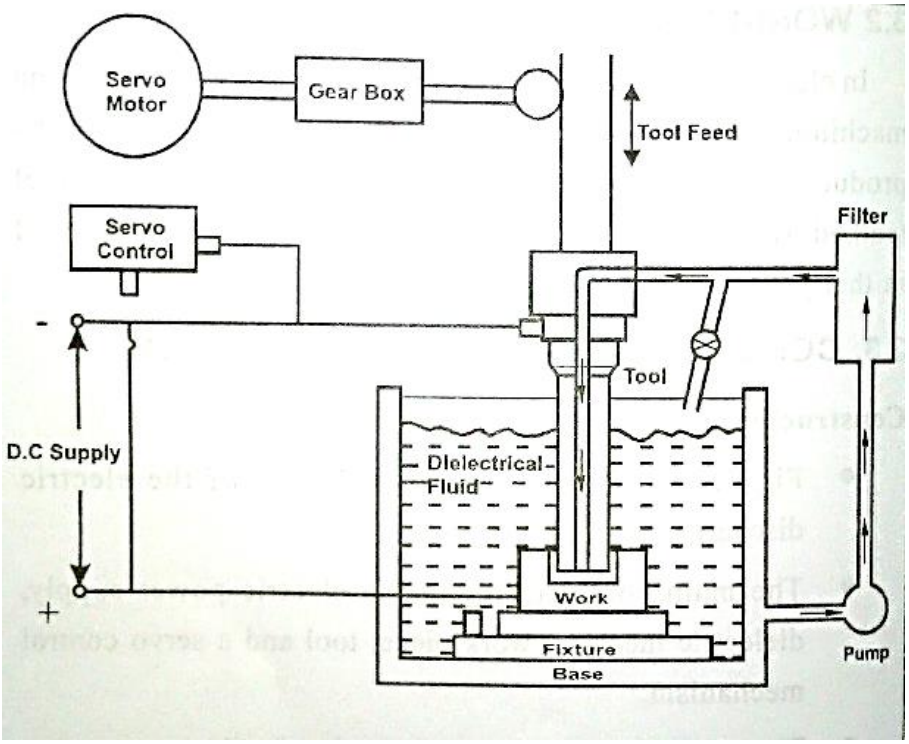
- Low viscosity and good wetting capacity.
- Chemically neutralized.
- High flash point.
- Cannot emit any toxic vapours.

15. What are the feasible dielectric flushing techniques applicable in EDM process?

- Pressure flushing
- Suction flushing
- Side flushing

PART –B (16 MARKS)

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



Principle:

In electrical discharge machining, metal is removed by producing powewrful electric spark discharge between the tool (cathode) and the work material (anode). This is the principle followed in this process.

Construction:

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

Working:

- When the D.C supply is given to the circuit, spark is produced across the gap between the tool and the workpiece.
- When the voltage across the gap becomes sufficiently larger (more than 250 V), the high power spark is produced. So, the dielectric breaks down and electrons are emitted from the cathode (tool) and the gap is ionized.
- This spark occurs in an interval of 10 to 30 microseconds and with a current density of 15-500A per mm^2 approximately. So, thousands of spark-discharge occur per second across the gap between the tool and the work, which results in increasing temperature of about 10,000°C.
- At this high pressure and temperature, workpiece metal is melted, eroded and some of it is vaporised. In this way the metal is removed from the workpiece.
- The removed fine material particles are carried away by dielectric fluid circulated around it.
- The metal removal rate depends on the spark gap maintained. If anode and cathode are made of same material, it has been found that the greatest erosion takes place at anode. Therefore, in order to remove maximum metal and have minimum wear on the tool, the tool is made as cathode the workpiece as anode.
- When the voltage drops to about 12 volts, the spark discharge extinguishes and the dielectric fluid once again

.

Advantages:

- It can be used for machining various materials such as tungsten carbides, electrically conductive materials and other hard materials.
- It gives good surface finish.
- Machining of very thin section is possible.
- It does not leave any chips or burrs on the workpiece.
- It is well suited for complicated components.

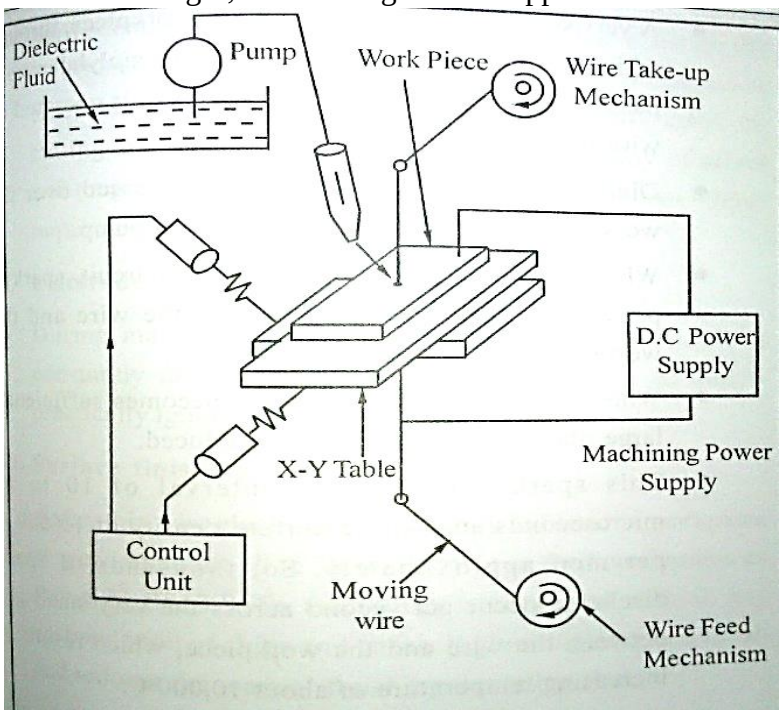
Disadvantages:

- It is only used for machining electrically conductive materials. So non-metallics such as plastics, ceramics or glass cannot be machined by EDM.
- It is suitable only for machining small workpieces.
- Electrode wear and over cut are serious problems.
- Perfectly square corners cannot be made by EDM process.
- Metal removal rate is slow.

Applications:

- Production of complicated and irregular shaped profiles.
- Thread cutting in jobs.
- Drilling of micro holes.
- Helical profile drilling.

2. Explain the principle, construction and working of Wire-cut EDM (WEDM) with a neat sketch. Also, State some of the advantages, disadvantage and its application.



Construction:

- A very thin wire (.02 to 0.3mm) made of brass or molybdenum having circular cross section is used as a electrode (tool).
- The wire is stretched and moved between two rollers. The part of wire is eroded by the spark.
- The prominent feature of a moving wire is that a complicated cutout can easily machined without using an electrode.

- It consist of
  i. Workpiece movement control unit.
  ii. Workpiece mounting table.
  iii. Wire drive section for accurately moving the wire at constant tension.
  iv. Dielectric fluid supplying unit
  v. Power supplying unit.

Working:

- Workpiece to be machined is mounted on the table which is operated by control unit.
- A very small hole is predrilled in the workpiece, through which a very thin wire made of brass or molybdenum is passed as shown in figure., and this wire is operated by wire feed mechanism.
- Dielectric fluid (distilled water) is passed over the workpiece and the wire (tool) by using pump.
- When the D.C. supply is given to the circuit, spark is produced across the gap between the wire and the workpiece.
- When the voltage across the gap becomes sufficiently large, the high power spark is produced.
- This spark occurs in an interval of 10-30 microseconds and with a current density of 15-500 A per square mm approximately. So, thousands of spark discharge occur per second across the very small gap between the wire and the workpiece, which results in increasing temperature of about 10,000^{o}C.
- At this high pressure and temperature, workpiece metal is melted, eroded and some of it is vaporised. The metal is thus removed in this way from the workpiece.
- The removed fine material particles are carried away by dielectric fuid circulated around it.

Advantages:

Straight holes

The electrode wire is maintained at optimum tension by a unique wire tension control mechanism. So, it prevents taper holes, barrel shaped holes, wire breakage and wire vibration.

Rejection

Rejection of materials is minimized due to initial planning and checking the program.

Economical

Since most of the programming can be easily done, it is economical for small batch production, including prototypes.

Cycle time

Cycle time for die manufacturing is shorter, as the whole work is done on one machine.

Inspection time

Inspection time for wire cut EDM process is reduced due to single piece construction dies with high positioning accuracy.

Disadvantages:

Capital cost is high.

Cutting rate is slow.

It is not suitable for large workpieces.

3. Briefly explain the following terms.

a. Types of flushing (4)

There are three types of flushing methods followed in EDM process. They are

1. Pressure flushing
2. Suction flushing
3. Side flushing

The pressure flushing is shown in figure, which is nothing but pressurized fluid flushes from the bottom of the work table and flushes upwards through the gap between tool and workpiece. In suction flushing, the dielectric fluid enters from outside through the gap between tool and workpiece in downward direction which flushes out in the bottom as shown in figure. Side flushing, the name itself gives the meaning that it flushes in the overall sides of tool and workpiece.

b. Types of spark generators (4)

Refer Question No. 4

c. Types of electrode holders (4)

d. Properties of dielectric fluid (4)

- It acts as an insulating medium.
- It cools the spark region and helps in keeping the tool and workpiece cool.
- It carries away the eroded metal particles along with it.
- It maintains a constant resistance across the gap.
- It remains electrically non-conducting until the required breakdown voltage has been reached.
- It breakdown electrically in the shortest possible time once the breakdown voltage has been reached.
- The dielectric fluid must circulate freely between the tool and workpiece.
- It must not be a hazardous to operators or corrosive to equipment.

4. Explain the four control circuits used in EDM process with neat sketch.

- Power generator is one of the most important part of an electrical discharge machining processes.
- Its primary function is to convert an alternating current (AC) into a pulsed direct current (DC) which is required to produce the unidirectional spark discharges between the gap of the tool and workpiece. A rectifier is used to convert the AC into DC.
- The most commonly used spark generating circuits are given below

1. Resistance - Capacitance circuit (RC circuit) or Relaxation circuit.
2. R-C-L circuit.
3. Rotary pulse generator circuit.
4. Controlled pulse generator circuit.

i. Relaxation circuit

Fig 3.3 shows the operation of Resistance – Capacitance (R-C) generator circuit. This type of generators are quite common because of its simplicity and lower cost. In this system, Direct Current (D.C) is flowing through a resistor (R) and it charges the capacitor (C). The charged capacitor is connected to the machine. When the voltage across the capacitor is sufficiently high (50 to 200V), dielectric medium breakdown occurs. So, the dielectric medium between the tool and workpiece is ionized and spark takes place. Millions of electrons are developed in each spark. During sparking period, the voltage falls and it again starts rising (since the capacitor is charged again) as shown in fig. 3.3.

Energy released per spark $= E = \frac{1}{2} C.V_d^2$

Where

C = Capacitor value

V_d = Discharge voltage

$= Vo [1 - \exp [-t/R_c]]$

V_o = D.C. Source voltage

For maximum power delivery, the discharge voltage (V_d) should be 75% of the supply voltage (V_o)

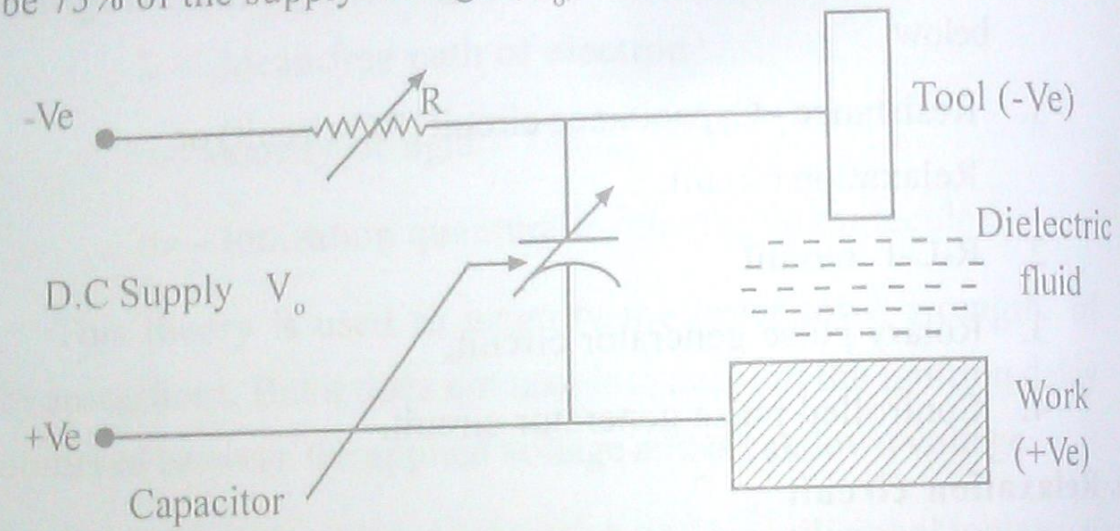


Fig. 3.3 Basic R-C Relaxation circuit

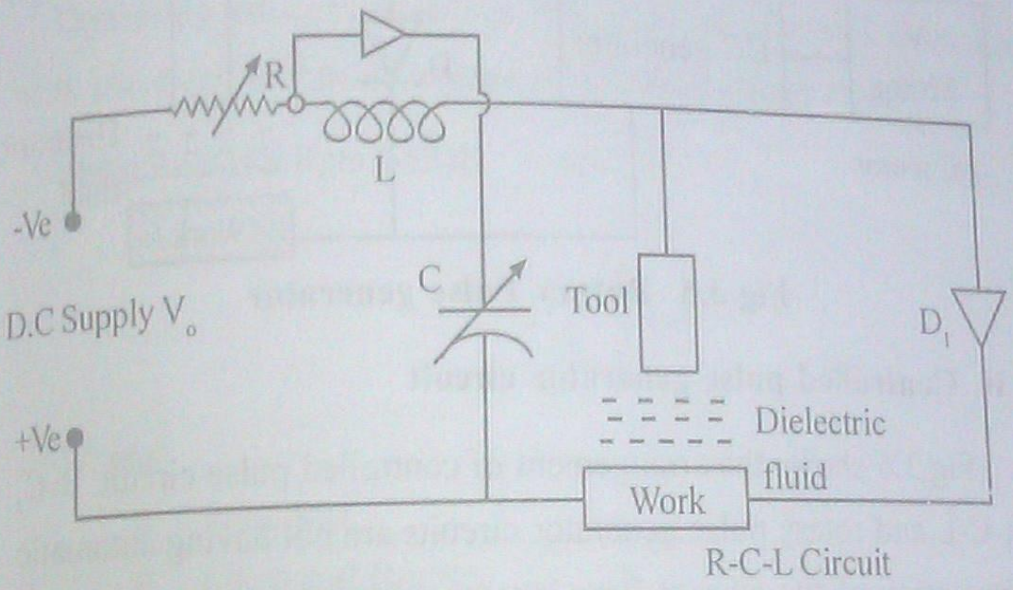
Drawbacks of Relaxation circuit

1. Though the discharge current in a relaxation circuit reaches a high value, it is of very short duration.
2. Since the time for charging the capacitor is high, the use of high frequencies is limited.

II. R-C-L circuit

In the relaxation circuit, metal removal rate increases as R is decreased. But R cannot be decreased below a critical value

If R decreases below a critical value, arcing will take place instead of sparking. Further, the capacitor charging time in R-C circuit is much higher than discharging time. Therefore an inductance (L) is included in the charging circuit. This R-C-L circuit is shown in Fig.3.4.



R-C-L Circuit

R- Resistance C- Capacitance L - Inductance

Fig. 3.4 Basic Principle R-C-L Circuit

iii. Rotary pulse generator

The introduction of pulse generator has overcome the drawbacks of R-C and R-C-L circuits

R-C and R-L-C circuits yield low metal removal rate. Therefore, rotary pulse generator is used for spark generation. It yields high metal removal rate, low tool wear and more precise control of parameters. Fig. 3.5 shows the schematic diagram of rotary impulse generator circuit. In this circuit, the capacitor (C) is discharged through the diode during the first half cycle. During the next half cycle, the sum of voltages generated by the generator and the charged capacitor is applied to the work- tool gap. This

arrangement gives more metal removal rate, but surface finishing is poor.

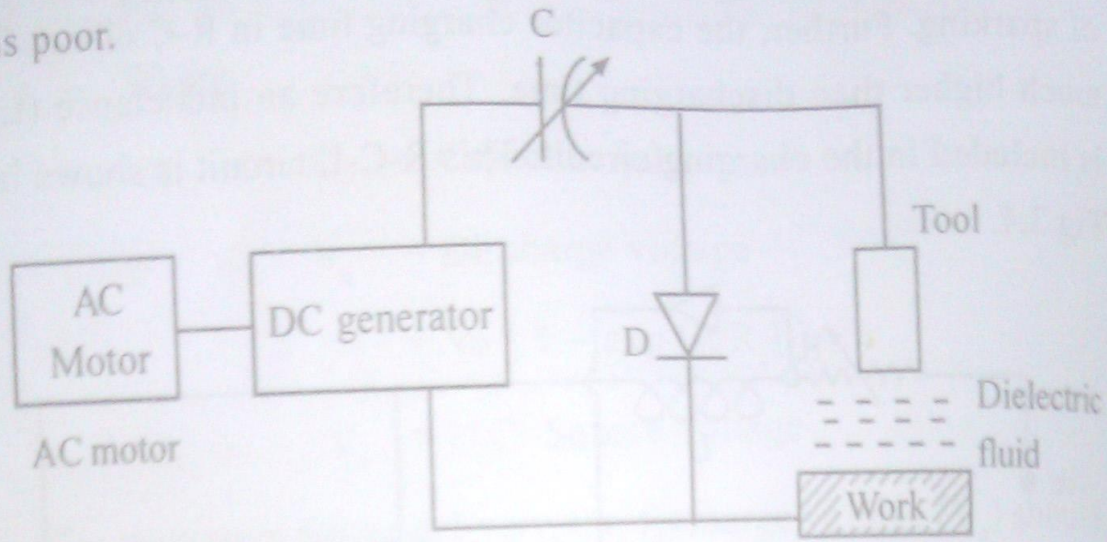


Fig 3.5 Rotary Pulse generator

iv. Controlled pulse generator circuit

Fig 3.6 shows the arrangement of controlled pulse circuit. R-C, R-C-L and rotary pulse generator circuits are not having automatic prevention of the current flow incase a short circuit is developed. To obtain such an automatic control, a vacuum tube or a transistor is used as switching device as shown in Fig. 3.6.

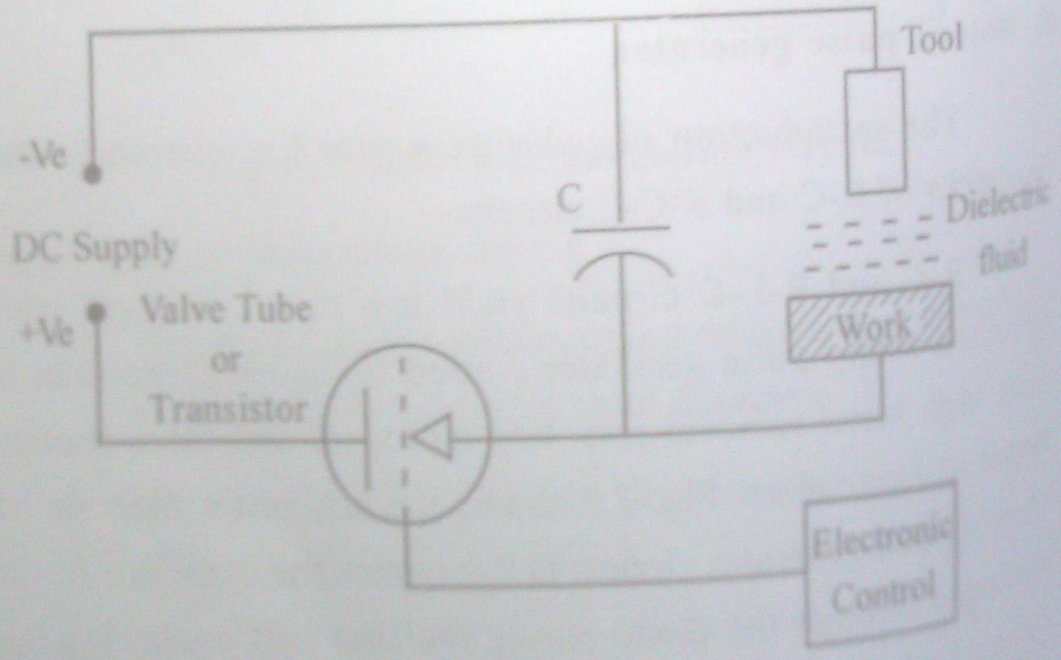


Fig 3.6 Controlled Pulse Circuits

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

The following factors influences the process parameters in EDM processes

1. Operating parameters

Operating process involves the removal of metal from the work piece and tool as a measure of electrical energy input.

Metal Removal Rate (MRR) $= \phi(E)\, f$

$$= \phi \int_0^{\tau_p} vi\, dt$$

Where

ϕ - Function

E - Electrical Energy

v - Voltage

i - Instantaneous current

dt - Time interval

f - Torque

τ_p - Pulse width

Tool Wear Rate (TWR) $= \psi(E)\, f = \psi \int_o^{\tau_p} vidt$

Based on the above considerations, it is well understood that the MRR, and TWR are governed by the following

i. Energy content of the pulses.

ii. The rate at which the energy supplied.

iii. Servo sensitivity.

iv. Gap width and

v. Dielectric parameters.

Tool wear rate is required to calculate tooling cost, machining accuracy and estimate the time of machining for a desired depth of cut.

There are three types of wear observed in the tool (Electrode) which is shown in fig. 3.7

They are

1. End wear
2. Corner wear
3. Side wear

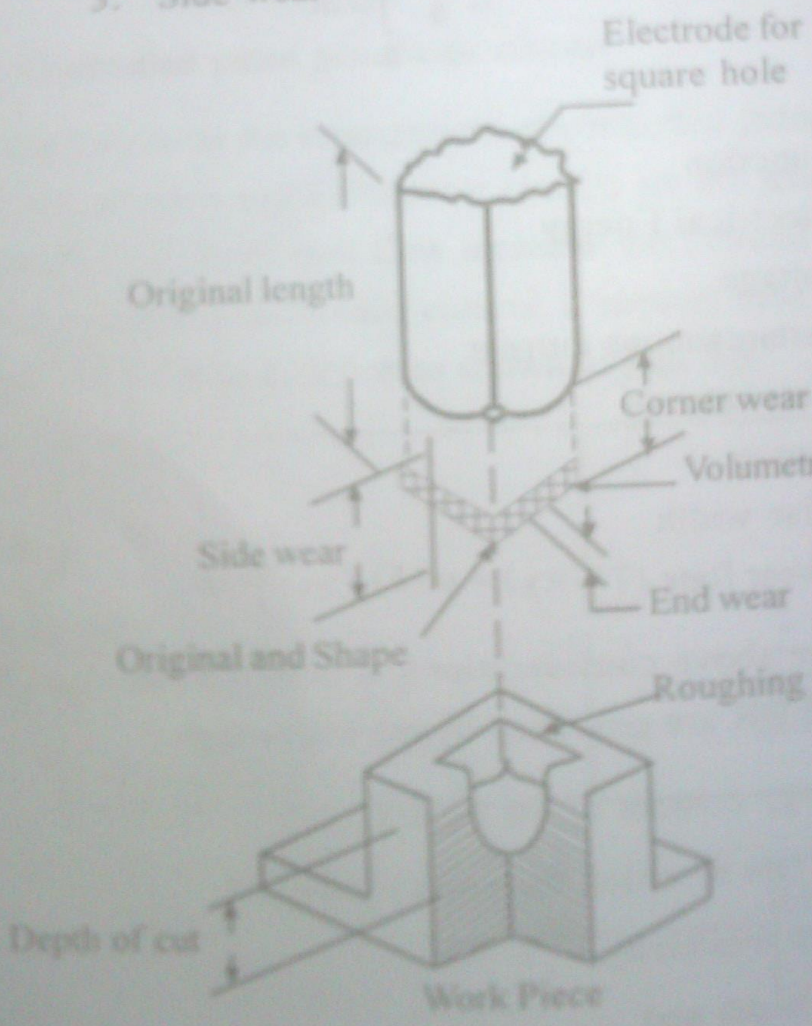


Fig. 3.7. Types of Electrode Wear in EDM Process

2. Taper

Tapering effect is observed due to the side sparks which is shown in fig. 3.8. Under high dielectric pollution, side sparks are more pronounced as compared to frontal sparks

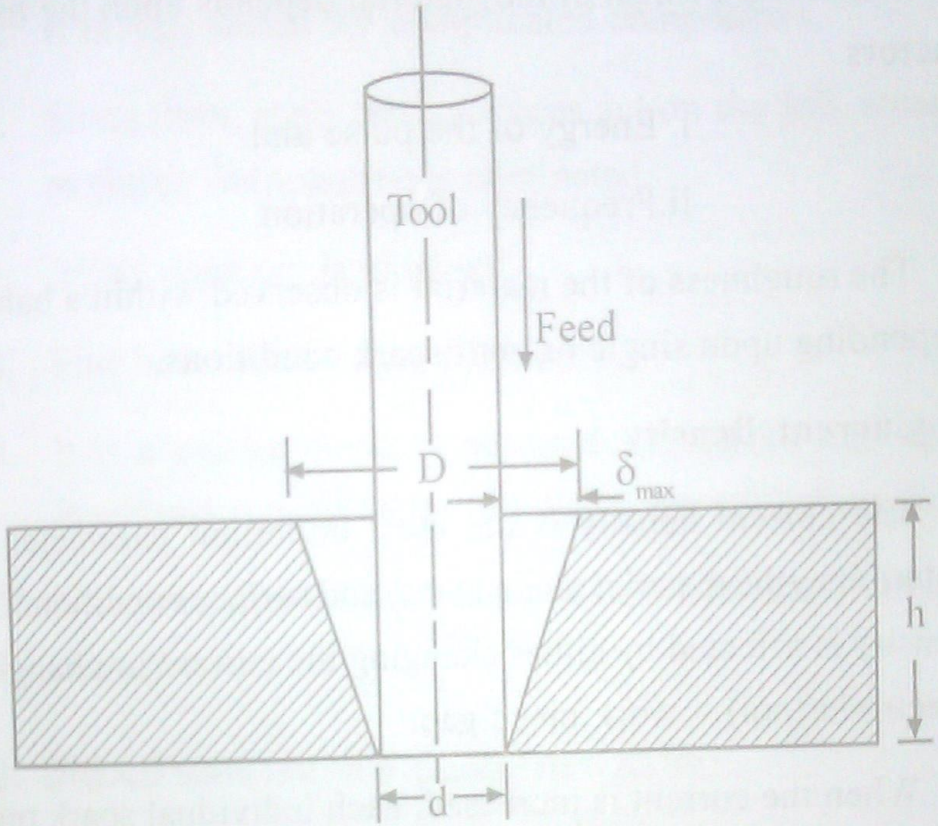


Fig. 3.8 Scheme of Taper

In this case, over cut at any instant is given by

$$\delta = C_3 \left(\frac{\pi}{4} d^2 \right) h$$

At maximum,

$$\delta_{max} = C_3 \left(\frac{\pi}{4} D^2 \right) h$$

where

h – Depth of machining at any instant.

$$\Rightarrow \quad Taper\ T_p = \frac{D-d}{2h} = \frac{\delta_{max}}{h} = \frac{C_3 \frac{\pi}{4} D^2}{h}$$

$$T_p = C_3 \frac{\pi}{4} D^2$$

3. Surface finish

The surface finish of the material depends upon the following factors

i. Energy of the pulse and

ii. Frequency of operation

The roughness of the material is observed within a bandwidth depending upon single or multispark conditions.

4. Current Density

The current density is the most important parameter which determines the material removal rate and surface condition. Current density is affected by either changing the current or changing the electrode(tool) – work piece gap.

When the current is increased, each individual spark removes a larger crater of metal from the workpiece. But it also increases surface roughness. Increasing spark frequency results in decrease in surface roughness and reduces the removal of crater of metal from the work piece.

The gap between the electrode (tool) and workpiece is determined by the spark voltage and current. A small gap produces more accuracy with a better surface finish and slower metal removal rate.

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

Advantages:

- It can be used for machining various materials such as tungsten carbides, electrically conductive materials and other hard materials.
- It gives good surface finish.
- Machining of very thin section is possible.
- It does not leave any chips or burrs on the workpiece.
- It is well suited for complicated components.
- Since there is no cutting forces acting on the job, error due to elastic deformation is eliminated.
- High accuracy is obtained.
- Fine holes can be easily drilled.
- It is quicker process. So, harder materials can also be machined at much faster than conventional machining.
- The process once setup does not need constant operator's attention.

Disadvantages:

- It is only used for machining electrically conductive materials. So non-metallics such as plastics, ceramics or glass cannot be machined by EDM.
- It is suitable only for machining small workpieces.
- Electrode wear and over cut are serious problems.
- Perfectly square corners cannot be made by EDM process.
- Metal removal rate is slow.
- Power requirement is very high.
- In many cases, the surface machined has been found to have micro cracks.

Applications:

- Production of complicated and irregular shaped profiles.
- Thread cutting in jobs.
- Drilling of micro holes.
- Helical profile drilling.
- Curved hole drilling.
- Resharpening of cutting tools and broaches.
- Remachining of die cavities without annealing.

6. i) What are the 8 basic requirements of tool material? (8)

- It should have low erosion rate.
- It should be electrically conductive.
- It should have good machinability.
- Melting point of the tool should be high.
- It should have high electron emission.
- It should have a less tear and wear then only the tool have long life.
- The tool wear ratio should be maintained in low level to get long life of tools.
- The selected tool material should have low metal removal rate.

ii) Compare EDM and ECM process. (8)

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

7. i) List out advantages, disadvantages and applications of EDM (8)

Advantages:

- It can be used for machining various materials such as tungsten carbides, electrically conductive materials and other hard materials.
- It gives good surface finish.
- Machining of very thin section is possible.
- It does not leave any chips or burrs on the workpiece.
- It is well suited for complicated components.
- Since there is no cutting forces acting on the job, error due to elastic deformation is eliminated.
- High accuracy is obtained.
- Fine holes can be easily drilled.
- It is quicker process. So, harder materials can also be machined at much faster than conventional machining.
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Disadvantages:

- It is only used for machining electrically conductive materials. So non-metallics such as plastics, ceramics or glass cannot be machined by EDM.
- It is suitable only for machining small workpieces.
- Electrode wear and over cut are serious problems.
- Perfectly square corners cannot be made by EDM process.

- Metal removal rate is slow.
- Power requirement is very high.
- In many cases, the surface machined has been found to have micro cracks.

Applications:

- Production of complicated and irregular shaped profiles.
- Thread cutting in jobs.
- Drilling of micro holes.
- Helical profile drilling.
- Curved hole drilling.
- Resharpening of cutting tools and broaches.
- Remachining of die cavities without annealing.

ii) List any 8 Characteristics of EDM process. (8)

Metal removal technique	: By using powerful electric spark
Work material	: Electrically conductive materials and alloys
Tool material	: Copper, Yellow brass, Alloy of zinc, Copper tungsten, etc.
Metal removal rate	: 15-80 mm3/s
Spark gap	: 0.005 - 0.05 mm
Spark frequency	: 200- 500 kHz
Volts	: 30 – 250 V
Current	: 5- 60 A
Temperature	: 10,000^{o}C
Dielectric fluid	: Petroleum based hydrocarbon fluids, paraffin, white spirit, etc.,

8. i) Differentiate EDM process and WEDM process. (8)

S.No.	EDM PRCOESS	WEDM PROCESS
1.	Very thin wire made of brass or molybdenum is used as electrode (tool).	Expensive alloy of silver and tungsten are used as electrode (tool) which are traditionally made by cutting and grinding
2.	The whole workpiece is not submerged in dielectric medium instead, the working zone alone is supplied with a co-axial jet of dielectric medium.	The whole workpiece is submerged in dielectric medium.
3.	It is easy to machine complex two dimensional profiles.	It is difficult to cut complex two dimensional profiles.
4.	It is easy to drill holes of micro sizes	It is difficult to drill holes of micro sizes
5.	Metal removal rate (MRR) is slow when compare to WEDM.	Metal removal rate (MRR) is high.
6.	Perfectly square corners cannot be made. Machining of very thin sections is possible	Perfectly square corners can be made. Machining of very thin sections is not possible or difficult.
7.	It gives good surface finish.	It needs surface finishing operation.
8.	It is quicker process when compare to WEDM.	It is moderate process.

ii) List out the features and limitations of WEDM process. (8)

Features:

1. Manufacturing Electrode

In this process a very thin wire made of brass or molybdenum is used as the electrode (tool) to machine the workpiece material. So, there is no need for manufacturing electrodes (as in EDM) which are traditionally made by cutting and grinding by using an expensive alloy of silver and tungsten. This feature is used to reduce the man- hour requirements and ensures greater economy.

2. Electrode wear

During machining process, the wire electrode (tool) is constantly fed into the workpiece. So the wear of tool is practically ignored.

3. Surface finishing

A very thin wire electrode is constantly fed into the workpiece at speed of about 10-30 mm/s by wire feed mechanism. So machining is continued without any accumulation of chips and gases. It gives high surface finish and reduces the manual finishing operating time.

4. Complicated shapes

By using program, complicated and very minute shapes can be efficiently machined. So there is no need of skilled operators.

5. Time utilization

Since all the machine motions of wire cut EDM processes are controlled by NC, it can be operated throughout the day without any fire hazards.

6. Straight holes

The electrode wire is maintained at optimum tension by a unique wire tension control mechanism. So, it prevents taper holes, barrel shaped holes, wire breakage and wire vibration.

7. Rejection

Rejection of materials is minimized due to initial planning and checking the program.

8. Economical

Since most of the programming can be easily done, it is economical for small batch production, including prototypes.

9. Cycle time

Cycle time for die manufacturing is shorter, as the whole work is done on one machine.

10. Inspection time

Inspection time for wire cut EDM process is reduced due to single piece construction dies with high positioning accuracy.

Limitations:

- Capital cost is high.
- Cutting rate is slow.
- It is not suitable for large workpieces.

9. i) What are the functions of dielectric fluid?

- It acts as an insulating medium.
- It cools the spark region and helps in keeping the tool and workpiece cool.
- It carries away the eroded metal particles along with it.
- It maintains a constant resistance across the gap.
- It remains electrically non-conducting until the required breakdown voltage has been reached.
- It breakdown electrically in the shortest possible time once the breakdown voltage has been reached.
- The dielectric fluid must circulate freely between the tool and workpiece.

- It must not be a hazardous to operators or corrosive to equipment.

ii) Explain the process parameters which influence MRR & surface finish of EDM process.

Refer Question No. 5 (i)

10. Briefly explain the following terms of WEDM process.

a. Dielectric system

b. De ionized water

c. Positioning system

d. Wire drive system

Refer Question No.2