Module-3: ADVANCED MATERIAL REMOVAL PROCESSES

Lecture No-9

Electrical Discharge Machining (EDM)

It is an advanced machining process primarily used for hard and difficult metals which are difficult to machine with the traditional techniques. Only electrically conducting materials are machined by this process. The EDM process is best suited for making intricate cavities and contours which would be difficult to produce with normal machines like grinders, end-mills or other cutting tools. Metals such as hardened tool-steels, carbides, titanium, inconel and kovar are easily machined through EDM.

EDM is a thermal process which makes use of spark discharges to erode the material from workpiece surface. The cavity formed in EDM is a replica of the tool shape used as the erosions occur in the confined area. Since spark discharges occur in EDM, it is also called as "spark machining". The material removal takes place in EDM through a rapid series of electrical discharges. These discharges pass between the electrode and the workpiece being machined. The fine chips of material removed from the workpiece gets flushed away by the continuous flowing di-electric fluid. The repetitive discharge creates a set of successively deeper craters in the work piece until the final shape is produced.

History

In 1770, Joseph Priestly a british scientist first discovered the erosive effects of electrical discharges. In 1943, soviet scientists B. Lazarenko and N. Lazarenko had exploited the destructive effect of an electrical discharge and developed a controlled process for machining materials that are conductors of electricity.

EDM Principle

The schematic of the basic EDM process is illustrated in Fig. 3.9.1. In this process, the workpiece and tool are submerged into a non-conducting, dielectric fluid which is separated by a small gap (for sparking). The dielectric fluid insulates the workpiece from the tool and creates the resistance of electricity flow between the electrodes. The dielectric fluid may be typical hydrocarbon oil (kerosene oil) or de-ionized water. It also helps in cooling down the tool and workpiece, clears the inter-electrode gap (IEG), and concentrates the spark energy to a small cross sectional area under the electrode.

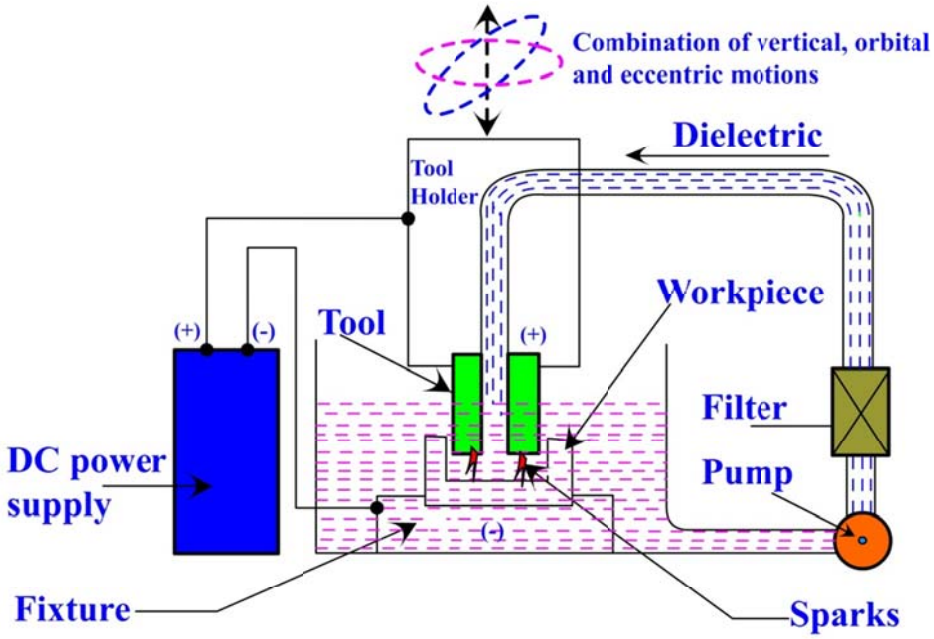

Fig. 3.9.1 Schematic of Electric Discharge Machining

As the two electrodes come closer to one another, the electric field intensity increases beyond the strength of the dielectric enabling it to break and thereby allow the current to flow between the two electrodes. As a result of this effect, intense heat gets generated near the zone, which melts and evaporates the material in the sparking zone. As the flow of current is momentarily stopped, some fresh dielectric liquid particles come in position between the inter-electrode gap which restores the insulating properties of the dielectric. The solid particles (debris) are carried away by the flowing dielectric. Flushing refers to the addition of new liquid dielectric to the inter-electrode volume. A close view of the EDM process is shown in Fig. 3.9.2. The sparks occur at spots where the tool and the workpiece surfaces are the closest and since the spots change after each spark (because of

the material removal after each spark), the spark travels all over the surfaces. This results in uniform removal of material, hence exact shape get reproduced on the workpiece surface.

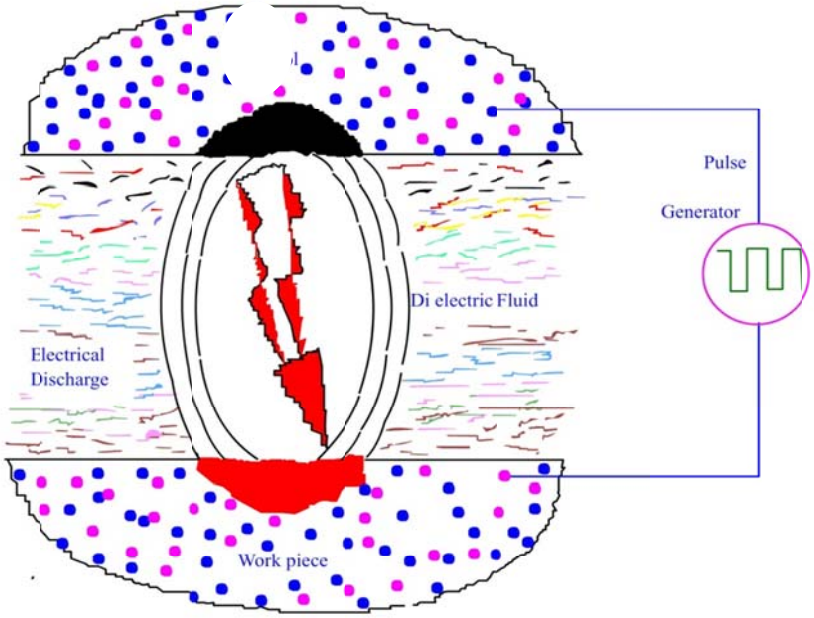

Figure 3.9.2 Close View of ED Machining region

Advantages of EDM

The major advantages of the process are:

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

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

Limitations of EDM

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

Applications of EDM

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

Mechanism of Material Removal in EDM

In EDM, for a particular machining condition there are numerous phenomena involved, i.e., heat conduction and radiation, phase changes, electrical forces, bubble formation and collapse, rapid solidification etc. Thermo-electric phenomenon is the most appropriate theory for the explanation of the electrical discharge machining process. The removal of material in EDM is associated with the erosive effects produced when discrete and spatial discharge occurs between the tool and workpiece electrodes. Short duration sparks are generated between these two electrodes. The generator releases electrical energy, which is responsible for melting a small quantity of material from both the electrodes. At the end of the pulse duration, a pause time begins. The forces that may be of electric, hydrodynamic and thermodynamic in nature remove the melted pools. The material removal process by a single spark is as follows:

- An intense electric field develops in the gap between electrode and workpiece.
- There are some contaminants inside the dielectric fluid which build a high-conductivity bridge between the electrode and workpiece.
- When the voltage increases, the bridge and dielectric fluid between the electrode and workpiece heat up. The dielectric is ionized to form a spark channel. The temperature and pressure rapidly increase and a spark is generated. A small amount of material is evaporated on the electrode and workpiece at the spark contact point.
- Bubbles rapidly expand and explode during sparking until the voltage is turned off. Next the heating channel collapses and the dielectric fluid enters into the gap in-order to flush away the molten metal particles.

The material removal rate depends on the following factors:

- Peak amperage or intensity of the spark
- Length of the ON time
- OFF time influences the speed and stability
- Duty cycle: percentage of on-time relative to total cycle time
- Gap distance: Smaller the gap better is the accuracy and slower is the material removal rate.

The material removal phenomena in EDM are shown schematically in the Fig. 3.9.3

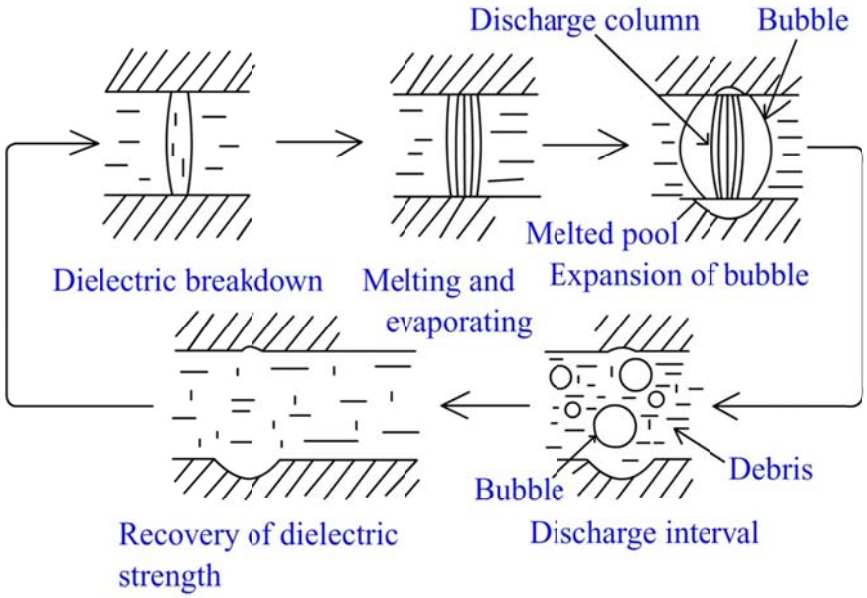

Fig. 3.9.3 Schematic of the material removal phenomena in EDM

Types of EDM Processes

1. Die Sinker EDM
2. Wire Cut EDM
3. Powder Mixed EDM