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DEPARTMENT OF MECHANICAL ENGINEERING -ATME-

Introduction to Non-Traditional Machining BME405A

ELECTRICAL DISCHARGE MACHINING - EDM

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Module - 4

ELECTRICAL DISCHARGE MACHINING (EDM)

- Introduction, mechanism of metal removal, EDM equipment: spark erosion generator (relaxation type),
- Dielectric medium-its functions & desirable properties, electrode feed control system.
- Flushing types; pressure flushing, suction flushing, side flushing, pulsed flushing.
- EDM process parameters: Spark frequency, current & spark gap, surface finish, Heat Affected Zone.
- Advantages, limitations & applications of EDM
- Electrical discharge grinding, Traveling wire EDM.

INTRODUCTION

- Electrical Discharge Machining (EDM) is a non-traditional machining process used to remove material from electrically conductive workpieces using controlled electrical discharges (sparks).
- In this process, both the tool (electrode) and the workpiece are submerged in a dielectric fluid and connected to a DC power supply.
- When a voltage difference is applied, electrical sparks occur between the tool and the workpiece, generating intense localized heat that melts and vaporizes small portions of the material. The molten debris is then flushed away by the dielectric fluid.
- EDM is especially useful for machining hard, complex, and precise shapes that are difficult to produce by conventional methods.
- Common applications include the manufacturing of dies, molds, and intricate components in aerospace, automotive, and tool-making industries.

NEED FOR EDM

- **Machining Hard Materials:**

EDM is essential for machining very hard and tough materials such as carbides, hardened steels, titanium, and superalloys that cannot be easily cut by conventional methods.

- **Complex and Precise Shapes:**

It enables the production of intricate shapes, fine holes, sharp corners, and delicate contours that are difficult or impossible to achieve with traditional cutting tools.

- **No Mechanical Stresses:**

Since there is no direct contact between the tool and workpiece, there are no cutting forces, vibrations, or mechanical stresses on the material.

- **High Dimensional Accuracy and Surface Finish:**

EDM provides excellent accuracy and surface quality, which is vital for die and mold making industries.

- **Machining of Thin or Fragile Parts:**

It is suitable for machining thin sections or fragile components where conventional methods might cause deformation or damage.

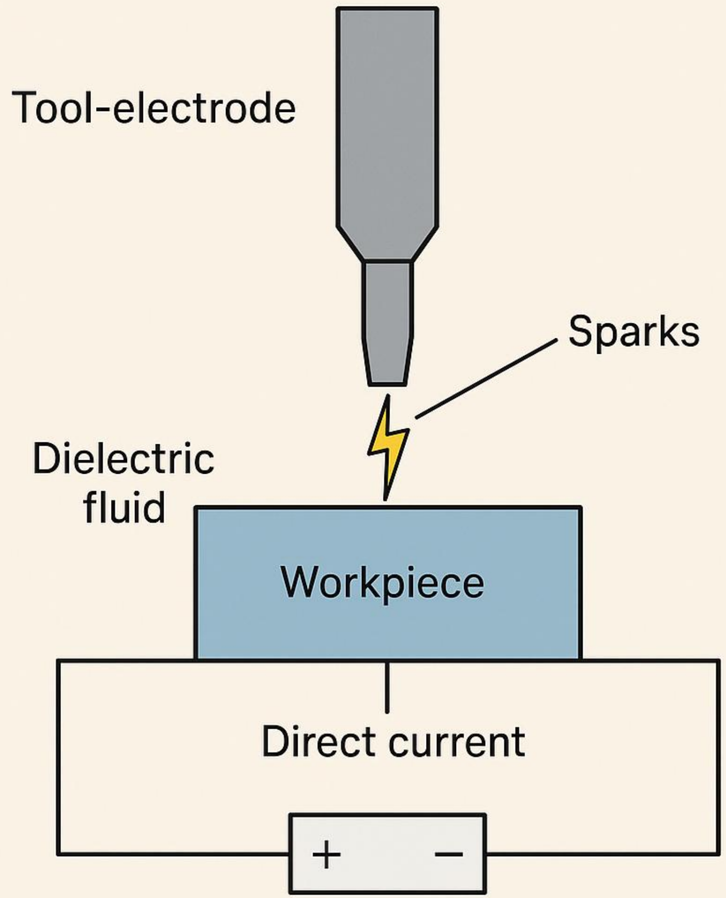
- **Tool Wear Reduction for Hard Materials:**

Conventional tools wear rapidly on hard materials, whereas EDM uses an electrical discharge process, minimizing tool wear.

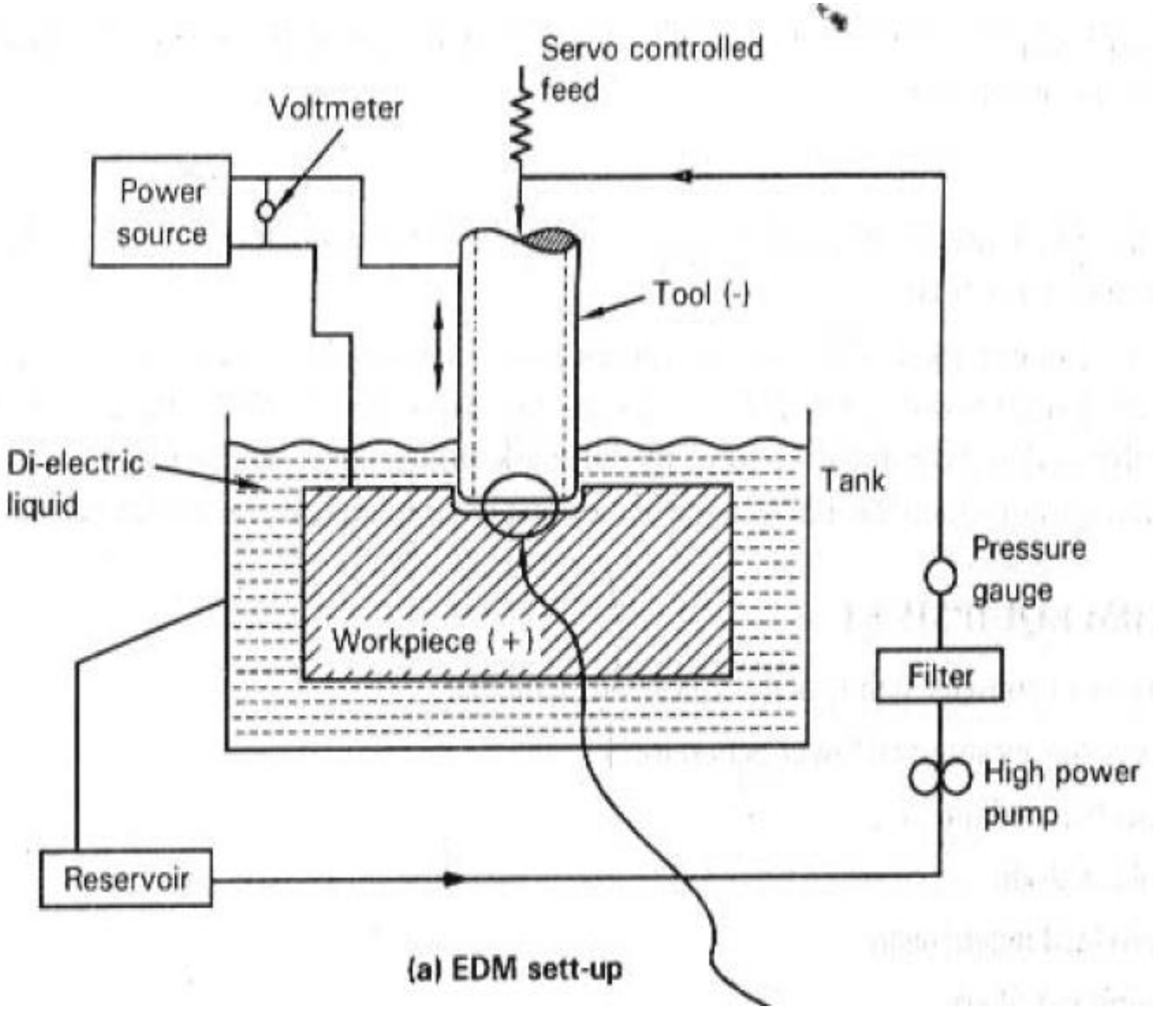
PRINCIPLE OF EDM

- Electrical (or Electric) discharge machining, also referred as spark machining or spark erosion machining is a controlled metal removal process based on the principle of erosive effects of electrical discharges (sparks) taking place between two electrically conducting materials immersed in a dielectric fluid.
- One of the conducting materials is called the tool-electrode, or simply the tool, while the other, the workpiece electrode, or simply the workpiece.
- The shape of the tool is similar to that desired in the workpiece.
- The tool and the workpiece are separated by a dielectric fluid and connected to DC power supply to create a potential difference between the tool and the workpiece.
- When the potential difference is sufficiently high, the dielectric fluid in the gap is ionized under the pulsed application of the direct current, thus enabling a spark discharge to pass between the tool and the workpiece.
- Metal removal from the workpiece takes place due to the erosion caused by the electric spark. The amount of material removed is very small and is flushed away with the continuously flowing fluid. The downward movement of the tool will produce the desired shape on the workpiece.

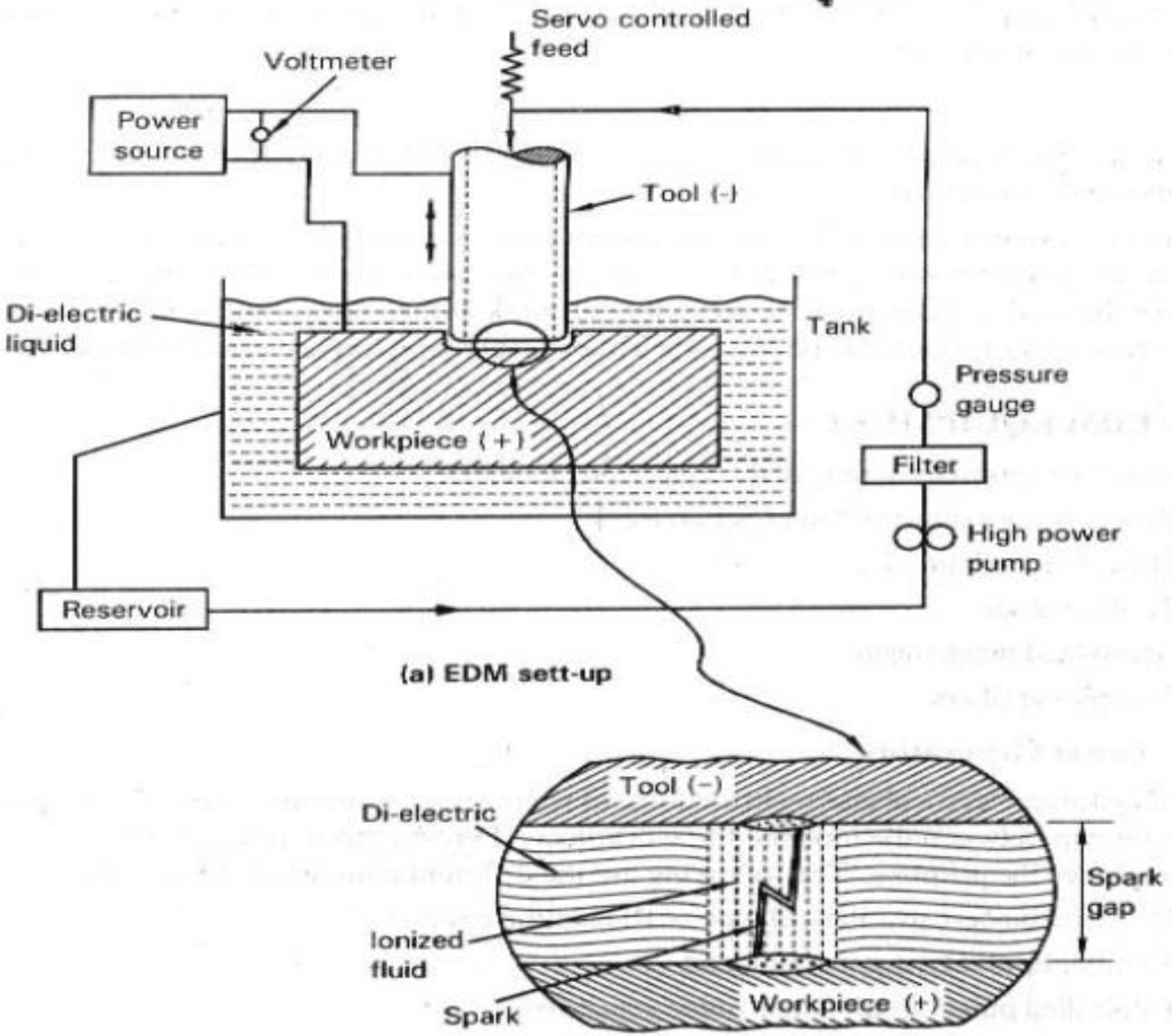
ELECTRICAL DISCHARGE MACHINING (EDM)



- Figure shows the set-up for EDM process. In operation, the tool (shaped electrode) is connected to the –ve terminal (cathode), while the workpiece to the +ve terminal (anode) of the power source.
- The tool and the workpiece are separated by a small gap known as spark gap, filled by the dielectric fluid as shown in figure.
- The spark gap usually ranges from 0.01–0.05 mm.
- When the potential difference between the tool and the workpiece is sufficiently high, a transient spark discharges through the fluid removing a very small amount of material from the workpiece. The mechanism of metal removal is shown in figure.



(a) EDM sett-up


Servo controlled
feed
Voltmeter
Power
source
Tool (-)
Di-electric
liquid
Tank
Pressure
gauge
Workpiece (+)
Filter
High power
pump
Reservoir
Tool (–)
Di-electric
Spark
gap
Ionized
fluid
Spark
Workpiece (+)

(a) EDM sett-up

MECHANISM OF METAL REMOVAL

- Initially, the gap between the tool & the workpiece, which consists of the dielectric fluid, is not conductive. But, under the pulsed application of DC, the dielectric fluid in the gap is ionized, causing the spark to discharge or jump between the tool & the workpiece as shown in figure.
- The spark impinges on the elevated surface of the workpiece at a very high temperature of around 10,000°C causing a small portion of the workpiece to melt and/or vapourize as shown in figure.
- The forces of electric and magnetic fields caused by the spark produce a tensile force resulting in tearing of particles of molten and softened metal from the worksurface thereby causing metal removal to take place. The continuously flowing fluid flushes away the excess material removed from the machining gap.

EDM EQUIPMENT

EDM Equipment consists of mainly of the following elements

1. Power Supply Source
2. Die Electric Medium
3. Tool Electrode
4. Servo Feed Mechanism
5. Pumps and Filters

EDM EQUIPMENT

Power Supply Source

In the EDM process, **short duration electrical energy impulses** must be supplied to the machining gap between the tool and the workpiece. **Direct current pulse power generators** are used to achieve this.

The different types of EDM generators are:

- **RC (resistance-capacitance) type** or **Relaxation generator**
- **Rotary impulse type generator**
- **Controlled pulse circuit** (static pulse generator)

EDM EQUIPMENT

DIE ELECTRIC MEDIUM

In the Electrical Discharge Machining (EDM) process, the tool and the workpiece are separated by a dielectric fluid. This fluid may consist of deionized water, transformer oil, paraffin oil, kerosene, lubricating oils, or other petroleum distillate fractions.

Functions of Dielectric Fluid

The dielectric fluid performs several essential functions in the EDM process:

1. **Spark Conduction:** It acts as a spark conductor, concentrating the heat energy to a very narrow region on the work surface.
2. **Flushing Medium:** It helps to carry away the tiny metal particles removed during machining.
3. **Cooling Medium:** It quenches the spark and cools the tool electrode during machining.

EDM EQUIPMENT

DIE ELECTRIC MEDIUM

Requirements of a Good Dielectric Fluid

An ideal dielectric fluid for EDM should possess the following characteristics:

1. It should have **sufficiently high dielectric strength** to remain electrically non-conductive until the required breakdown voltage is reached.
2. It should **deionize rapidly** after the spark discharge has taken place.
3. It must be **chemically neutral**, ensuring that it does not attack the tool, workpiece, or other machine components.
4. It should possess a **high flash point** to avoid any fire hazards.
5. It must have **high viscosity** for easy circulation and good wetting capacity.
6. Should not emit any Toxic vapors or unpleasant Oduors.
7. Provide an effective cooling medium to the tool.
8. Be cheap and easily available

FLUSHING METHODS

Flushing is the process of circulating the dielectric fluid between the tool electrode and the workpiece in a proper way so as to maintain clean environment for efficient machining of the workpiece.

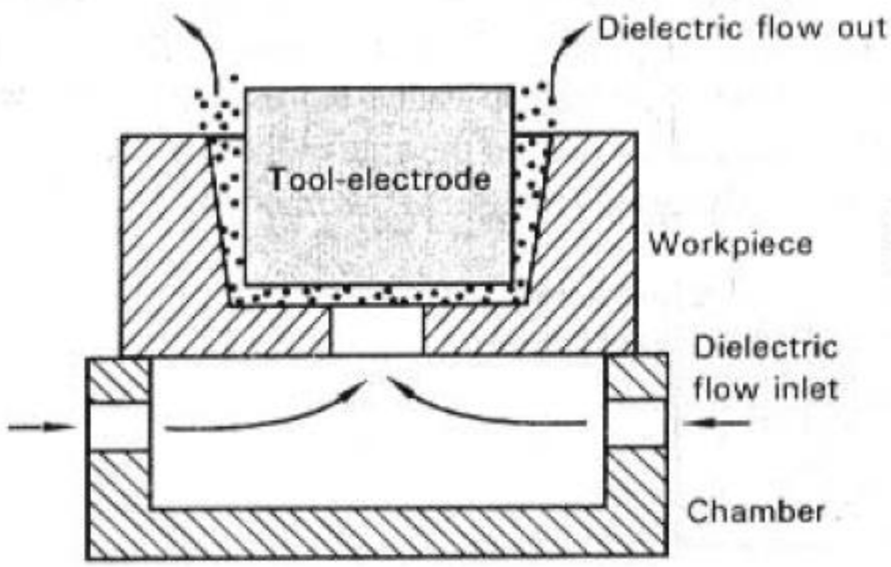
There are few types of flushing methods and are listed below

1. Injection or Pressure Flushing
   - Through Workpiece
   - Through Tool
2. Suction Flushing
   - Through Workpiece
   - Through Tool
3. Side Flushing

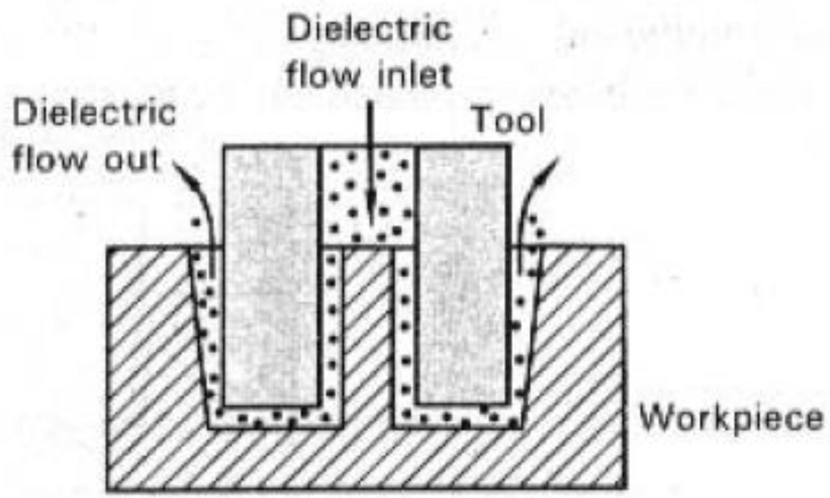
FLUSHING METHODS

Injection or Pressure Flushing

- Through Workpiece
- Through Tool



Through Workpiece

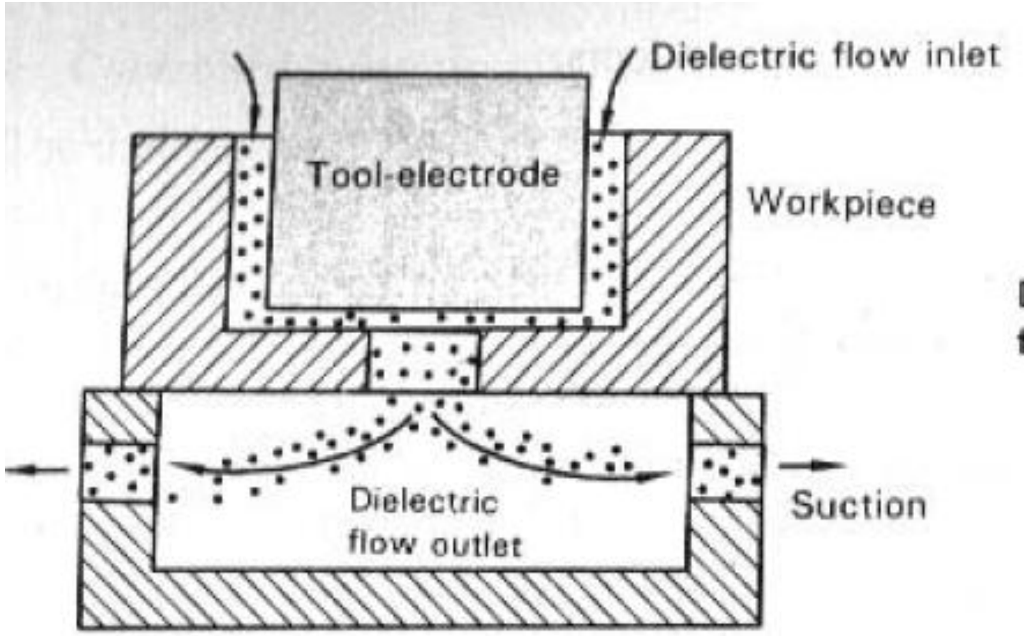


Through Tool

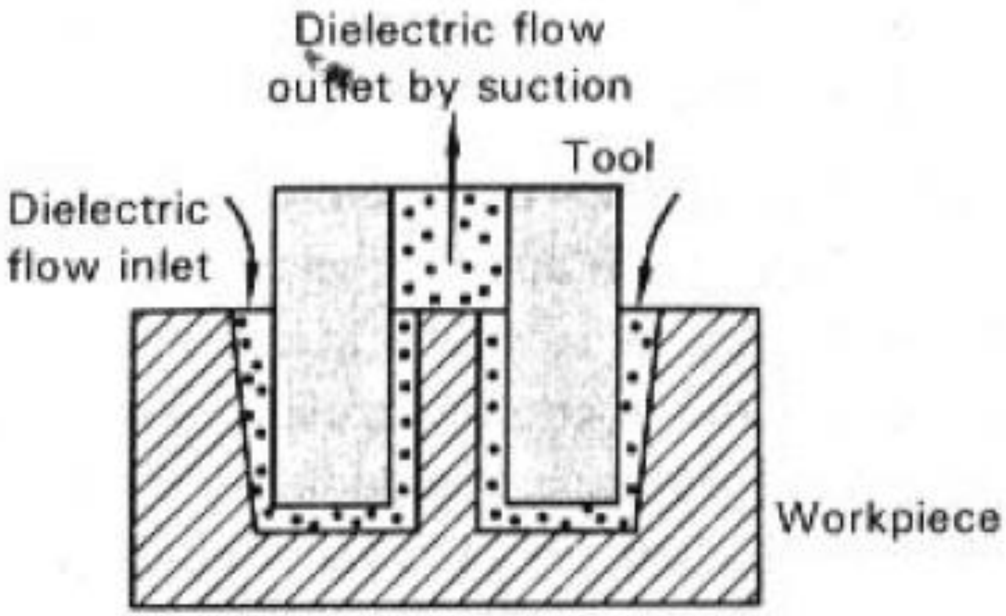
FLUSHING METHODS

Suction Flushing

- Through Workpiece
- Through Tool



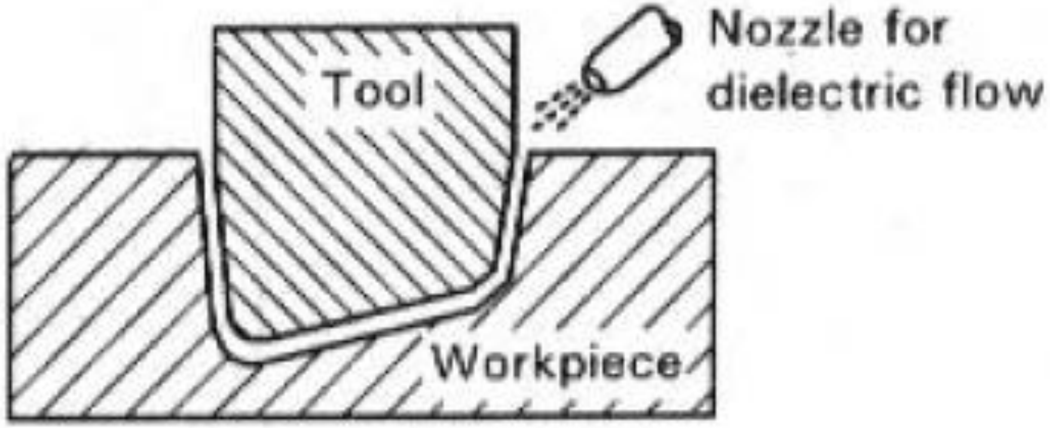
Through Workpiece



Through Tool

FLUSHING METHODS

Side Flushing



TOOL ELECTRODE

In **EDM process**, the shape of the **tool is similar to that desired in the workpiece**. During machining, both the **workpiece as well as the tool get eroded**. Although comparatively less metal is eroded from the tool, the factor must be considered for efficient machining. The material selected for manufacturing EDM tools is based on the following factors:

- Should be **good conductor of heat and electricity**
- Possess **maximum possible metal removal rate**
- **Easily machinable** to the desired shape and size
- **Resist its erosion** during the machining process, and
- **Low cost**.

TOOL ELECTRODE

Various materials like copper, zinc alloys, brass, graphite, tungsten, copper-tungsten, silver-tungsten alloy, etc., are used for manufacturing EDM tools. Table 6.1 shows the factors for tool selection.

Sl. No.	Tool Material	Wear ratio*	MRR	Fabrication	Cost	Application
1	Copper	Low	High on rough ranges	Easy	High	Can be used on all metals
2	Brass	High	High on finishing ranges	Easy	Low	On all metals
3	Steel	High	Low	Easy	Low	For finishing work only
4	Zinc based alloys	High	High on rough ranges	Easily die casted	Low	On all metals
5	Tungsten	Lowest	Low	Difficult	High	Only where small holes are to be drilled.
6	Tungsten-silver alloy	High	High	Difficult	High	Used for high accuracy work
7	Tungsten-copper alloy	Low	Low	Difficult	High	Used for high accuracy work, machining carbides, & small holes.

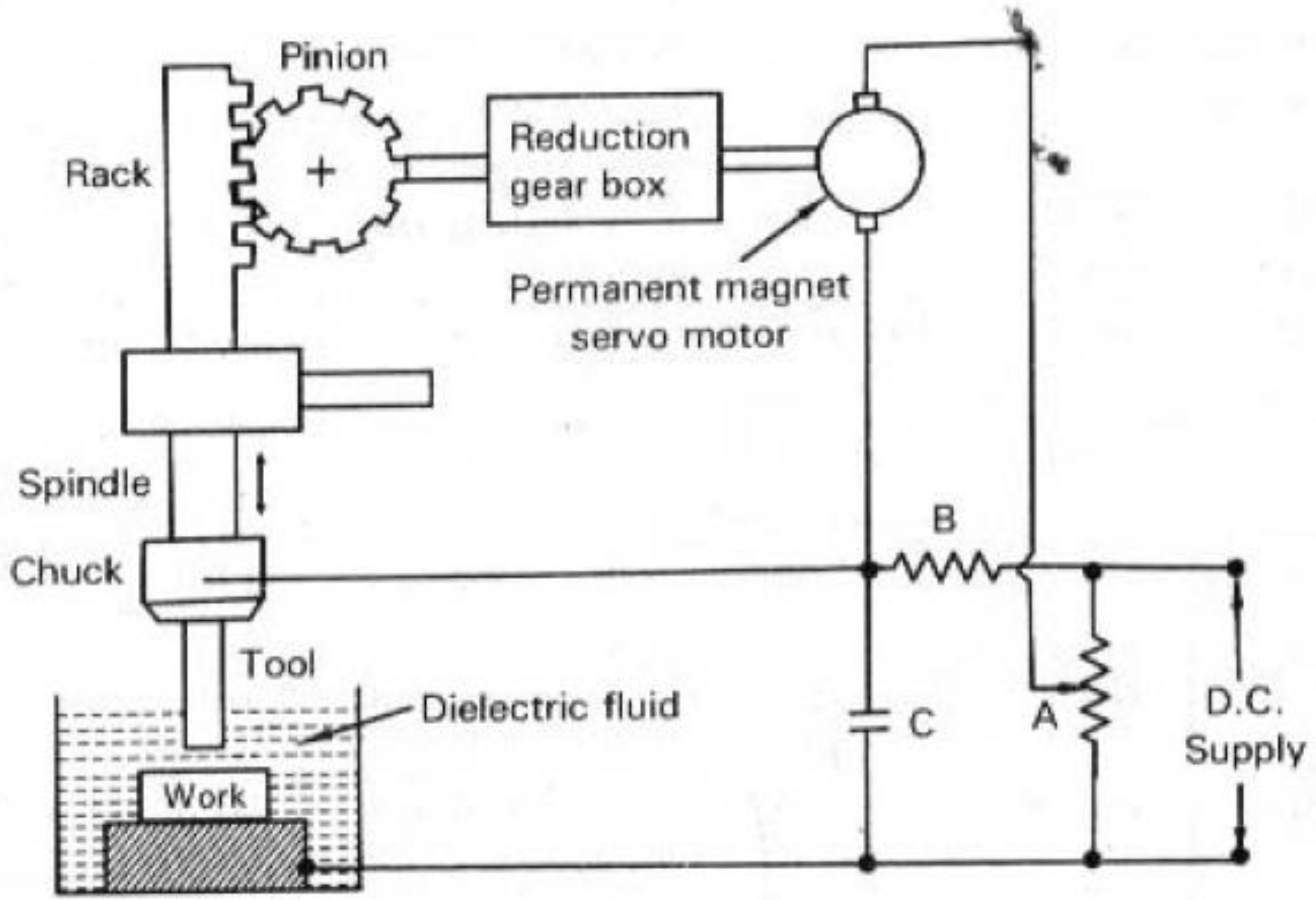
SERVO FEED MECHANISM

EDM machines are equipped with **servo control mechanism** that automatically moves the tool at a proper rate thereby maintaining a **constant gap between the tool and the workpiece**, which is one of the most important parameter in the process. Servo-mechanisms may be either of the form **electric-motor-driven, solenoid operated, or hydraulically operated**, or a combination of these. Figure shows the schematic of an electric-motor-driven type of gap control mechanism.

In this type of mechanism, the tool held in a chuck is fitted to a **spindle**, to which a **rack** is attached. The axial movement of the spindle is by means of a **rack and a pinion arrangement** controlled through a **reduction gear box** driven by a **DC shunt motor**.

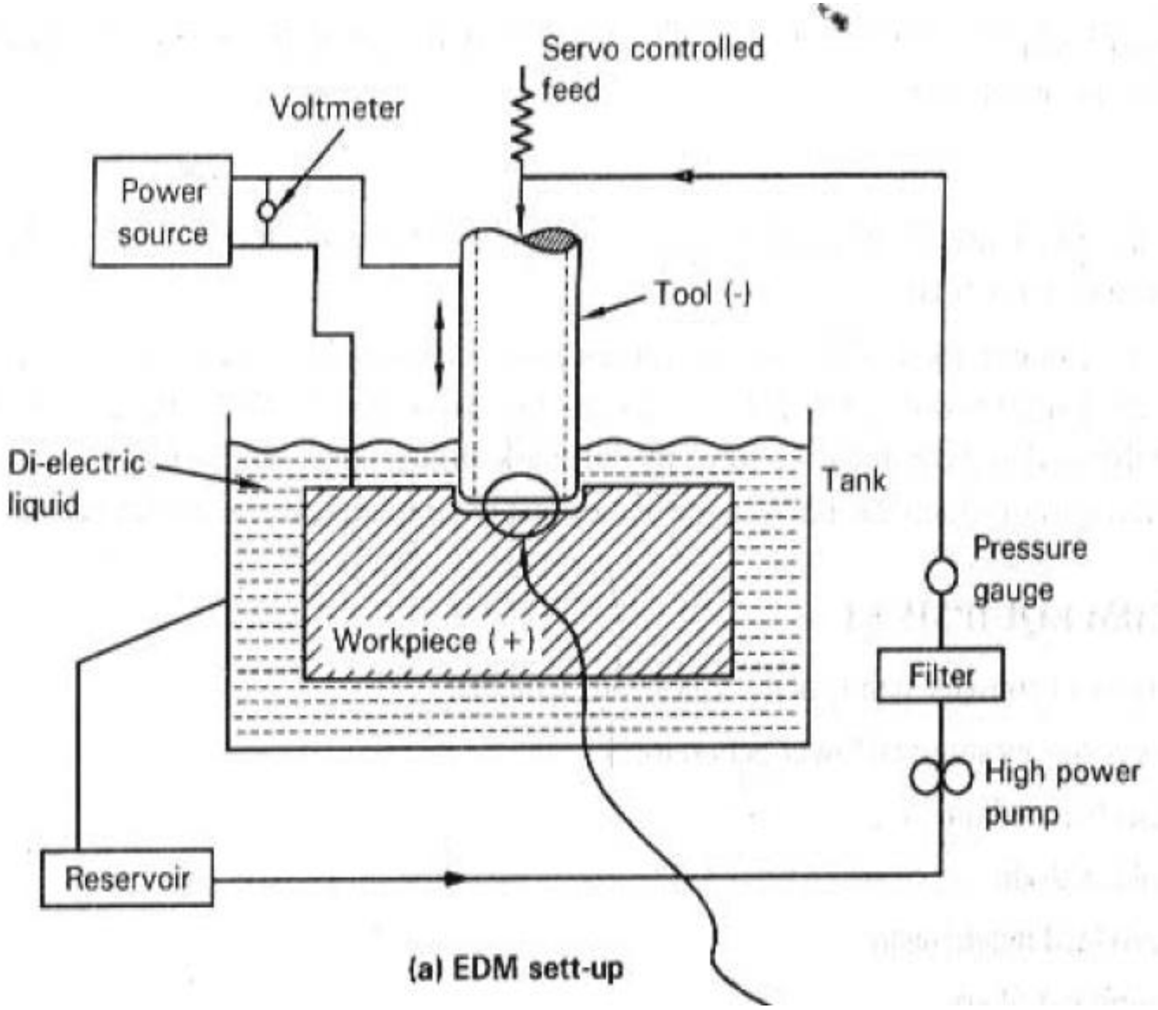
The shunt motor is **reversible** so that the tool can be withdrawn in case when the spark gap is flooded with wear debris, or the tool overshoots (advances rapidly) closing the spark gap that leads to **short circuiting**. The armature of the motor is connected across a **bridge network**, the arms of which consist of a potential divider A connected across the DC supply, while the other arm consists of the **ballast resistance B and capacitor C** of the charging circuit as shown in the figure. **Hydraulic feed mechanism** has proven to be more effective than the electro-motor-driven type.

SERVO FEED MECHANISM



PUMPS AND FILTERS

Pumps are used to circulate the dielectric fluid at a suitable pressure into the spark gap, while filters serve their usual purpose of filtering the wear debris and other impurities thereby circulating clean dielectric fluid to the machining gap resulting in efficient machining to take place.



(a) EDM sett-up

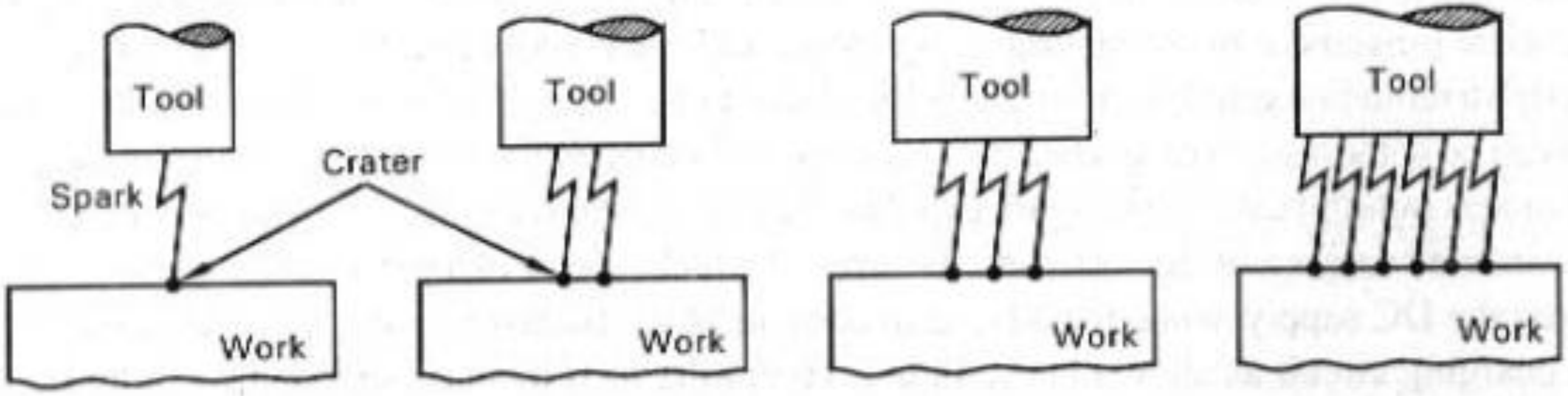
EDM PROCESS PARAMETERS

Parameters that determine the accuracy and surface finish of a workpiece are

1. Influence of spark frequency
2. Influence of current
3. Spark gap

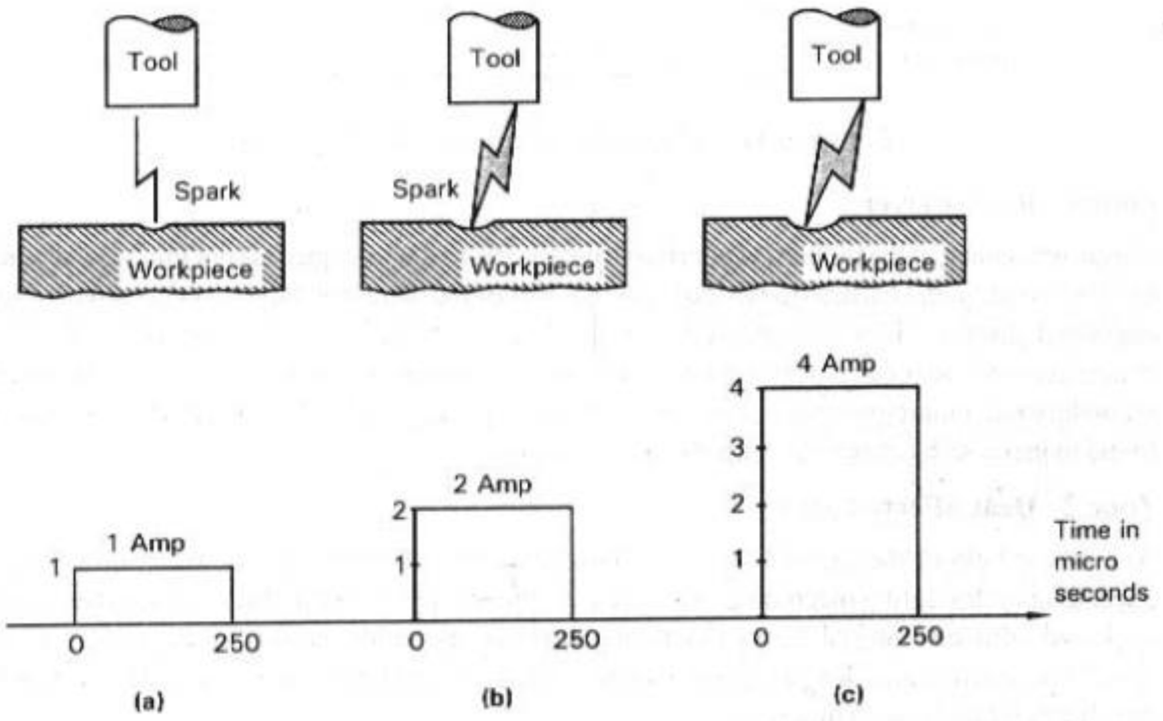
Influence of spark frequency

Higher spark frequency produces finer discharges, leading to better surface finish but lower material removal rate. Lower frequency results in rougher surfaces with higher removal rates.



Influence of current

An increase in current raises the material removal rate but causes a rougher surface finish. Lower current produces a smoother surface with reduced removal efficiency.



SPARK GAP

- A smaller spark gap enhances accuracy and surface finish but may cause unstable machining
- A larger spark gap increases material removal but decreases dimensional accuracy.

ADVANTAGES:

- Capable of machining very hard materials and complex shapes.
- Produces fine surface finishes with high dimensional accuracy.
- No direct contact between tool and workpiece, reducing mechanical stress.

DISADVANTAGES:

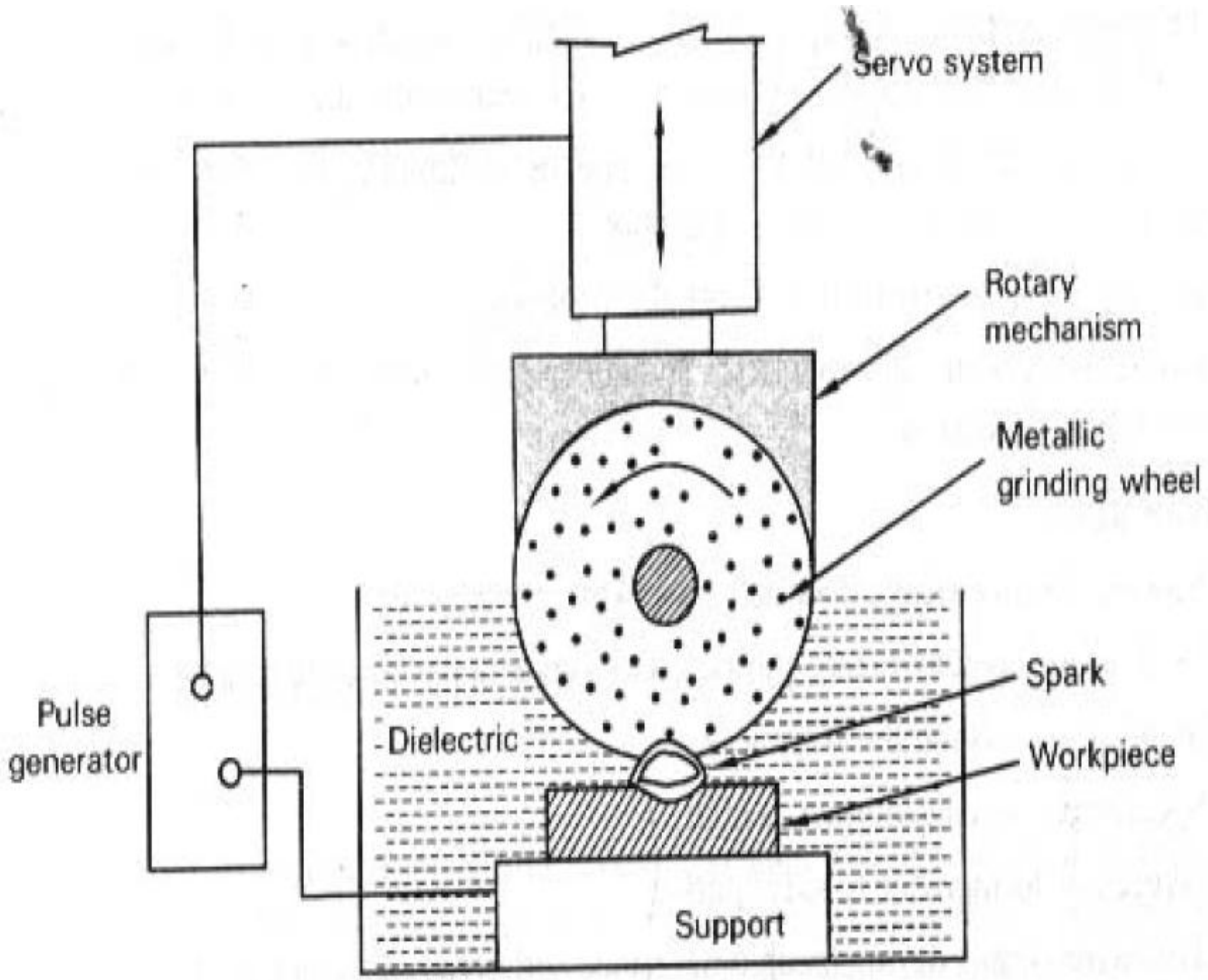
- Material removal rate is relatively low.
- High tool wear and electrode cost.
- Requires proper flushing and control to avoid surface defects or cracks.

APPLICATIONS:

- Manufacturing of dies, molds, and precision components.
- Machining hard materials like tungsten carbide, titanium, and tool steels.
- Used in aerospace, automotive, and electronics industries for micro-hole drilling and fine finishing.

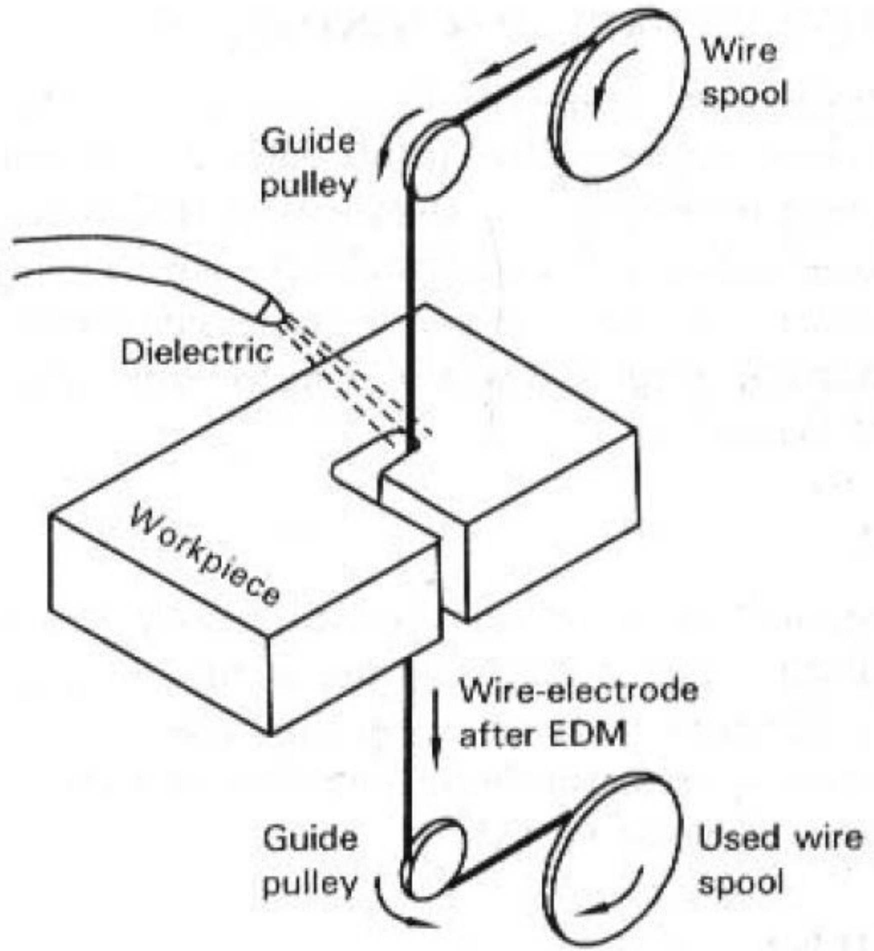
ELECTRICAL DISCHARGE GRINDING

Electrical Discharge Grinding (EDG) is a hybrid machining process that combines the principles of Electrical Discharge Machining (EDM) and conventional grinding. In this process, a rotating metallic grinding wheel acts as the tool and is connected to the negative terminal of a pulse generator, while the workpiece is connected to the positive terminal. The workpiece and wheel are submerged in a dielectric fluid. When a voltage pulse is applied, controlled sparks occur between the wheel and the workpiece, melting and vaporizing a small portion of the material. The wheel rotation helps remove the molten debris and maintains a consistent gap. This process enables precise material removal from hard and conductive materials while achieving fine surface finish and high accuracy.



TRAVELLING WIRE EDM

Travelling Wire Electrical Discharge Machining (TWEDM), also known as Wire-Cut EDM, operates on the same principle as conventional EDM, where material is removed by a series of controlled electrical discharges between a continuously moving wire electrode and the conductive workpiece. The thin wire, usually made of brass or copper, is fed from a spool and guided through pulleys while being immersed in a dielectric fluid. As high-frequency voltage pulses are applied, sparks occur between the wire and workpiece, melting and vaporizing small portions of material to form a precise cut. The dielectric fluid flushes away debris and cools the machining zone. The continuous movement of the wire prevents wear at a single point, allowing high-accuracy cutting of intricate profiles and contours in hard materials.



Thank You