International Journal of Current Research in Science and Technology

Volume 2, Issue 11 (2016), 11–24.

ISSN: 2394-5745

Available Online: http://ijcrst.in/

International Journal of Current Research in Science and Technology

A Review-Study on Electric Discharge Machining (EDM)

Research Article

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Abstract: Electric discharge machining is unconventional machining process used for machining of hard materials which cannot machined by conventional machining process. Electric discharge machining is an electro sparking method of metal working involving an electric erosion effect. A pulse discharge occurs in a small gap between the work piece and the electrode and removes the unwanted material from the parent metal through melting and vaporizing. In recent years, EDM researchers have explored a number of ways to improve EDM Process parameters such as Electrical parameters, Non-Electrical Parameters and Electrode based parameters. This new research shares the same objectives of achieving more efficient metal removal rate reduction in tool wear and improved surface quality. EDM technology is increasingly being used in tool, molds, dies, and in aerospace products and in surgical equipments making industries, for machining of advanced materials requiring high precision, complex shapes and high surface finish.

Keywords: EDM, Types, Machining Parameters, Study of machining processes.

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1. Introduction of EDM

Electrical Discharge Machining is a most basic nontraditional machining process, where material is removed by thermal energy of spark occurring by means of repeated sequences of electrical ejections between the small gap of an electrode and a work piece. EDM is commonly used for machining of electrically conductive hard metals and alloys in automotive, aerospace and die making industries. EDM process is removing undesirable material in the form of debris and produce shape of the tool surface as of a metal portion in the existence of dielectric liquid. In this machining process work piece is called the anode because it is connected with positive terminal and electrode is connected with negative terminal. Dielectric fluid may be kerosene, transformer oil, distilled water, etc.

The history of EDM Machining Techniques goes as far back as 1770, when English chemist Joseph Priestly discovered the erosive effect of electrical discharges or sparks. The EDM process was invented by two Russian scientists, Dr. B.R. Lazarenko and Dr. N.I. Lazarenko in 1943. The spark generator used in 1943, known as the Lazarenko circuit, has been employed over many years in power supplies for EDM machines and proved to be used in many current applications.

The Lazarenko EDM system uses resistance capacitance type of power supply, which was widely used at the EDM machine in the 1950's and later served as the model for successive development in EDM. Further developments in the 1960's of pulse and solid state generators reduced previous problems with weak electrode as well as the inventions of orbiting systems. In the 1970's the number of electrodes is reduced to create cavities. Finally, in the 1980's a computer numerical controlled (CNC) EDM was introduced in USA.

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2. EDM-Principle of Operation

In this machining method the metallic particle is removed as of the work piece owed to controlled wearing away action by means of repeatedly occurring spark ejection with the help of discharge current applied by power supply taking place in small gap in the range of $10 - 125\mu m$ between the tool and work piece. The below schematic Figure 1 shows the schematic setup of Wire Electric Discharge Machining for how the machining will do the work. The tool is attached to cathode terminal and the work piece is attached to anode terminal. After the potential differences apply by power supply crossways the small gap develops adequately high electrical discharges through the small break in the form of the spark in interval of 10 of micro seconds. Then the electron ions are present accelerated towards the positive ions, bringing on a discharge passage that turn out to be conductive. It is only at a given instant of time when the suitable voltage is built up across the tool and work piece the accelerated electron ions may ultimately collisions with the dielectric fluid molecules causing creation of a passage of plasma. An instant fall of the electrical resistance of the plasma passage permits that current density attains very large amounts, creating a rise of ionization between molecules and powerful magnetic field results of a very high temperature on the electrodes in the range of $(10000 - 12000°C)$. This high temperature spark causes sufficiently compressive force developed between work piece and tool as an outcome that more or less metallic particles are liquefied and eroded.
Plasma passage occurring exciting increase of temperature make use to remove material. Material removal takes place because of on the spot vaporization of the metallic particle as well as owed to melting process. The melted particle is not withdrawn altogether, however just partly. By means of the potential difference is drawn the plasma passage is no longer continued. As the plasma passage breakdown, it produces pressure force or shock waves, which clears the molten material by flushing method making a depression of removing material all over the place of the spark.

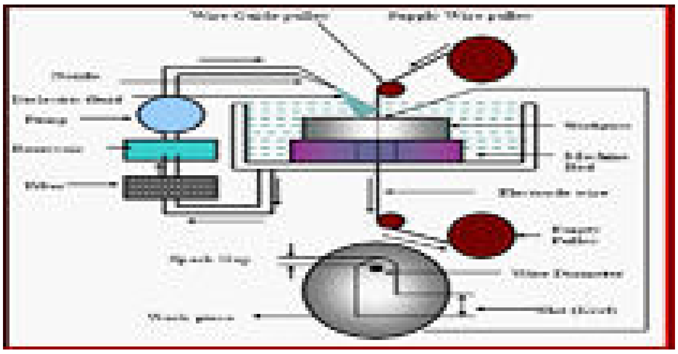

Figure 1. **Shows the schematic setup of Wire Electric Discharge Machining**

3. Components of EDM

- Work-piece-all the conductive material can be worked by EDM
- Tool Electrode-The EDM electrode is the tool that determines the shape of the cavity to be produce.
- Dielectric fluid-The EDM setup consists of tank in which the dielectric fluid is filled. Electrode & wokpiece submersed into the dielectric fluid.
- Servo system-The servo system is commanded by signals from gap voltage sensor system in the power supply and control the feed of electrode & workpiece to precisely match the rate of material removal.

- Power supply-The power supply is an important part of any EDM system. It transform the alternating current from the main utility supply into the pulse direct current (DC) required to produce the spark discharge at the machining gap.
- The DC pulse generator is responsible for supplying pulses at a certain voltage and current for specific amount of time.

4. Types of EDM

Basically there are two types of EDM: Die-sinking EDM and Wire-cut EDM.

(A). **DIE-SINKING EDM:** Die-sinking EDM, also known as Volume EDM or cavity type, consists of an electrode and workpiece submerged in an insulating fluid is EDM oil/ kerosene / transformer oil. In sink EDM, the most common electrode materials are copper and graphite. This is due to the high conductivity of copper and the high melting point of graphite. The electrode and workpiece are connected to a suitable power supply. The power supply generates an electrical potential between the two parts. As the electrode approaches the workpiece, dielectric breakdown occurs in the fluid, forming a plasma channel, and a small spark jumps. These sparks usually strike one at a time because it is very unlikely that different locations in the inter-electrode space have the identical local electrical characteristics which would enable a spark to occur simultaneously in all such locations. These sparks happen in huge numbers at random locations between the electrode and the workpiece. As the base metal is eroded, and the spark gap subsequently increased, the electrode is lowered automatically by the servo control of the machine .so that the process can continue uninterrupted. Several hundred thousand sparks occur per second, with the actual duty cycle carefully controlled by the setup parameters.

In this period the discharge current is varied within range of 0.5 to 400 A, at 40-300 V applied voltage range and pulse duration can be varied from 2 to 2000 micro second. Different type of flushing method is applied to remove and prevent from accumulation of melted material from the work piece and smoothen the process

(B). **WIRE-CUT EDM:** Wire EDM Machining (also known as Spark EDM) is an electro thermal production process in which a thin single metal wire which acts as an electrode [1], in conjunction with de-ionized water which is used to conduct electricity, allows the wire to cut through metal by the use of heat from electrical sparks. A thin single-strand metal wire diameter of 0.02-0.33 mm and is usually made from brass or in the case of very thin wires, tungsten or molybdenum. Brass or steel wires coated in zinc are also commonly used [2], is fed through the workpiece, submerged in a tank of dielectric fluid, typically deionized water. The speed of wire movement is up to 3 m/min.

Wire EDM is mostly used when low residual stresses are required, as it does not needs high cutting forces for removal of material. Wire-cut EDM is typically used to cut plates as thick as 300mm and to make punches, tools, and dies from hard metals that are difficult to machine with other methods. In today's competitive world the demand is increasing for high speed machining with good quality of surface finish, Wire Electrical Discharge Machining (WEDM) can serve the purpose. WEDM is a machining technique for producing complex parts and precision components out of hard conductive materials.

5. Various Process Parameters in EDM

(A). **ELECTRICAL PARAMETERS:**

(a). **Duty cycle (t):** It is a percentage of the on-time relative to the total cycle time. This Parameter is calculated by dividing the on-time by the total cycle time (on-time pulse off- time). We multiplied by 100 for the percentage of efficiency which is called duty cycle

(b). **Voltage (V):** It is a potential that can be measure by volt it is also effect to the material removal rate and allowed to per cycle.

(c). **Discharge current (current Ip):** Current is measured in amp Allowed to per cycle. Discharge current is directly proportional to the Material removal rate.

(d). **Spark On-time (pulse time or Ton):** The duration of time (μs) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on-time. This energy is really controlled by the peak current and the length of the on-time.

(e). **Spark Off-time (pause time or Toff):** The duration of time (μs) between the sparks (that is to say, on-time). This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable.

(f). **Diameter of electrode (D):** This tool is used not only as a electrode but also for internal flushing.

(g). **Over cut:** It is a clearance per side between the electrode and the workpiece after the machining operation.

(h). **Arc gap (or gap):** The Arc gap is distance between the electrode and workpiece during the process of EDM. It may be called as spark gap. Spark gap can be maintained by servo system.

(i). **Average Current:** It is the maximum current available for each pulse from the power supply/generator in the circuit. Average current is the average of the amperage in the spark gap measured over a complete cycle. It is calculated by multiplying peak current by duty factor.

$$Average\ Current\ (A) = Duty\ Factor\ (\%) \times Peak\ Current$$

(j). **Pulse Frequency:** It is the number of cycles produced across the gap in one second. The higher the frequency, finer is the surface finish that can be obtained. With an increase of number of cycles per second, the length of the pulse on-time decreases. Short pulse on-times remove very little material and create smaller craters. This produces a smoother surface finish with less thermal damage to the workpiece. Pulse frequency is calculated by dividing 1000 by the total cycle time (pulse on-time + pulse off-time) in microseconds.

$$Pulse\ Frequency\ (kHz) = 1000/Total\ cycle\ time\ (\mu s)$$

(k). **Polarities:** Electrodes are often the most expensive part of an EDM operation. Most electrodes for EDM are usually made of graphite, although brass, Cu, or Cu/W-alloys may be used. These electrodes are shaped by forming, casting, and powder metallurgy, or, frequently, by machining. EDM tool wear is an important factor, as it affects the dimensional and form accuracy. It is related to melting point of the tool material involved-the higher the melting point, the lower the wear rate. The tool wear can be minimized by reversing the polarity, which depends on the tool/workpiece combination.

Where, S-straight polarity (WP positive electrode); R-reverse polarity (WP Negative electrode).

(l). **Wire Feed:** Wire feed is the rate at which the wire-electrode travels along the wire guide path and is fed continuously for sparking. It is always desirable to set the wire feed to maximum. This will result in less wire breakage, better machining stability and slightly more cutting speed.

Electrodematerial	Work material				
	Steel	Tungsten carbide	Copper	Aluminium	Ni-base alloys
Graphite	+. -	-	-	+	+, -
Copper	+	+, -	-	+	+
Cu –W	+	+, -	-	+	+
Steel	+, -	+	-	-	-
Brass	-	-		+	-

Table 1. **The recommended polarity for various Tool /Workpiece material combinations**

(m). **Wire Tension:** Wire tension determines how much the wire is to be stretched between upper and lower wire guides. This is a gram-equivalent load with which the continuously fed wire is kept under tension so that it remains straight between the wire guides. More the thickness of job more is the tension required. Improper setting of tension may result in the job inaccuracies as well as wire breakage.

(B). **NON ELECTRICAL PARAMETERS:**

(a). **DIELECTRIC FLUID:** In EDM, material removal mainly occurs due to thermal evaporation and melting. As thermal processing is required to be carried out in absence of oxygen so that the process can be controlled and oxidation avoided. Oxidation often leads to poor surface conductivity (electrical) of the work piece hindering further machining. Hence, dielectric fluid should provide an oxygen free machining environment. Further it should have enough strong dielectric resistance, so that it does not breakdown electrically too easily but at the same time ionize when electrons collide with its molecule. Moreover, during sparking it should be thermally resistant as well.

The dielectric fluid has the following functions:

- It helps in initiating discharge by serving as a conducting medium when ionized, and conveys the spark. It concentrates the energy to a very narrow region.
- It helps in quenching the spark, cooling the work, tool electrode and enables arcing to be prevented.
- It carries away the eroded metal along with it.
- It acts as a coolant in quenching the sparks.

Type of Dielectric fluid: The electrode wear rate, metal removal rate and other operation characteristics are also influenced by the dielectric fluid. The transformer on silicon oil, EDM oil, kerosene (paraffin oil) and de-ionized water are used as dielectric fluid in EDM.

- **Kerosene** is used with certain additives that prevent gas bubbles and doddering
- **Silicon fluids** and a mixture of these fluids with petroleum oils have given excellent results.
- **Tap water** cannot be used as it ionizes too early and thus breakdown due to presence of salts as impurities occur. Dielectric medium is generally flushed around the spark zone. It is also applied through the tool to achieve efficient removal of molten material.

Dielectric Fluid	Machining Rate	Wear Ratio
50 viscosity hydro carbon oil	39	2.8
Distilled water	54.6	2.7
Tap water	57.7	4.1
Tetra ethylene glycol	102.9	6.8

Table 2. **Performance of several dielectric fluids**

(b). **FLUSHING METHODS:** Flushing is the most important function in any electrical discharge machining operation. Flushing is the process of introducing clean filtered dielectric fluid into the spark gap. There are a number of flushing methods used to remove the metal particles efficiently. Flushing of the dielectric plays a major role in the maintenance of stable machining and the achievement of close tolerance and high surface quality. Inadequate flushing can result in arcing, decreased electrode life, and increased production time.

Four methods of introducing dielectric fluid to the machining gap are

- **Normal flow:** In the majority of EDM applications, the dielectric fluid is introduced, under pressure, through one or more passages in the tool and is forced to flow through the gap between the tool and the workpiece. Flushing holes are generally placed in areas where the cuts are deepest. Normal flow is sometimes undesirable because it produces a tapered opening in the workpiece as shown in Figure 3.
- **Reverse flow:** This method is particularly useful in machining deep cavity dies, where the taper produced using the normal flow mode can be reduced. The gap is submerged in filtered dielectric, and instead of pressure being applied at the source a vacuum is used. With clean fluid flowing between the workpiece and the tool, there is no side sparking and, therefore, no taper is produced as shown in Figure 3.
- **Jet flushing:** In many instances, the desired machining can be achieved by using a spray or jet of fluid directed against the machining gap. Machining time is always longer with jet flushing than with the normal and reverse flow modes.
- **Immersion flushing:** For many shallow cuts or perforations of thin sections, simple immersion of the discharge gap is sufficient. Cooling and machining debris removal can be enhanced during immersion cutting by providing relative motion between the tool and workpiece. Vibration or cycle interruption comprises periodic reciprocation of the tool relative to the workpiece to effect a pumping action of the dielectric fluid. Synchronized, pulsed flushing is also available on some machines. With this method, flushing occurs only during the non-machining time as the electrode is retracted slightly to enlarge the gap. Increased electrode life has been reported with this system.

For proper flushing conditions, the following was recommended:

- Flushing through the tool is more preferred than side flushing.
- Many small flushing holes are better than a few large ones.
- Steady dielectric flow on the entire workpiece-electrode interface is desirable.
- Dead spots created by pressure flushing, from opposite sides of the workpiece, should be avoided.
- A vent hole should be provided for any upwardly concave part of the tool- Electrode to prevent accumulation of explosive gases.
- A flush box is useful if there is a hole in the cavity.

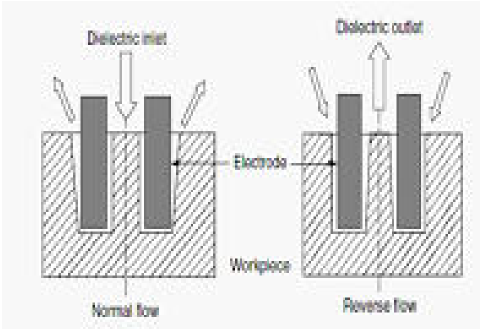

Figure 2. **Normal flow & Reverse flow**

(C). **ELECTRODE BASED PARAMETER:**

(i). **Selection of Electrode Material**

Four main factor determine the suitability of a material for use as an electrode

- The maximum possible metal removal rate
- Wear ratio
- Ease with which it can be shaped or fabricated to the desired shape
- Cost

Electrode Materials: Metals with a high melting point and good electrical conductivity are usually chosen as electrode materials for EDM. Tool material should be such that it would not undergo much tool wear when it is impinged by positive ions. Thus the localized temperature rise has to be less by tailoring or properly choosing its properties or even when temperature increases, there would be less melting. Further, the tool should be easily workable as intricate shaped geometric features are machined in EDM.

Thus the basic characteristics of electrode materials are:

- **High electrical conductivity** – electrons are cold emitted more easily and there is less bulk electrical heating.
- **High thermal conductivity** – for the same heat load, the local temperature rise would be less due to faster heat conducted to the bulk of the tool and thus less tool wear.
- **Higher density** – for the same heat load and same tool wear by weight there would be less volume removal or tool wear and thus less dimensional loss or inaccuracy.
- **High melting point** – high melting point leads to less tool wear due to less tool material melting for the same heat load.
- **Easy** – manufacturability.
- **Cost** – cheap.

The followings are the **different electrode materials** which are used commonly in the industry:

- **Graphite** is the most common electrode material since it has fair wear characteristics and is easily machinable and small flush holes can be drilled into graphite electrodes.
- **Copper** has good EDM wear and better conductivity. It is generally used for better finishes in the range of 0.5 mRa.

- **Copper tungsten and silver tungsten** are used for making deep slots under poor flushing conditions especially in tungsten carbides. It offers high machining rates as well as low electrode wear.
- **Copper graphite** is good for cross-sectional electrodes. It has better electrical conductivity than graphite while the corner wear is higher.
- **Brass** ensures stable sparking conditions and is normally used for specialized applications such as drilling of small holes where the high electrode wear is acceptable.

Material	Wear ratio	Metal removal rate	Fabrication	Cost	Application
Copper	low	High on rough range	Easy	High	On all metals
Brass	High	High only on finishing range	Easy	Low	On all metals
Tungsten	Lowest	Low	Difficult	High	Small holes are drilled
Tungsten copper alloy	Low	Low	Difficult	High	Used higher accuracy work.
Cast iron	Low	Low	Easy	Low	Used on few materials
Steel	High	Low	Easy	Low	Used for finishing work
Zinc based alloy	High	High on rough range	Easy die casted	High	On all metals
Copper graphite	Low	High	Difficult	High	On all metals

Table 3. **Different electrode material**

(ii). **Design of tool electrodes for different shape of workpiece**

Design of tool electrode is made to produce the following workpiece

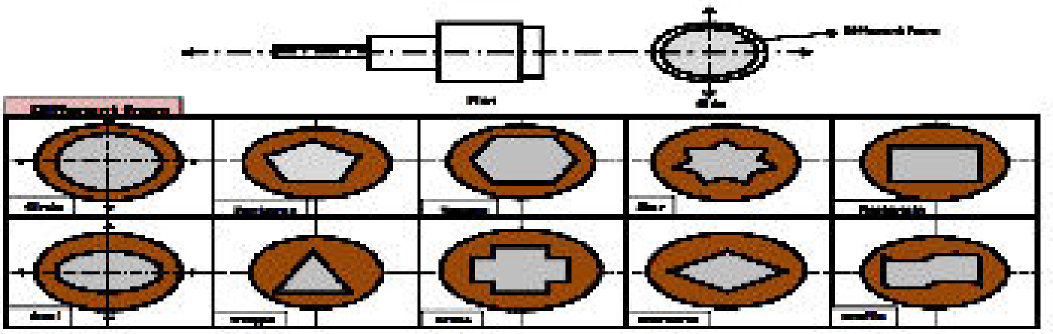

Figure 3. **The different Electrode design**

As we know EDM produce a mirror image on tool on the workpiece. However, a certain amount of clearance should be provided between the tool and work cavity produced. The magnitude of the clearance varies with the rate of metal removal, the material of the tool and workpiece. Different tools may be needed for rough and fine machining. The effect of operating on side clearance shows in Table 4. We use different computer-aided systems that have been experimentally implemented in the design of the electrode. The major research interest in the production of electrodes using the rapid prototyping technique is also used.

Rate of cutting	Finish	Side clearance (mm)
Rapid	coarse	0.5-0.6
Medium	medium	0.2-0.3
Very slow	fine	0.03-0.06

Table 4. **Effect of operating condition on side clearance [3]**

6. Performance Parameters

These parameters measure the various process performances of EDM results large numbers of papers have been focused on ways of yielding optimal EDM performance. Performance measures in EDM are MRR, TWR and SR. In MRR research work focused on metal removal mechanism and methods of improving MRR [4, 5, 6, 7]. Similarly research work on tool wear process and methods of improvement in process has been reported [8,9,10]. Though EDM is essentially a material removal process, efforts have been made to use it as a surface treatment method and/or an additive process. Many surface changes have been reported ever since the process established itself in the tool rooms of manufacturing industry [11].

(a). **Material removal rate(MRR):** MRR is a performance measure for the erosion rate of the workpiece and is typically used to quantify the speed at which machining is carried out. It is expressed as the volumetric amount of workpiece material removed per unit time

$$MRR = \frac{W_{jb} - W_{ja}}{t} \tag{1}$$

Whereas W_{jb}-Weight of workpiece before machining, W_{ja}-Weight of workpiece after machining, t-Machining time.

Volumetric removal rate (VRR), in mm3/min is given by

$$VRR = \left(4 \times 10^4\right) iT_w^{-1.23} \tag{2}$$

Where i-current, Tw-Melting point of the work piece ($^\circ C$).

(b). **Tool Wear Rate (TWR):** TWR is a performance measure for the erosion rate of the tool electrode and is a factor commonly taken into account when considering the geometrical accuracy of the machined feature. It is expressed as the volumetric amount of tool electrode material removed per unit time.

$$TWR = \frac{W_{tb} - W_{ta}}{t} \tag{3}$$

Wear rate of the electrode tool material (Wt) is also given by

$$W_t = \left(11 \times 10^3\right) iT_t^{-2.38} \tag{4}$$

Where wt-wear rate of the tool, mm3/min, i-current Amp, Tt-melting point of the tool, $^\circ C$

(c). **Wear Ratio (WR):** WR is the ratio of TWR/MRR and is used as a performance measure for quantifying tool workpiece material combination pairs since different material combinations gives rise to different TWR and MRR values.

$$WR = TWR/MRR \tag{5}$$

A material combination pair with the lowest WR indicates that the tool-workpiece material combination gives the optimal TWR and MRR condition.

$$R_w = 2.25T_r^{-2.3} \tag{6}$$

Where Tr-ratio of the work piece to tool melting point

Material of electrode	Work piece material	Available form	Performance		Type of machining	Wear ratio		Machinability	Best application
			Relaxation type	Pulse type		VWR R	CWR R		
Graphite	steels	Blocks, Rods	Poor	Excellent	R,F	100:1	5:1	Excellent	Press tooling dies
Brass	All metals	Brass tube, wire	Fair	Excellent	R,F	1:1	7:1	Good	Hole Size
Copper-tungsten	All metals	Shorts Bars, Flats Shims, Wire, Tubes	Excellent	Excellent	S-F,F	8:1	3:1	Fair	Machining of carbides, slots and micro machining
Copper	All metals	Bars,Wire, Tubes	Excellent	Good	R,F	2:1	1:1	Good	Hole
Tungsten	All metals & refractory metals	Wire Rods	Good	Good	S-F,F	10:1	5:1	Poor	Small Slots & Holes
Tungsten carbide	All metals & refractory metals	Sintered Rods	Good	Good	S-F,F	10:1	6:1	Poor	Hole
Steel	Non ferrous materials	Rod, Ingots, Forgings	Poor	Good	S-F	4:1	4:1	Good	Small Slots & Holes
Zinc	Steel only	Cast Shapes	Poor	Fair	R,S-F	2	7:1	Good	Through Holes
Aluminium	Steel only	Cast Shapes, Extruded Bars	Poor	Fair	R	5:1	5:1	Good	Forging Die Cavities

Table 5. **The wear ratio of different material**

Where, R: Rough machining; F: Finish Machining; S-F: Semi-Finish Machining; V_{WR}: Volume wear ratio; C_{WR}: Corner wear ratio.

(d). **Surface roughness(SR):** SR is a classification of surface parameter used to describe an amplitude feature, which translates to roughness of the surface finish. Of the many parameters available to quantify SR, the most commonly used in EDM are arithmetical mean surface roughness (Ra),maximum peak-to-valley surface roughness (Rmax) and root mean square surface roughness (Rq).Average roughness can be expressed in terms of pulse current ip (A) and pulse duration tp (s) by

$$R_a = 0.0225 i_p^{0.29} t_p^{0.38} \tag{7}$$

(e). **Over-Cut (OC):** It is the measure of cut produced exceeding the diameter of the tool. The impression created while EDM process is generally slightly larger than the original diameter of the tool electrode. This is because the spark is generated from along the side of the tool and hence erosion takes place in that direction also. OC is calculated as half the difference of the diameter of the hole produced to the tool diameter.

$$OC = D_{jt} - D_t \tag{8}$$

Where, D_{jt}-diameter of hole produced in the workpiece, Dt - Diameter of tool.

(f). **Heat affected zone(HAZ):** HAZ refers to the region of a workpiece that did not melt during electrical discharge but has experienced a phase transformation, similar to that of heat treatment processes, after being subjected to the high temperatures of electrical discharge.

(g). **Recast layer thickness:** The recast layer refers to the region of re-solidified molten material occurring as the top most layer of the machined surface. The recast layer is usually located above the heat affected zone.

(h). **Kerf (Width of cut):** Kerf is one of the important performance measures in WEDM. Kerf is the measure of the amount of the material that is wasted during machining. It affects the dimensional accuracy of the finished part. Kerf of EDMed workpiece depends on gap voltage, pulse on time, pulse off time, wire feed and flushing pressure.

(i). **Wire wear ratio:** As WEDM is a thermo- electrical process in which material is eroded by a series of sparks between the work piece and the wire electrode, along with the workpiece material some particles from wire also will erode, this phenomenon is called wire wear and this should be kept to a minimum. Wire failure occurs in wire-EDM process as a result of severity in wire wear rate, which is a function of discharge current and discharge time.

7. Comparison of Die-Sinker and Wire-Cut Machines

Both die-sinker and wire-cut EDM machines use sparks to remove electrically conductive material. But while both types are electrical discharge machines, there are differences in their use and operation. Some of these differences are listed in the following text.

Dielectric fluid:

- Die-sinker EDM machines use hydrocarbon oil and submerse the workpiece and spark in the fluid.
- Wire-cut EDM machines generally use deionized water and contain only the sparking area in the fluid.

Applications:

- Die-sinker EDM machines are normally used for producing three dimensional Shapes. These shapes utilize either cavity-type machining or through-hole Machining.
- Wire-cut EDM machines are always used for through-hole machining, since the electrode wire must pass through the workpiece being machined.

Sparking:

- Die-sinker machines produce sparks that occur between the electrode end and the workpiece.
- Wire-cut machines produce sparks that occur between the electrode-side surface and the workpiece.

8. Application of EDM & WEDM.

APPLICATION OF EDM

- The EDM process is most widely used by the mould-making tool and die industries, but is becoming a common method of making prototype and production parts, especially in the aerospace, automobile and electronics industries in which production quantities are relatively low.
- It is used to machine extremely hard materials that are difficult to machine like alloys, tool steels, tungsten carbides etc.
- It is used for drilling of curved holes.
- It is used for machining sharp edges and corners that cannot be machined effectively by other machining processes.

- Higher Tolerance limits can be obtained in EDM machining. Hence areas that require higher surface accuracy use the EDM machining process.
- Ceramic materials that are difficult to machine can be machined by the EDM machining process.
- Electric Discharge Machining has also made its presence felt in the new fields such as sports, medical and surgical, instruments, optical, including automotive R&D areas.
- It is a promising technique to meet increasing demands for smaller components usually highly complicated, multi-functional parts used in the field of micro-electronics.

Applications of WEDM Process

- Parts with complex geometry's
- Thin or delicate parts that are susceptible to tool pressure
- Progressive, blanking and trim dies
- Extrusion dies Precious metals.
- Narrow slots and keyways
- Mold components
- Medical, Aerospace, defense and electronic parts.

9. Electric Discharge Machine Capabilities & Limitations

There are a lot of benefits when using electrical discharge machine (EDM) when machining. This is due to its capabilities and advantage. To summarize, these are the electric discharge machine (EDM) capabilities compare to other method :

- Material of any hardness can be cut
- High accuracy and good surface finish are possible
- No cutting forces involved
- Intricate-shaped cavities can be cut with modest tooling costs
- Holes completed in one “pass”
- Thin fragile sections such as webs or fins can be easily machined without deforming the part.

LIMITATIONS: But, when using electric discharge machine (EDM) when machining there are a few limitation. These are electric discharge machine (EDM) limitation

- Limited to electrically conductive materials
- Slow process, particularly if good surface finish and high accuracy are required
- Dielectric vapour can be dangerous
- Heat Affected Zone (HAZ) near cutting edges
- Die sinking tool life is limited.

10. Conclusion

Following conclusion can be drawn for EDM

- EDM can be used effectively for machining of complex shapes.
- EDM machining process is independent of material's mechanical properties.
- EDM machining can result in high accuracy.
- EDM is widely being used as non-traditional machining process in manufacturing process.

References

[1] M.T.Antar, S.L.Soo, D.K.Aspinwall and D.Jones, *Productivity and Workpiece Surface Integrity When WEDM Aerospace Alloys Using Coated Wires*, Proceedings Engineering, 19(2011), 3-8.

[2] Balbir Singh, Sudhir Kumar and Jatindar Kumar, *A Review of Eelctro Discharge Machining of Aluminum Metal Matrix Composites*, Proc. of 3rd International Conf. on Advances in Mechanical EngH., S.V. NIT, Surat, India, , Jan. 4-6(2010), 993-997.

[3] G.F.Benedict, *Non traditional manufacturing process*, Marcel Dekker Inc, New York & Basel, (1987), 231-232.

[4] C.Bhaskar Reddy, V.D.Reddy, G.J.Reddy and C.E.Reddy, *Unconventional Mchining-Role of Electric Discharge Machining-A Review*, Proc. of 4th National Conf. on Emerging Trends in Mechanical Engg., (ETME-2011), G.H. Patel College of Engineering & Technology, Vallabha Vidya Nagar, Gujarat, India, March (2011), 18-19.

[5] Farnaz Nourbakhsh, K.P.Rajurkar, A.P.Malshe and Jian Cao, *Wire electro-discharge machining of titanium alloy*, Procedia CIRP, 5(2013), 13-18.

[6] D.Ghodsiyeh, A.Golshan and Jamal Azimi Shirvanehdeh, *Review on Current research trend in WEDM*, Indian Journal of Science & Technology, 6(2)(2013), 4128-4140

[7] L.Houman, *Total EDM in Jameson (Ed), Electrical Discharge Machining: Tooling*, Methods and Applications, SME, Dearborn, Michigan, (1983), 5-19.

[8] K.H.Ho and S.T.Newman, *State of the art electrical discharge machining (EDM)*, International Journal of Machine Tools & Manufacture, 43(2003), 1287-1300.

[9] K.H.Ho, S.T.Newman, S.Rahimifard and R.D.Allen, *State of art in wire electrical discharge machining (WEDM)*, International Journal of Machine Tools and Manufacture, 44(2004), 1247-1259.

[10] T.Kaneko and M.Tsuchiya, *Three dimensionally controlled EDM using cylindrical electrode*, Journal Japan Society of Electrochemical Machining and Engineering, 18(35)(1984), 1-4.

[11] J.Kapoor, S.Singh and J.S.Khamba, *Recent developments in Wire electrodes for high performance WEDM,* Proceedings of World Congress on Engineering, 2(2010), 1065-1068.

[12] N.Kinoshita, M.Fukui and T.Fujii, *Study on Wire-EDM: Accuracy in Taper Cut*, CIRP Annals-Manufacturing Technology, 36(1)(1987), 119-122.

[13] M.Kunieda, B.Lauwers, K.Rajurkar and B.Schumacher, *Advancing EDM through Fundamental Insight into the Process*, Annals of the CIRP-Manufacturing Technology, 54(2)(2005), 64-87.

[14] P.C.Pandey and H.S.Shan, *Modern Machining Process*, Tata McGraw- Hill Education, (1999), 84-113.

[15] J.Marafona and C.Wykes, *A new method of optimizing material removal rate using EDM with copper tungsten electrodes*, International Journal of Machine Tools & Manufacture, 40(2)(2000), 153-164.

[16] N.Mohri, M.Suzuki, M.Furuya and N.Saito, *Electrode wear process in electrical discharge Machining*, Annals of the CIRP, 44(1)(1995), 165-168.

[17] V.Parashar, A.Rehman, J.L.Bhagoria and Y.M.Puri, *Kerfs width analysis for wire cut electro discharge machining of SS 304L using design of experiments*, Indian Journal of Science and Technology, 3(4)(2010), 369-373.

[18] B.J.Ranganath, K.G.Sudhakar and A.S.Srikantappa, *Wire failure analysis in Wire-EDM process*, Proceedings of International Conference on Mechanical Engineering (ICME2003), Dhaka, Bangladesh, December (2003), 26-28.

[19] F.Roethel and V.Garbajs, *Contributions to the micro-analysis of spark eroded surfaces*, Annals of the CIRP, 25(1)(1976), 135-140.

[20] Sanjeev Kumar, Rupinder Singh, T.P.Singh and B.L.Sethi, *Surface modification by electrical discharge machining: A review*, Journal of Material Processing Technology, 209(2009), 3675-3687.

[21] B.M.Schumacher, *EDM technology for precision workpieces with excellent surface quality*, Proceedings of the ISEM-7, (1983), 124-135.

[22] M.Seernivasa Rao and N.Venikaiah, *Review on Wire-Cut EDM Process*, International Journal of Advanced Trend in Computer Science & Engineering, 2(2)(2013), 12-17

[23] S.Shivanaga Malleswara Routhor and Ch.V.S.Parameswara Rao, *Optimization and Influence of Process Parameters for Machining with WEDM*, International Journal of Innovative Research in Science Engineering and Technology, 3(1)(2014).

[24] J.S.Soni and G.Chakraverti, *Experimental investigation on migration of material during EDM of T 215 Cr12 die steel*, Journal of Materials Processing and Technology, 56(1996), 439-451.

[25] F.Staelens and J.P.Kruth, *A computer integrated machining strategy for planetary EDM*, Annals of the CIRP, 38(1)(1989), 187-190.

[26] H.C.Tsai, B.H.Yan and F.Y.Huang, *EDM performance of Cr/Cu based composite Electrodes*, International Journal of Machine Tools and Manufacturing, 43(3)(2003), 245-252.