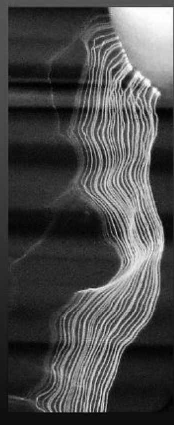
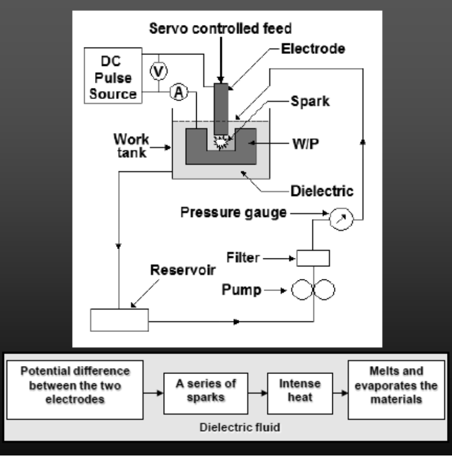
Electrical Discharge Machining EDM

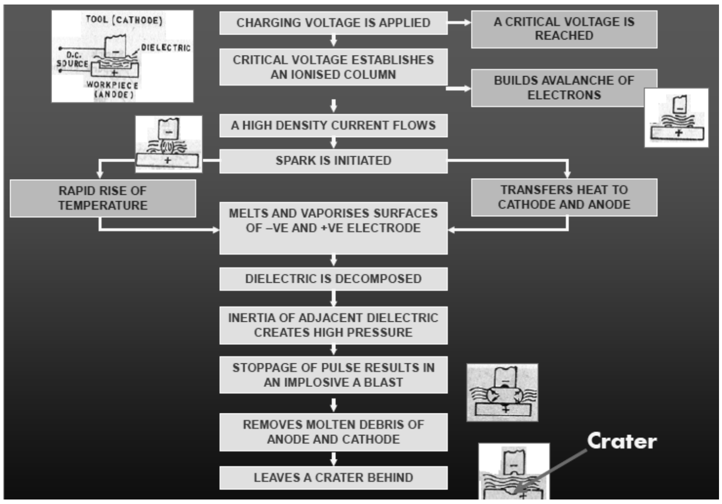
Electrical Breakdown

Rapid reduction in the resistance of an electrical insulator that can lead to a spark jumping around or through the insulator.

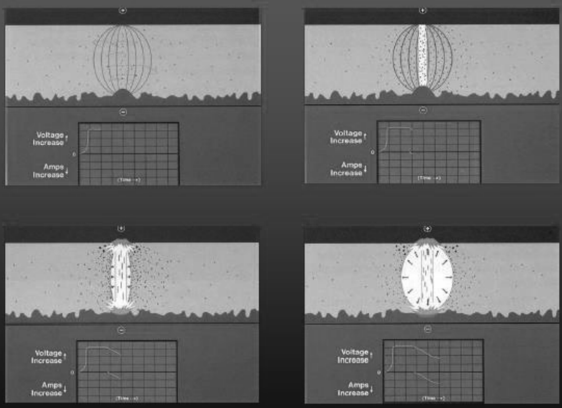


Scheme of EDM

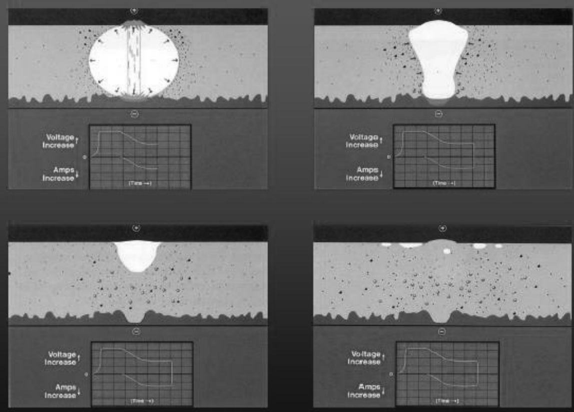


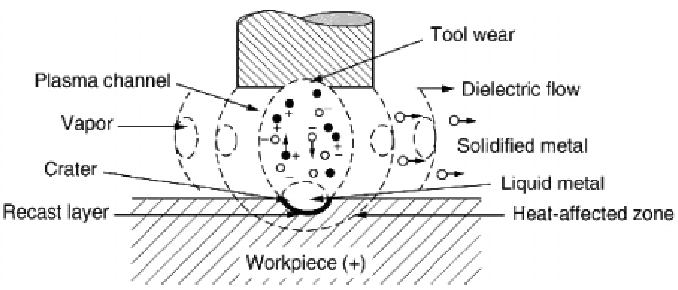


Material Removal Mechanism in EDM

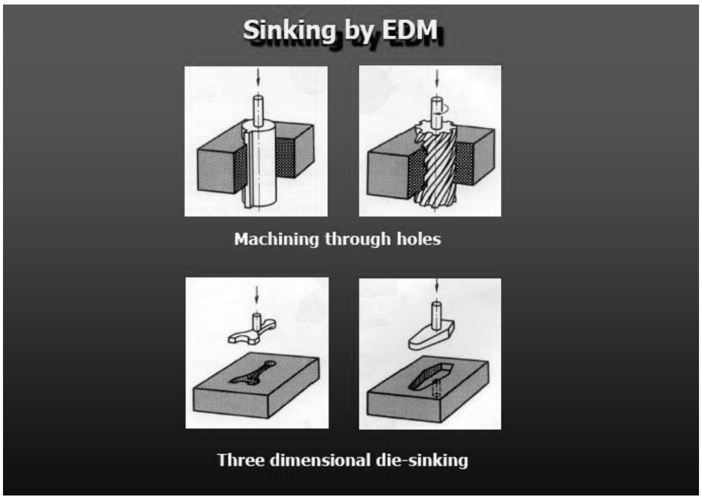


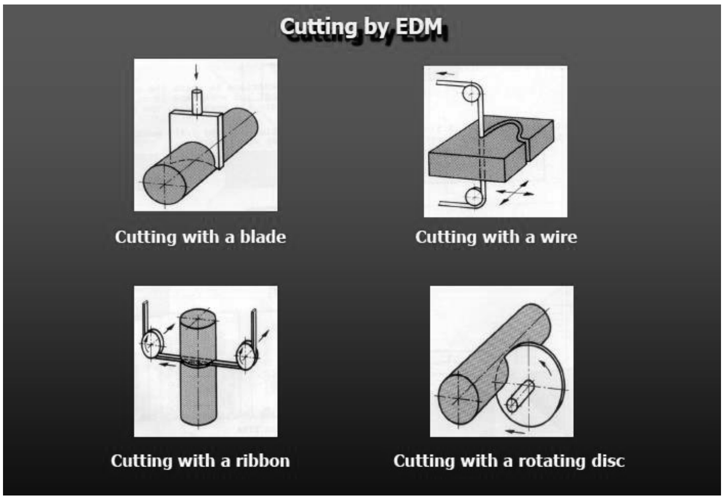
Material Removal Mechanism in EDM

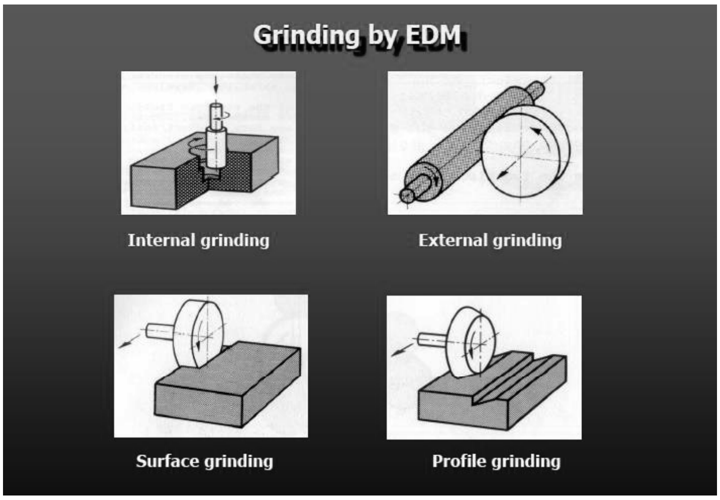




- Need → control the spark energy to employ for machining
- Sparking frequency → many thousands per second
- Final shape of the job → a result of thousands of craters each one superimposed over the other and it is inverse shape of that of the tool.


Sinking by EDM
Machining through holes
Three dimensional die-sinking


Cutting by EDM
Cutting with a blade
Cutting with a wire
Cutting with a ribbon
Cutting with a rotating disc


Grinding by EDM
Internal grinding
External grinding
Surface grinding
Profile grinding

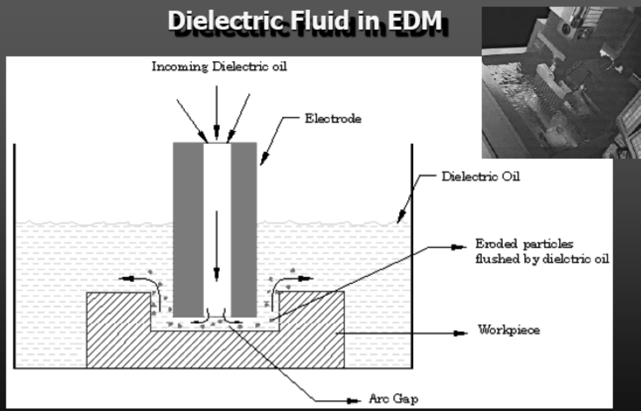

EDM Die-Sinking Machine

EDM Machine Elements

Elements of EDM

- **Dielectric system**
- **Servo system**
- **Electrodes: work piece and tool**
- **Power supply**

Dielectric Fluid in EDM



Main functions of dielectric Fluid in EDM

- To provide insulation in the gap between the electrode and the workpiece below threshold voltage.
- Stabilize the spark process by ionizing and deionizing the spark channel at fixed frequencies.
- Concentrate the spark channel.
- To flush the eroded particles, produced during machining, from the discharge gap.
- To cool the section that was heated by the discharge machining.

Ideal Characteristics Dielectric Fluid

- Good electrical discharge efficiency ← enables quick ionisation & deionisation
- Low viscosity ← enables easy flow in narrow gap
- High flash point ← reduces fire hazard
- Good thermal & oxidation stability ← less degradtion
- Minimum odor ← environment friendly
- Low cost

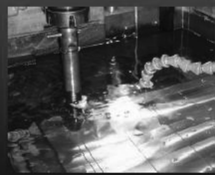
Commonly used Dielectric Fluids in EDM

- Transformer oil
- Paraffin oil
- Lubricating oil
- Kerosene oil
- Deionized water → high MRR, high TWR, corrosive, good coolant → used in WEDM

Need for Flushing in EDM

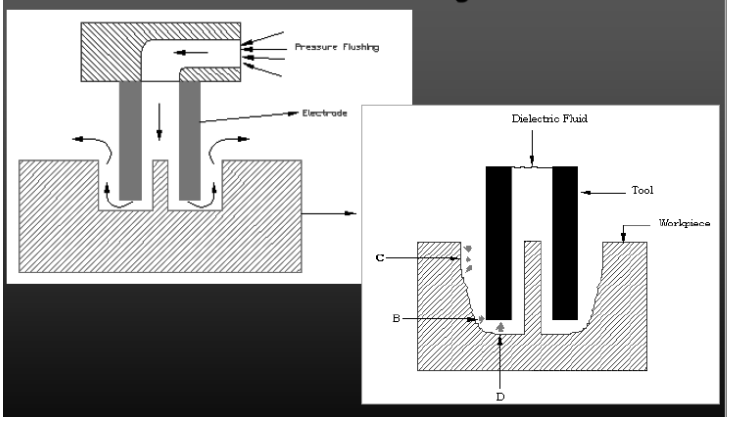
- Inadequate flushing → result in arcing, decreased electrode life, and increased production time.
- The fluid should have the ability to flow through the spark gap, removing debris, chips, and particles eroded by the EDM process. ← low viscosity

<u>Flushing Techniques</u>

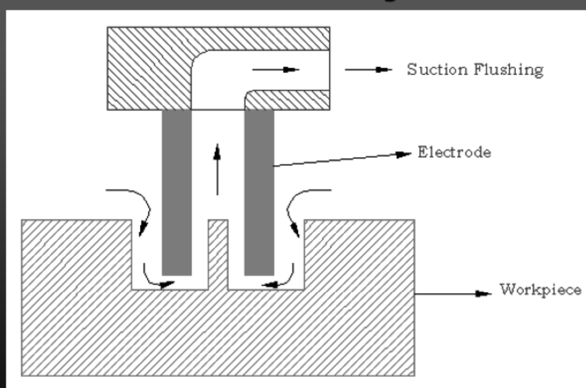


- Normal flushing
- Reverse flushing
- Jet flushing
- Immersion flushing
- Intermittent opening up the gap by lifting tool

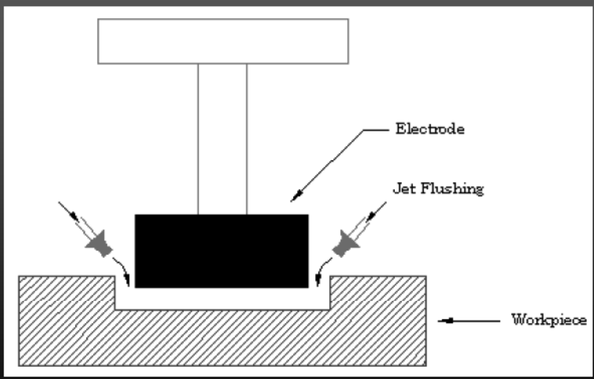
Normal Flushing



Reverse Flushing



Jet Flushing



Electrode Materials for EDM

Copper electrode
Bass electrode
Copper-tungsten electrode
Silver-tungsten electrode
Tungsten electrode
Graphite electrode
Copper impregnated graphite
Eletroformed electrode

Selection of Electrode Materials for EDM

Material	Wear Ratio	MRR	Fabrication	Cost	Application
Copper	Low	High in roughing	Easy	Moderate	All metals
Brass	High	High on finish range	Easy	Low	All metals
Tungsten	Lowest	Low	Difficult	High	Only where small holes are to be drilled
W-Cu alloys	Low	Low	Difficult	High	High accuracy job
Copper-Graphite	Low	High	Very delicate, Difficult	Material	All metals
Zn-based alloy	High	High in roughing	Easily die-casted	Low	All metals

Tool Wear

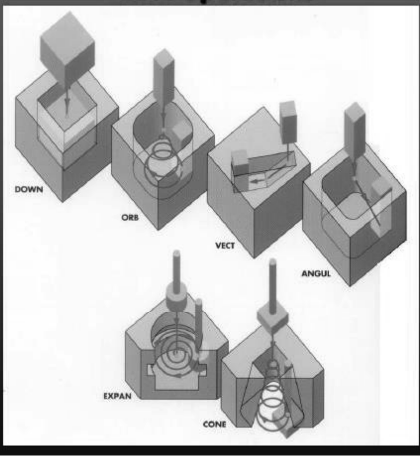
- Compensation for reduced length ← tool wear
- Electrode refeeding → brings tool to a reference point

Automatic Tool Changer

- Many tools mounted on a magazine – called one at a time by CNC program
- Reduces tool-changing time
- CNC-EDM more popular

EDM Operations

- •Downwards
- •Orbital
- •Vectorial
- •Angular
- •Expanding
- •Conical



EDM equipped with CNC

Better removal of debris and ease of machining in attaining complex form

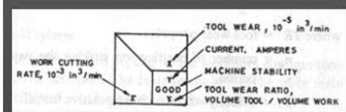
Process Parameters of EDM

- Pulse on time
- Pulse off time
- Duty factor
- Peak current setting
- Gap voltage
- Capacitance
- Polarity

Process Variables

- Increase in current or spark voltage → increased MRR, higher surface roughness
- Increase in spark frequency → improved surface finish ← as energy is shared by more number of sparks → decreased crater size
- Low Inter-electrode Gap → low MRR, high SF, better accuracy
- Decreased pulse duration → low MRR, better SF, high electrode wear

Effect of Polarity

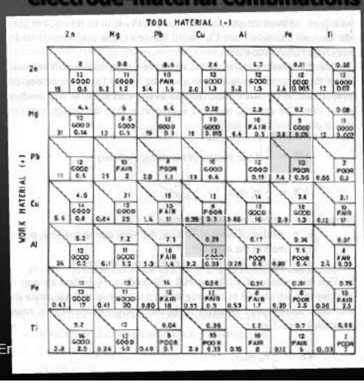


For machining ferrous material with copper tool, what polarity should be given to the work piece and why?

Coosing iron "negative and cooper tool "positive" gives a stronger discharge than vice versa.

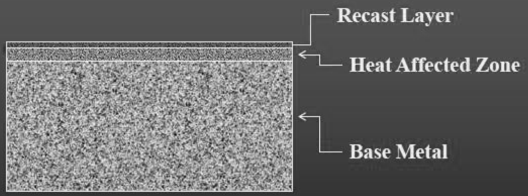
Iron atom can give away electrons more easily…

Electro-discharge maching characteristics of various electrode-material combinations

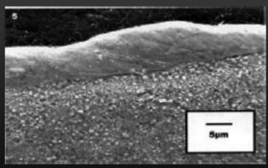


Surface Integrity in EDM

Surface topography nad subsurface metallurgy



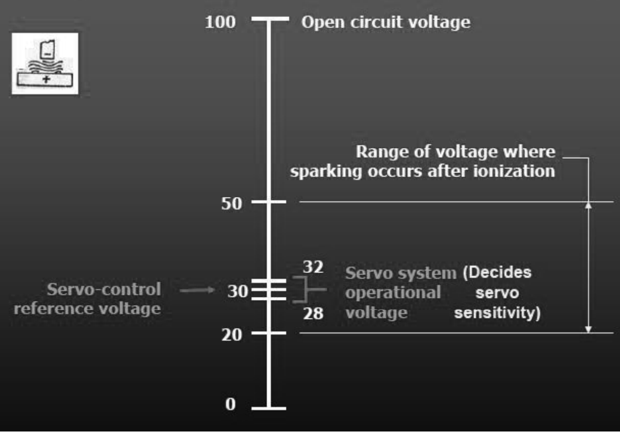
Recast Layer →
Molten metal not flushed away, resolidified on workpiece → hardened due to fast cooling → thin : 2.5 – 50 micron → hard (6o HRC), may contain micro-cracks → should be removed



Servo system in EDM

- To maintain pre-determined gap between the electrodes
- Gap bridged by electrically conductive materials → signal to servo system → reverse direction
- Reciprocates towards work piece until dielectric flushes gap
- If flushing is inefficient → very long cycle time

Servo Operation Based on Machining and Reference Voltage



Pulses in EDM

- Performance measures such as MRR, tool wear, and surface finish for the same energy depend on the shape of the current pulses.
- Depending upon the situation in the gap which separates both electrodes, principally four different electrical pulses may be distinguished:

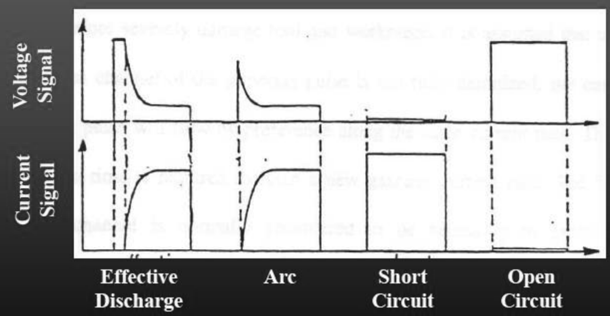
a) Open circuit or open voltage

b) Effective discharges or real Sparks

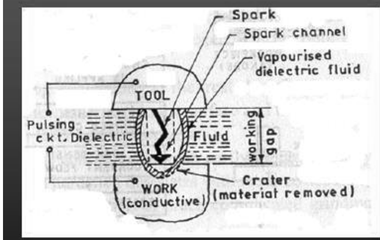
c) Arcs and

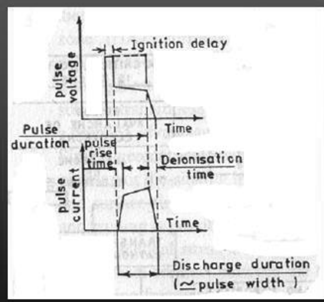
d) Short circuits

Pulses in EDM



Puse Waveform for Effective Discharge



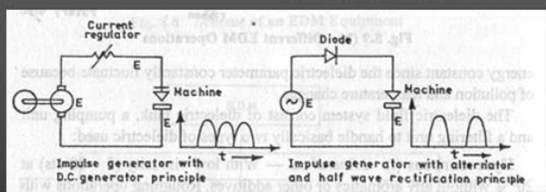


Pulse Generators

Controlled pulse generator governs shape and frequency of pulsing. It enables

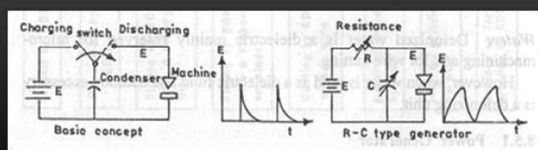
→ rough machining (high energy and low frequency) or
→ finish machining (low energy and high frequency)

Pulse Generators



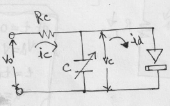
Rotary Impulse Generator (now obsolete)

High discharge R , low tool wear



Relaxation Generator

$\underline{EDM}$ → Relaxation Generator →.



V_0 = source voltage
i_c = Charging current at t.
V_c = Condenser voltage achieved at t
C = Capacitor value
R = Charging resistance

Charging ckt:→

$$i_c = \frac{V_0 - V_c}{R_c} = C.\frac{dV_c}{dt}$$

$$\Rightarrow \frac{dV_c}{V_0 - V_c} = \frac{1}{CR_c}dt$$

limit:

at $t=0$, $V_c=0$ } $t = t_c$, $V_c = V_c$

$$\Rightarrow \int_0^{V_c} \frac{dV_c}{V_0 - V_c} = \int_0^{t_c} \frac{dt}{CR_c}$$

$$\Rightarrow \left[\log (V_0 - V_c)\right]_0^{V_c} = -\frac{1}{CR_c}t_c$$

$$\Rightarrow \log\left[\frac{V_0 - V_c}{V_0}\right] = -\frac{1}{CR_c}t_c$$

$$\Rightarrow \frac{V_0 - V_c}{V_0} = e^{-\left(\frac{1}{CR_c}\right)t_c}$$

$$\Rightarrow 1 - \frac{V_c}{V_0} = e^{-\frac{t_c}{CR_c}}$$

$$\Rightarrow \frac{V_c}{V_0} = 1 - e^{-\frac{t_c}{CR_c}}$$

$$\Rightarrow V_c = V_0\left[1 - e^{-t_c/CR_c}\right]$$

⇒ Exponential decay of charging.

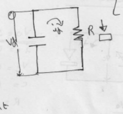
$$i_c = \frac{V_0 - V}{R_c}$$

$$\Rightarrow i_c = \frac{V_0 - V_0\left[1 - e^{-\frac{t_c}{CR_c}}\right]}{R_c}$$

$$\Rightarrow i_c = \frac{V_0}{R_c}e^{-t_c/CR_c}$$

Discharging ckt

{ V_{c0} = Charge-/Breakdown voltage



at $t=0$
$V_d = V_{c0}$
$t = t_d$
$V_d = V_d$

$$\frac{V_d}{R} = i_d = -C\frac{dV_d}{dt}$$

$$\frac{dV_d}{V_d} = -\frac{1}{CR}dt$$

$$\Rightarrow \int_{V_{c0}}^{V_d} \frac{dV}{V} = -\frac{1}{CR}\int_0^{t_d} dt$$

$$\Rightarrow \left[\log V\right]_{V_{c0}}^{V_d} = -\frac{t_d}{CR}$$

$$\frac{V_d}{V_{c0}} = e^{-\frac{t_d}{CR}}$$

$$\Rightarrow V_d = V_{c0}\left[e^{-t_d/CR}\right]$$

$$i_d = \frac{V_d}{R}$$

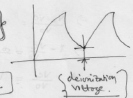
$$\Rightarrow i_d = \left[\frac{V_{c0}}{R} \cdot e^{-t_d/CR}\right]$$

#

$$t_c = \frac{CR_c}{\log\left[1 - \frac{V_{c0}}{V_0}\right]}$$

$$t_d = \frac{RC}{\log\left[\frac{V_d}{V_{c0}}\right]}$$

$$f = \frac{1}{t_c + t_d}$$



R-C

{deionization voltage.}

{Voltage at which Ion column collapse}

$\boxed{\text{Power} = \frac{1}{2}CV_{c0}^2}$ {Pulse energy $E_P = \frac{1}{2}CV^2$}

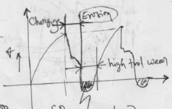
for maximum Power dissipation

$$\boxed{V_{c0} = 0.716\,V_0}$$

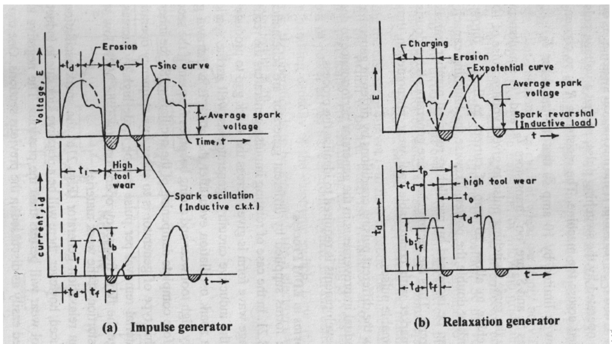
R-L-C ⟶ due to presence of inductance

{Effect discharge ckt → R-L.
e = Back emf Generated in the ckt}

Cause of tool wear [more R] [less e]

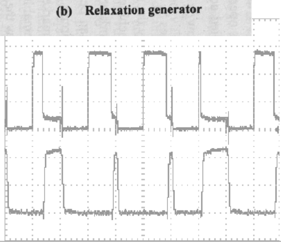


{Spark reversal (Inductive load)}

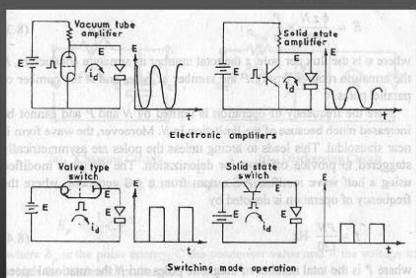


(a) Impulse generator (b) Relaxation generator

Surface finish depends on pulse energy and frequency

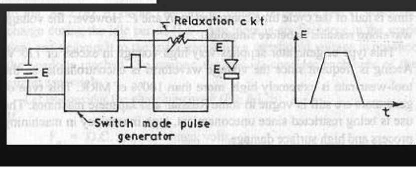


Pulse Generators



Electronic Pulse Generator

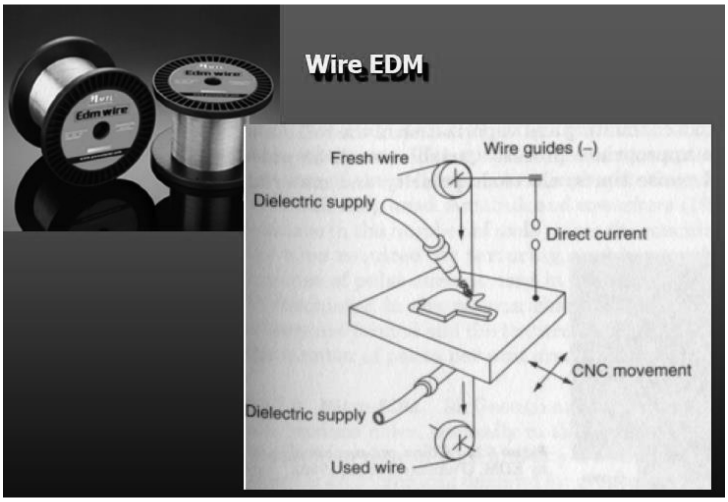
To arrest back emf. vis-à-vis tool wear



Hybrid Pulse Generator (Electronic + Relaxation)

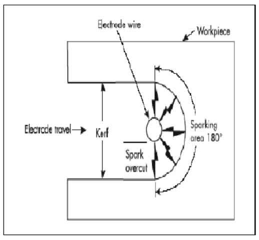
Wire EDM

Wire EDM



- In this process, a thin metallic wire is fed on-to the work piece, which is submerged in a tank of dielectric fluid such as deionized water.
- The wire, which is constantly fed from a spool, is held between upper and lower diamond guides. The guides are usually CNC-controlled.
- In the wire-cut EDM process, water is commonly used as the dielectric fluid. Filters and de-ionizing units are used for controlling the resistivity and other electrical properties.
- Wires made of brass are generally preferred.

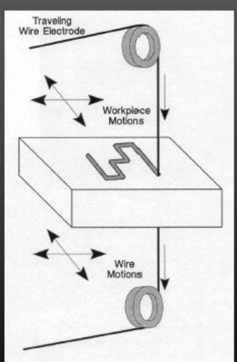
- The area where in discharge takes place gets heated to very high temperatures such that the surface gets melted and removed. The cut particles (debris) get flushed away by the continuously flowing dielectric fluid and keep the wire and workpiece cool.
- The wire and workpiece must be electrically conductive.
- Schematic illustration of the wire EDM process. As much as 50 hours of machining can be performed with one reel of wire, which is then discarded.
- Pieces over 16 in thick can be machined.

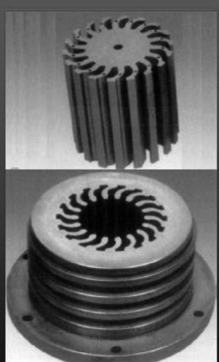


(b)

Parameters	Symbol	Unit	Level 1	Level 2	Level 2
Gap Voltage	V	Volt	40		
Peak Current	PC	A	10		
Pulse-on Time	T_{on}	µm	6		
Pulse-off Time	T_{off}	µm	12		
Wire Feed Rate	WFR	mm/min	3	5	7
Wire Tension	WT	N	11		
Wire Size	WS	Mm	0.25		
Wire Material	WM	-	Brass Wire		
Dielectric	-	-	Deionized Water		
Polarity	-	-	Wire electrode: a negative polarity Workpiece: a positive polarity		
Environment Temperature	ET	°C	20±1		
Environment Humidity	EH	%	40±5		

Wire EDM





❑Advantages Of WEDM:

- ➢ Excellent surface finish
- ➢ High degree of accuracy
- ➢ Allows machining of features that would be very difficult or impossible using conventional machining methods
- ➢ Suitable for hardened and exotic materials (Conductive only)
- ➢ Wire can be threaded through a pre-existing pilot hole to allow access to internal features

The disadvantages of Wire EDM include:

- **The wire must pass through the entire part which means this process is not suitable for 'blind-hole' applications**
- **The process can be time-consuming depending on the amount of material to be removed**
- **Brass deposits can be found on the part post-machining**
- **The tighter the tolerance the more cuts required to hold – Each pass results in additional processing time**

Applications

- Aerospace, Medical, Electronics and Semiconductor applications
- Tool & Die making industries.
- In making Gauges & Cams
- Cutting of Gears
- Manufacturing hard Electrodes.

1. Which of the following material cannot be machined by EDM
   (a) steel
   (b) WC
   (c) Titanium
   (d) Glass

2. w(W)hich of the following is used as dielectric medium in EDM
   (a) tap water
   (b) kerosene
   (c) NaCL solution
   (d) KOH solution

3. Tool should not have
   (a) low thermal conductivity
   (b) high machinability
   (c) high melting point
   (d) high specific heat

1 – (d)
2 – (b)
3 – (a)

1. In a RC type generator, the maximum charging voltage is 80 V and the charging capacitor is 100 μF. Determine spark energy.

2. If in a RC type generator, to get an idle time of 500 μs for open circuit voltage of 100 V and maximum charging voltage of 70 V, determine charging resistance. Assume C = 100 μF.

3. For a RC type generator to get maximum power dissipation during charging $V_c^* = V_o x0.716$. Determine idle time for $R_c = 10\ \Omega$ and C = 200 μF

4. Determine on time or discharge time if V_o = 100 V and V_d^* = 15 V. Spark energy = 0.5 J. Generator is expected for maximum power during charging. Machine resistance = 0.5 Ω.

Solution to Prob. 1

$$E_s = \frac{1}{2}CV^2 = \frac{1}{2}x100x10^{-6}x80^2 = 0.32J$$

Solution to Prob. 2

$$t_c = -\frac{R_c C}{\ln\left(1 - \frac{V_c^*}{V_c}\right)}$$

$$500x10^{-6} = -\frac{R_c x100x10^{-6}}{\ln\left(1 - \frac{70}{100}\right)}$$

$R_C \cong 6\ \Omega$ **Answer**

$$t_c = -\frac{R_c C}{\ln\left(1 - \frac{V_c^*}{V_o}\right)} = -\frac{10x200x10^{-6}}{\ln(1-0.716)}$$

t_c = 1.58 ms **answer**

Solution to Prob. 4

$$V_c^* = 0.716 V_o = 71.6\ V$$

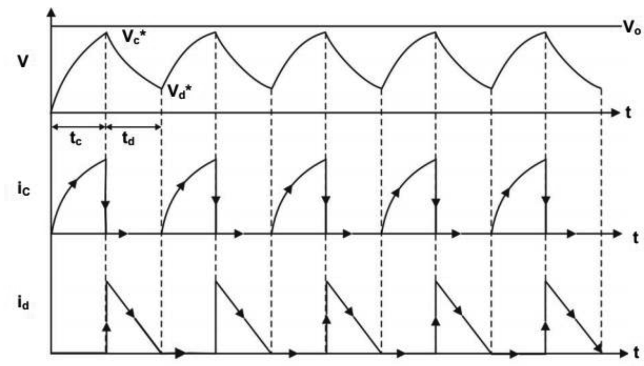
$$E_s = \frac{1}{2}CV^2 = 0.5\ J$$

$$\therefore\ C = 2x0.5x\frac{1}{(71.6)^2} = 195\ \mu F$$

$$t_d = -\frac{R_m C}{\ln\left(\frac{V_d^*}{V_c^*}\right)} = 62\ \mu F$$ **answer**

Quarries?

Voltage and current pulse for RC Type Generator



For maximum power dissipation in RC type EDM generator $V_c^* = 0.716\ V_o$.
The charging time or idle time or off time, t_c, can be expressed as

$$t_c = -\frac{R_c C}{\ln\left(1-\frac{V_c^*}{V_c}\right)}$$

The discharging time or machining time or on time can be expressed as

$$t_d = -\frac{R_m C}{\ln\left(\frac{V_d}{V_c^*}\right)^*}$$

$\therefore$ Frequency of operation, f

$$f = \frac{1}{t_c + t_d} = \frac{1}{\dfrac{R_c C}{\ln\left(1-\frac{V_c^*}{V_c}\right)} + \dfrac{R_m C}{\ln\left(\frac{V_d}{V_c^*}\right)}}$$

Total energy discharged through spark gap

$$= \int_0^{t_d} i_d^2 R_m\, dt = \int_0^{t_d} \frac{V_c^{*2}}{R_m^2} R_m e^{-\frac{2t}{R_m C}} dt$$

$$= \frac{V_c^{*2}}{R_m} \int_o^{t_d} e^{-\frac{2t}{R_m C}} dt$$

$$= \frac{V_c^{*2}}{R_m} \cdot \frac{R_m C}{2t} \left| -e^{-\frac{2t}{R_m C}} \right|_0^{t_d}$$

$$= \frac{1}{2} C V_c^{*2} \left\{ 1 - e^{-\frac{2t_d}{R_m C}} \right\}$$

$$\cong \frac{1}{2} C V_c^{*2}$$