UNIT- IV

Thermal Metal Removal processes

Electric Discharge Machining :-

→ When ever sparking takes place between two electrical contacts a small amount of material is removed from each of the contacts.

→ This was realized and the attempts were made to harness and control the spark energy to employ it for useful purpose, say, for machining of metals.

→ It was found that the sparks of short duration and high frequency are needed for efficient machining.

→ Further, it was also observed that if the discharge is submerged in dielectric, the energy can be concentrated into a small area.

Principle of EDM

→ EDM is a thermoelectric process in which heat energy of a spark is used to remove material from the workpiece.

→ The workpiece and tool should be made of electrically conductive materials.

→ As spark is produced between the two electrodes (tool and workpiece) and its location is determined by the narrowest gap between the two.

→ Duration of each spark is very short and entire cycle is usually few micro seconds (μs)

→ The frequency of sparking may be as high as thousands of sparks per second.

→ The spark radius is very small, and temp of the area under the spark is very high.

→ As a result, the spark energy is capable of partly melting and partly vaporizing material from localized area on both the electrodes i.e., workpiece and tool.

→ The material is removed in the form of craters which spread over the entire surface of the workpiece.

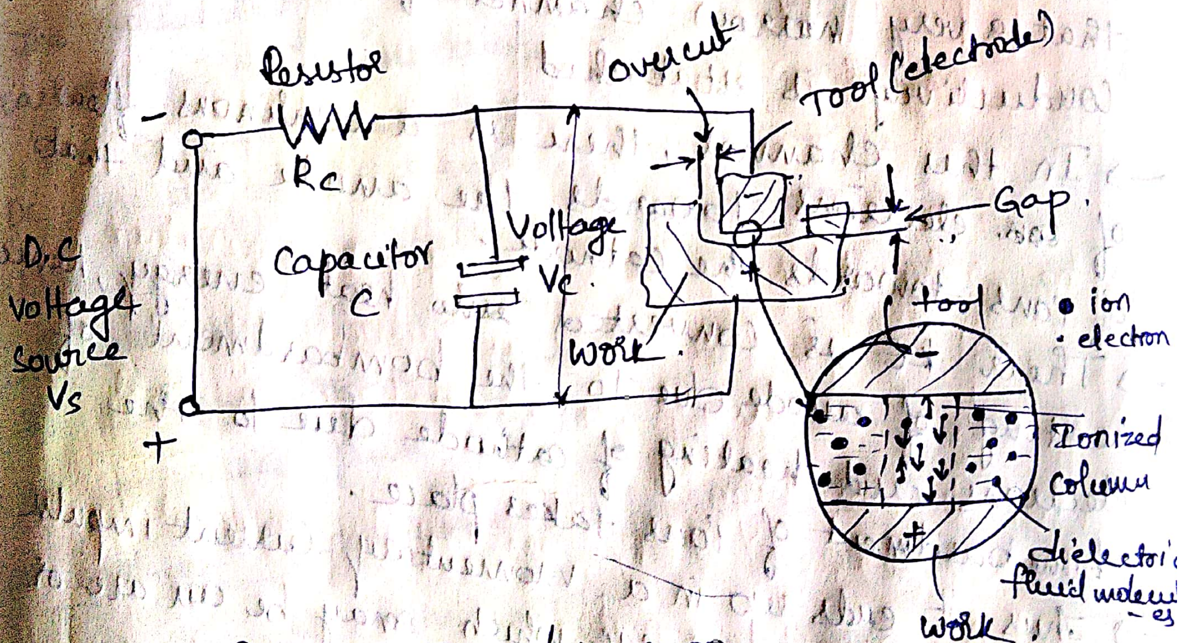
→ Finally, the cavity produced in the workpiece is approximately the replica of the tool.

→ To have machined cavity as replica of the tool, the tool wear should be zero.

→ To minimize wear of the tool the operating parameters and polarity should be selected carefully.

→ particles eroded from the electrodes are known as debris

→ Debris is the mixture of irregular shaped particles as well as hollow spherical particles



Schematic diagram

→ Usually the amt of material eroded from the tool surface is much smaller than that from the w/p surface

→ A very small gap b/w the two electrodes is to be maintained to have the spark to occur.

→ For this purpose, a tool driven by the servo System is continuously moved towards the Workpiece.

→ During the EDM, pulsed DC of 80 – 100V at approximately 5KHZ is passed through the electrod

→ Negatively charged particles break loose from the cathode surface and move towards the anod Surface under the influence of the electric field forces.

→ During this movement in the IEG (Inter Electrode gap) the elections collide with the neutral molecul of the dielectric (kerosene, water etc).

→ In this process, elections are also detached from these neutral molecules of the dielectric resulting in still more ionization.

→ The ionization soon becomes so intense that a very narrow channel of continuous Conductivity is established

→ In this channel, there is a continous flow of ~~con~~ elections towards the anode and that of ions towards the cathode.

→ Their KE is converted into heat energy, hence heating of anode due to the bombardment of elections and heating of cathode due to the bombardment of ions takes place.

→ Thus, it ends up in a momentary current impulse resulting in a discharge which may be an arc or a spark.

→ The Spark energy raises the localised temp of the tool and w/p it results in melting, or melting as well as vaporization of a small amount of material from the Surface of both electrodes at a pt of spark contact.

→ Due to the evaporation of dielectric the pressure in the plasma channel rises to a very high value and it prevents the evaporation of super heated metal.

→ As soon as the off time of a pulse starts, the pressure drops instantaneously allowing the super heated metal to evaporate.

→ The amount of material eroded from the w/p and the tool will depend upon the contributions of electrons and ions, respectfully.

kerosene, petroleum oils, hydrocarbon oils, silicon oils.

Power circuits for EDM :-

→ Different electric circuits are available to provide the pulsating dc across the work tool gap.

→ Though the operational characteristics are different, in almost all circuits a capacitor is used for storing the electric charge before the discharge takes place across the gap.

→ The suitability of the circuit depends on the machining conditions and requirements.

→ The commonly used ~~pea~~ for supplying the pulsating DC can be classified into following three groups

1) Resistance Capacitance relaxation circuit with a constant DC source

2) Rotary impulse generator

3) controlled pulse circuit.

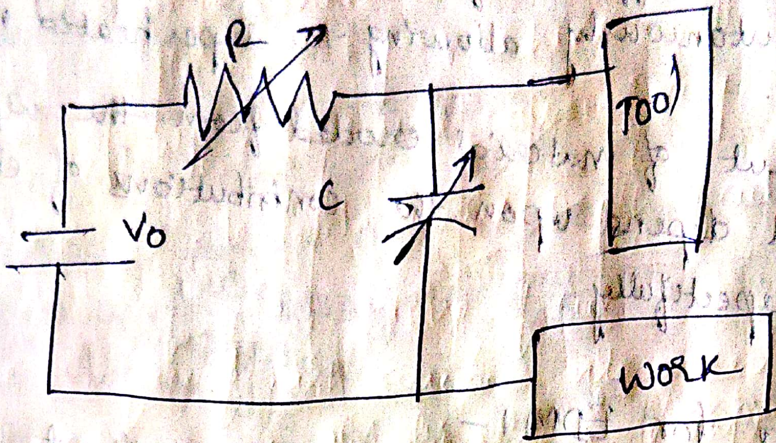
1) Resistance Capacitance Relaxation Circuit :-

→ It is used when the electric discharge m/cs were first developed.

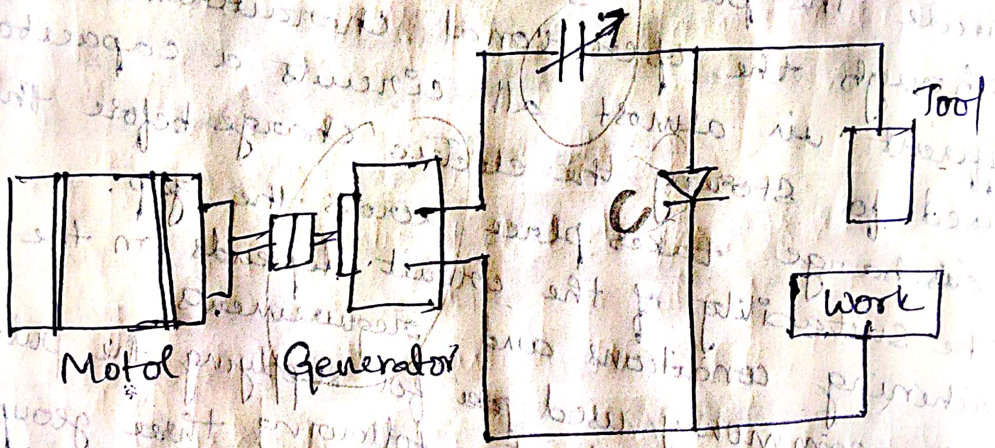
→ From the diagram, the capacitor C (which can be varied) is charged through a variable resistance R by the dc source of voltage V_0.

→ The voltage across the gap V^0 varies with time according to the relation

$$V = V_0(1 - e^{-t/(RC)})$$



2) Rotary Impulse Generator:-



→ The relaxation circuit for spark generation, though simple has certain advantages.

→ of these, an imp disadvantage is that the MRR is not high.

→ for increasing MRR, 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 voltage generated by the generator and the charged capacitor is applied to the work tool gap

→ The operating frequency is the frequency of the sine wave generation which depends on the motor speed.

→ Though the MRR is higher, such a system does not produce a good surface finish.

4) 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 acheive such an automatic control, a vacuum tube is used as the switching device.

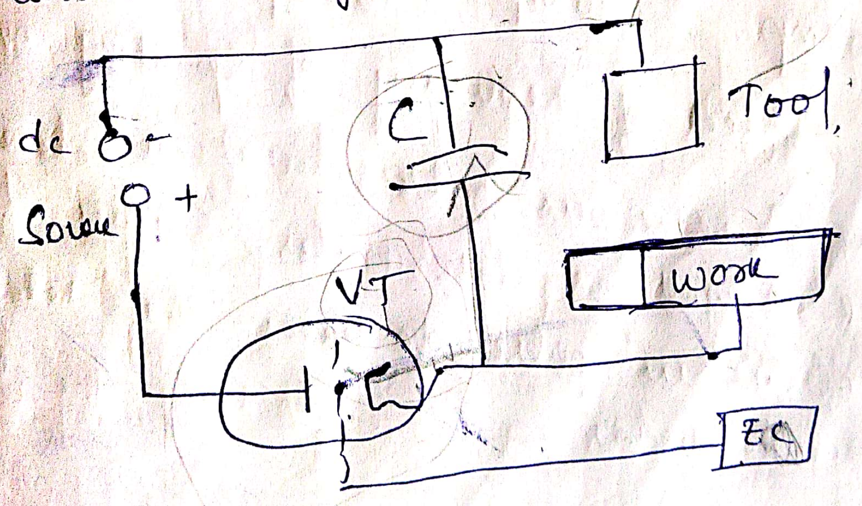
→ This system is known as a controlled pulse circuit.

→ During sparking, the current which flows through the gap comes from the capacitor.

→ When the current flows through the gap, the value tube (VT) is biased to cut off & behaves like an infinite resistance.

→ The bias control is done through an electronic control. (EC)

→ As soon as the current in the gap ceases, the conductivity of the tube increases, allowing the flow of current to charge capacitor for the next cycle.



Mechanics of metal Removal in EDM

→ Metal Removal rate is usually expressed as Cubic mm³ per minute.

→ MRR influenced by machine settings, melting point of w/p, thermal conductivity of the w/p

→ $$\text{MRR} = \frac{\text{Electrode area} \times \text{Depth of cut}}{\text{Time of cut}}$$

→ The surface finish can be measured by in terms arithmetic mean roughness (Ra in um)

$$\text{MRR}(\text{mm}^3/\text{min}) = \frac{\text{Mass loss of workpiece (g)}}{\text{Density of w/p}(\text{g/mm}^3) \times \text{Machining Time}}$$

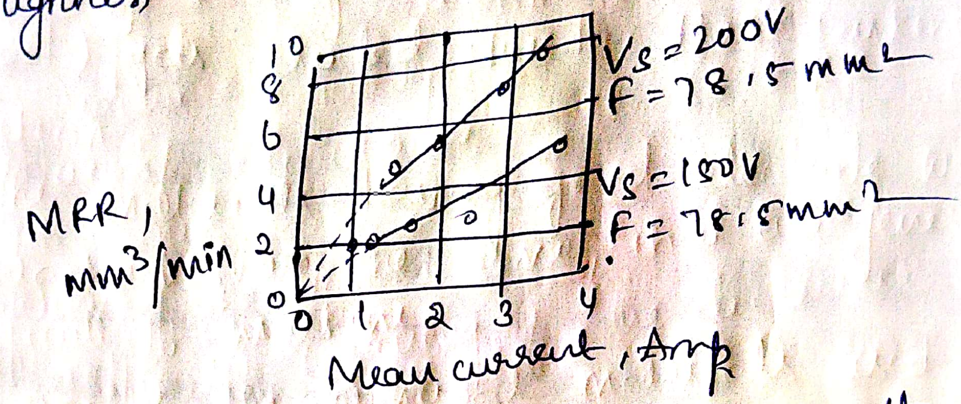
$$\text{EWR}(\text{mm}^3/\text{min}) = \frac{\text{Mass loss electrode (g)}}{\text{Density of electrode}(\text{g/mm}^3) \times \text{machining time (min)}}$$

$$\text{Duty factor}(\%) = \frac{\text{Pulse duration } (\mu s)}{\text{Pulse duration}(\mu s) + \text{pulse interval } (\mu s)}$$

Mechanism :-

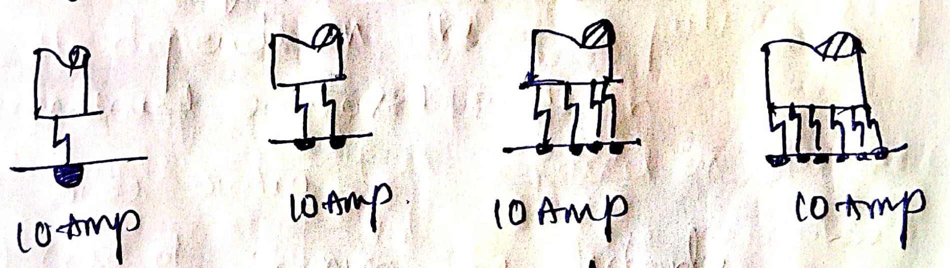
Process Parameters :-

→ An increase in current results in increase MRR as well as increased value of surface roughness



→ An increased in spark frequency results in an improved surface finish. Since the energy available for material removal during a given period of time is shared by a larger no. of spark the size of the crater is reduced.

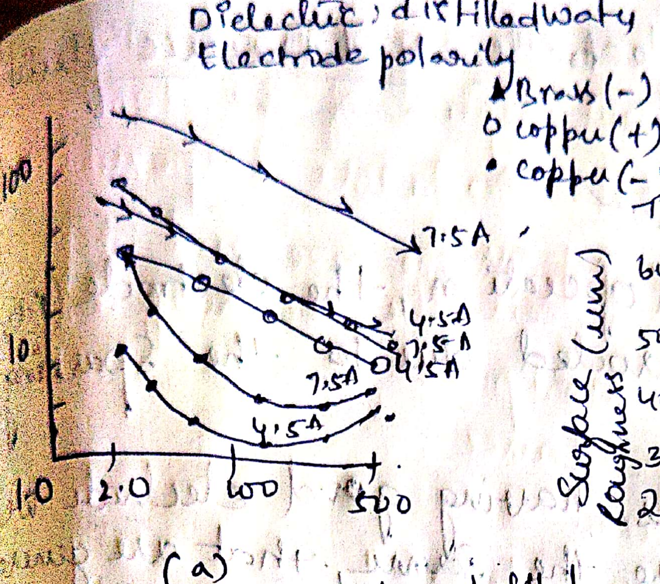
→ The inter electrode gap (12-80 um) is determined by the gap current and gap voltage. A decrease in the gap results in lower MRR, better surface finish, and high accuracy.

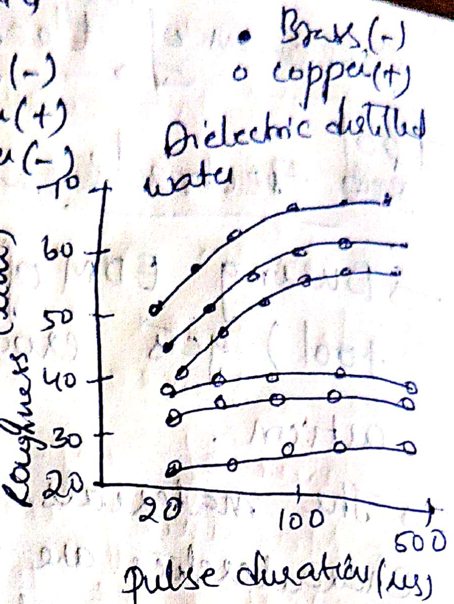


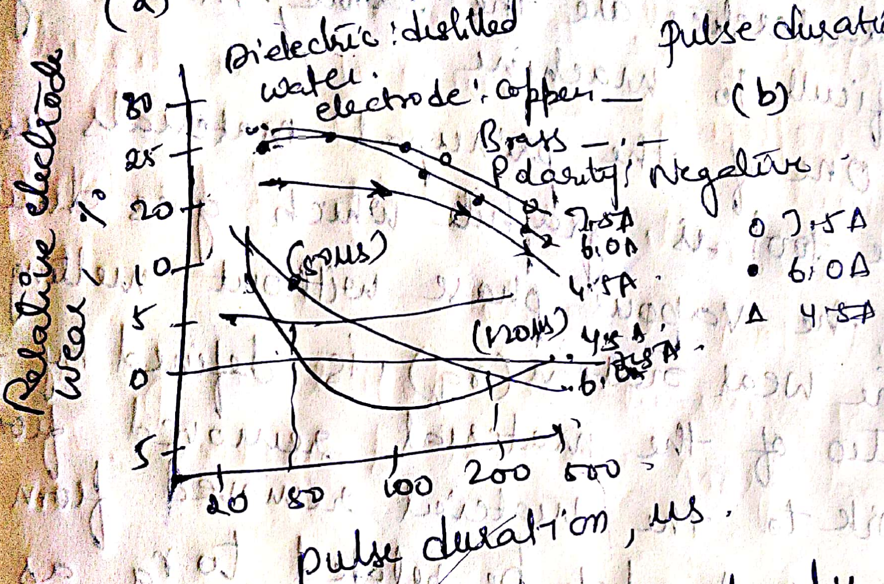
Effect of frequency of sparking on surface finish

→ An increase in pulse duration decreases MRR as well as deteriorates surface finish.

→ Increase in pulse decreases the relative electrode wear.







→ The relationship between MRR and pulse duration for different current values and electrode material with different polarities.

→ A decrease in MRR with increase in pulse duration is attributed to unsteady machining conditions observed for pulses greater than 20 µs.

Selection of Tool Electrode & Dielectric fluid.

Tool Electrode:-

→ During EDM operation, the electrode (i.e., the tool) gets eroded due to the sparking action.

→ The materials having good electrode wear characteristics are the same, that are generally difficult to machine.

→ One of the principal materials used for the tool is graphite which goes directly to the vapour phase without melting.

→ The wear ration (r_q), is defined by the ratio of the material removed from the work to the material removed from the tool, is found to be related to r_a as

$$r_q \simeq 2.5\, r_e^{-2.3}$$

Selection of Electrode material:-

It depends on the

1) material removal rate
2) wear ratio
3) case of shaping the electrode.
4) cost

→ The most commonly used electrode materials are brass, copper, graphite, Al alloys, copper-tungsten alloys and silver tungsten alloys.

→ The methods used for making the electrode are.

1) conventional machining (used for copper, brass, Cu-W alloys, Ag-W alloys and graphite)
2) casting (used for Zn base die casting alloy, Zn-Sn alloys and Al Alloys)
3) metal spraying
4) press forming

⇒ Flow holes are normally provided for the circulation of the dielectric, and these holes should be as large as possible for rough cuts to allow large flow rates at a low pressure.

Dielectric fluid:-

The basic requirement of an ideal dielectric fluids are

1) low viscosity
2) absence of toxic vapours
3) chemical neutrality
4) absence of inflaming tendency
5) low cost

→ The most commonly used type of fluid is hydrocarbon (petroleum) oil, kerosene liquid paraffin and silicon oils are also used as dielectric fluids.

Methods Surface finish and Machining accuracy:-

Accuracy of Machining:-

→ It has been observed practically that the size of the hole of cavity produced by this method is greater than the size of the tool employed during the machining

→ Moreover the shape reproduced, is also not the 100 percent replica of the tool shape

→ The following are the factors responsible for such in accuracy in the size and shape:

1) Side sparks between the tool surface and the machined workpiece
2) Value of capacitance
3) Machining area
4) Wear of the tool electrode
5) Inefficient cleaning of the dielectric fluid.
6) Inaccurate mounting of the workpiece and tool electrode
7) Displacement or deviation of the working head from vertical direction.

Surface finish:-

→ The roughness of the machined surface increases as the energy of the pulse increases.

→ In other words, at higher pulse energies the surface will be rough.

→ The pulse energy is a function of the capacitance and the working voltage of the circuit.

→ Therefore, by varying these two parameters fine surface could be obtained.

→ The surface produced by this process consists of microcraters.

According to Brash the volume of crater is proportional to cube of its depth. The depth can be assumed to be proportional to the crater are average, hav. Therefore.

$$(h_{av})^3 = \text{constant} \times \text{volume of the crater}$$
$$= K_1 \times \text{volume}.$$

where, K_1 = Constant of proportionality

Again the Volume of a crater is proportional to the pulse energy, so,

$$\text{Volume of crater} = K_2 . C . U^2$$
$$h_{av} = K_3 . C^{1/3} . U^{2/3}.$$

Characteristics of spark eroded surface & machine tool selection.

Characteristics of spark eroded surface:-

1) Recast Layer :- During EDM, material is removed by the erosive action of electric discharges.
→ This can lead to the formation of recast layer on the machined surface, which may affect surface finish and dimensional accuracy.

2) Surface finish :- Spark eroded surfaces typically have a distinctive texture characterized by small craters or dimples

3) Accuracy :- EDM can achieve high levels of accuracy and precision, often in the range of micrometers.

4) Material removal rate :- The material removal rate in EDM is generally slower compared to traditional machining methods like milling or turning.

5) Heat-Affected Zone :-

Advantages

1) Metal of any hardness, toughness or brittleness could be machined by this process provided they are conductor of electricity.

2) Dies of can be machined even in the hardened state.

3) Any complicated shape that can be made on the tool can be reproduced on a workpiece.

4) very fine holes can be drilled accurately since the cutting forces are tool small.

5) The accuracy of work produced can be as high as 0.005 mm on finishing operations.

6) There is no physical connection b/w the tool and the w/p

7) There is no cutting force except the blasting pressure

8) so cylinder and fragile w/p's could be machined without causing any damage to them.

9) The machining time specially for harder work materials is much less than conventional machining process.

~~Disadvantages~~ :- Applications :-

1) for machining dies for forging, blanking, extrusion etc.

2) for drilling fine deep holes like in fuel injection puzzles

3) Hydraulic valve can be machined

4) It is possible to manufacture fragile components which are difficult to machine by conventional methods because of high tool forces.

Disadvantages

1) The power requirement is very high compared to conventional processes.
2) Some of the materials may become brittle at room temperature and there is some chance of surface cracking.
3) Sometimes a layer of 0.01 to 0.1 mm containing 4% carbon may get deposited on steel workpiece.
4) The metal removal rate is comparatively low.

Wire cut EDM:

→ The wire cut EDM produces a complex shapes in through hole application eg., extrusion or press tool die cavities.

→ The wire electrode typically 0.25 mm diameter, is taken from a supply spool having efficient wire for 24 continuous operation, at a velocity of 0.1 to 8 m/min.

→ For highly accurate work, the wire is drawn through a sizing die and reduced in dia. by 0.015 mm,

→ It is then annealed and passed through sapphire guides to a device, which stabilises the tension at 0.5-10 kg.

→ The power supply is about 55 to 60 volts and 1 to 32 amps at pulse frequencies of 180 to 33 KHz and pulse durations 1 to 100s, wire tension is about 50 to 60% of the tensile strength of

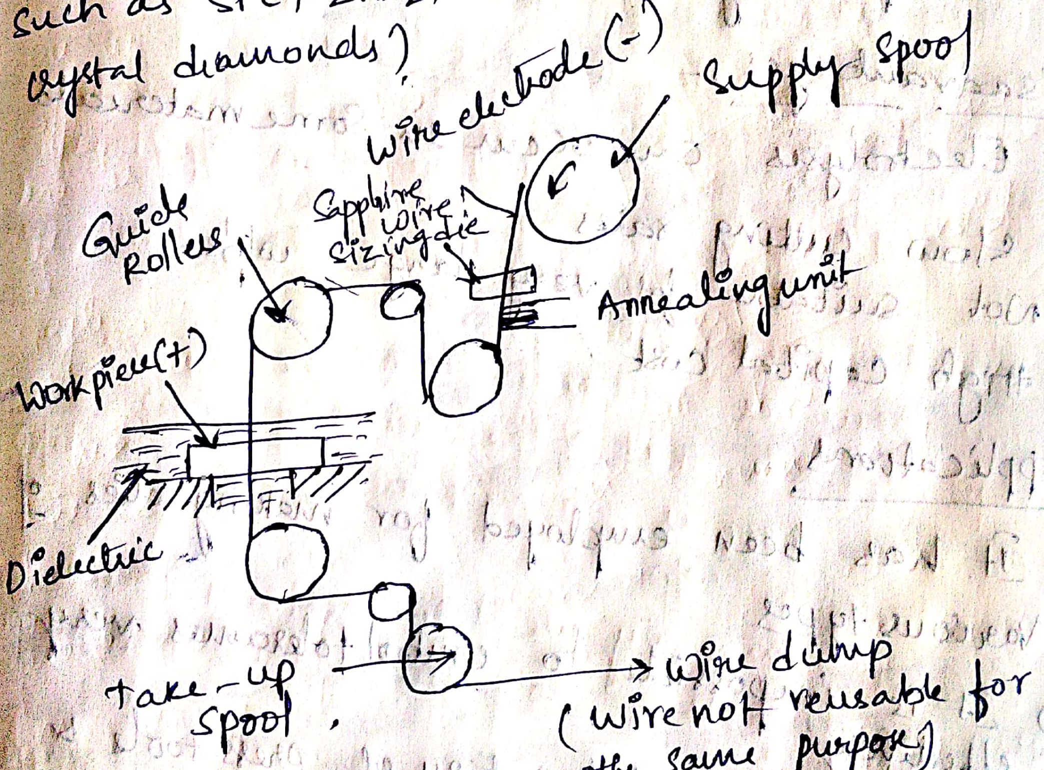
→ ~~Wire~~ the wire material are molybdenum, tungsten, copper & brass.

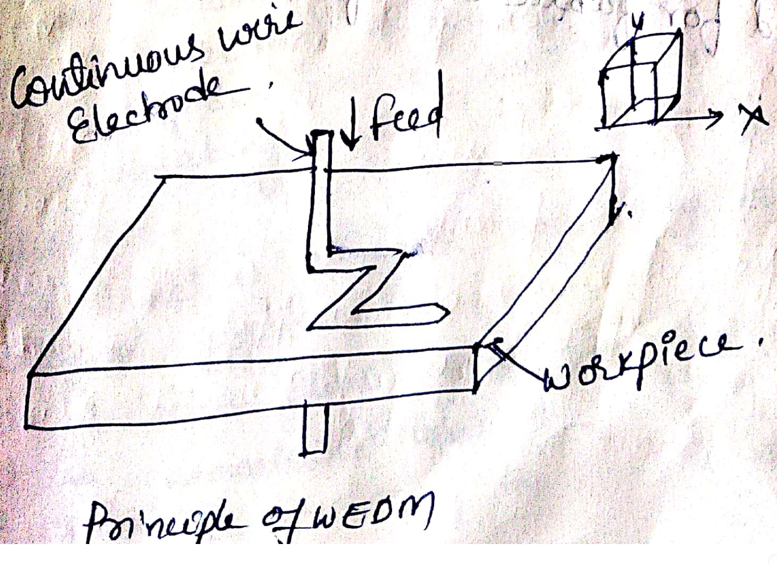
→ In operation deionised water is used as the dielectric

→ The electrode may be inclined at an angle of 1.5° to the perpendicular to provide means for machining clearance in the profile of dies.

→ Displacement of slides in the x and y axes are controlled by CNC.

→ The process is suitable for electrically conductive heat treated metals, sintered or cemented carbides and other ultra hard materials like electrically conductive ceramic materials such as SiC, ZrB_2, TiB_2, B_4C, CBN and PCD (Poly-crystal diamonds)





Principle of WEDM

Advantages :-

1) Wire cut EDM Can machine any complicated through hole dies of electrically conductive materials

2) Tool manufacturing and storage is avoided

3) The time utilisation of WEDM is high as it can continuously work throughout the day

4) Small batch productions including prototypes can be economically machined.

5) The process has high surface finish

6) It avoids wastage and rejections due to initial planning and checking of the program.

Disadvantages :-

1) Electrolysis can occur in some materials

2) Slow cutting rates

3) Not suitable for very large w/p's

4) High capital cost.

Applications

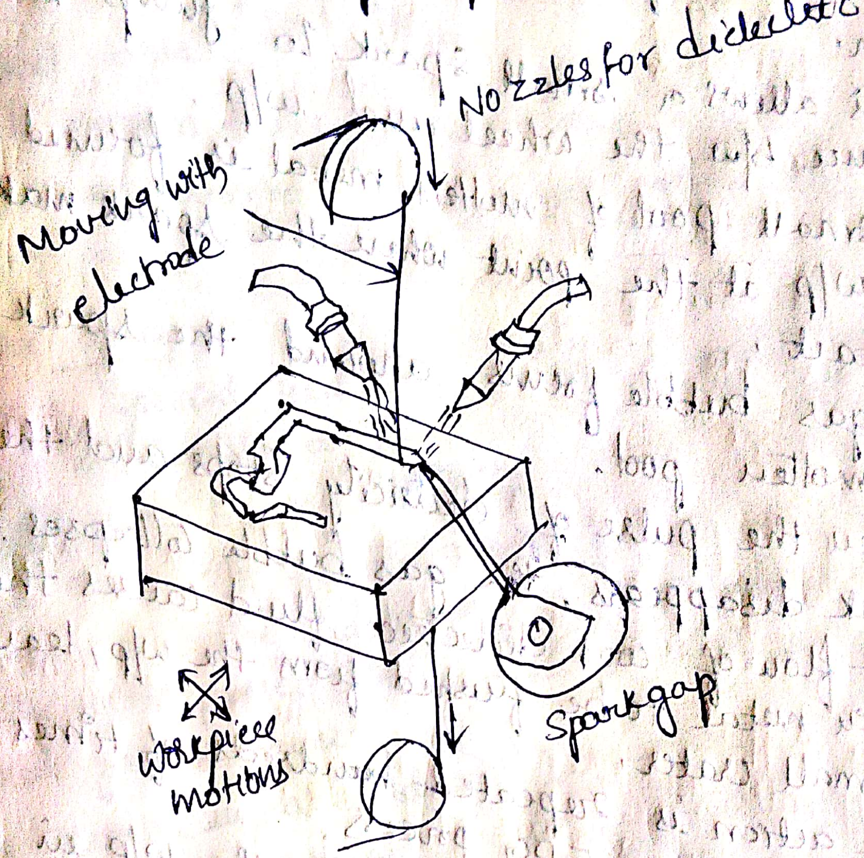
1) It has been employed for making dies of various types

2) It is impossible to control tolerances very effectively

3) It is used for fabrication of press tools & electrodes

Electric discharge Grinding (EDG):

EDG is a spark erosion process used for precision machining of electrically conductive w/p's. It is very similar in principle to EDM.



Schematic of EDG

→ Figure shows a schematic illustration of an EDG operation.

→ A rotating electrically conductive grinding wheel is used as the electrode in EDG.

→ Both the wheel and workpiece are submerged in a tank containing a dielectric hydro carbon oil.

→ pulsed electrical energy is delivered to the wheel and workpiece from a power supply that is capable of generating pulses at rates of upto 250000 pulses/sec.

→ The wheel is charged negatively and the workpiece is charged positively.

→ The dielectric fluid flows through a small gap that is maintained b/w the wheel and w/p.

→ The rotating motion of the EDG wheel helps to flush the dielectric liquid continuously without the need for a pump.

→ When each pulse of electricity is delivered from the power supply, the insulating properties of the dielectric fluid are temporarily broken down.

→ This allows a small spark to jump to shorten distance b/w the wheel and w/p.

→ A small pool of molten metal is formed on the w/p at the point where the spark makes contact.

→ A gas bubble forms around the spark and the molten pool.

→ When the pulse of electricity stops and the spark disappears, the gas bubble collapses.

→ The flow of cool dielectric fluid causes the molten metal to be flushed from the w/p, leaving a small crater.

→ The action is repeated hundreds of times each second during EDG process.

→ This removes material from the w/p in a shape opposite that of the grinding wheel.

→ Because there is no mechanical contact b/w the wheel and w/p.

→ EDG is commonly used to perform operations on very fragile parts or to produce thin section with out damage.

→ wheels can be dressed to produce complex shapes in one pass.

Equipment

Wheels:- Wheels used for EDG are made from porous, low grade graphite and are commonly b/w 100 & 305 mm in diameter.

→ wheel widths can range from 152mm to only 0.25mm

→ ~~EDG wheels are made from porous, lowgrade graphite and are com~~

→ EDG wheels are made of graphite, the Shaping of EDG wheels can be easily done by using high speed steel tools.

→ wheel erosion takes place from the sparking action of EDG, wheel dressing is performed after very machining pass.

Servodrive system:-

→ It is a special feed back device, it must sense & always maintain a constant gap b/w the wheel and w/p while feeding the w/p into the wheel.

→ This is done by the system monitoring electrical conditions at the machining gap & comparing the results with preset limits corresponding to the desired gap distance.

→ This results in a condition in which the wheel is feeding into the w/p at a rate equal to the rate at which material is being removed.

→ If the circuit senses that the gap is becoming blocked with particles of removed material, the w/p will move back to allow the gap to clear itself before starting to grind.

~~Process~~ parameters:-

Advantages :-

1) Noncontact grinding
2) Low cost wheels
3) Simple dressing procedure
4) Grinds any conductive material
5) No distortion is produced during machining

Disadvantages :-

1) Recast layer is produced
2) Oil fires are possible
3) Wheels are fragile.

Applications

1) Any shape that is ground by conventional grinding can be done by EDG
2) Grinding carbide tools, dies, form tools, and thin w/p's
3) Difficult to grind shapes such as grooves & slots can be ground by EDG.