Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 2, February-2016

Study the effect of various parameters of an Electrical Discharge Machining – A review

[1]Jay k. Lad, [2]Mihir A. Patel, [3]Devarsh P. Upadhyay, [4]Chirag N. Dabhi, [5]Samarth Bhaduwala

[1]Student (B.E), [2]Student (B.E), [3]Student (B.E), [4]Student (B.E), [5]Assistant Professor B.E (Mechanical)
Mechanical,
ITM UNIVERSE, VADODARA,

Abstract — *Electrical discharge machining (EDM) is regarded one of the dominant non-conventional machining processes. It is based on thermoelectric power between the work piece and tool. The process includes a controlled erosion of electrically conductive work piece by the introduction of rapid and repetitive spark discharge between the tool and work piece by the use of dielectric fluid. To generate a spark between the workpiece and the tool two conditions must be full filled as one is to have air gap between them and second is both of them have good electrical conductivity. There are various types of products which can be produced using EDM such as dies and moulds. Parts of aerospace, automotive industry and surgical components can be finished by EDM. This research paper reviews the vast array of electrical discharge machining and its various parameters such as material removal rate and surface finish.*

Keywords*- EDM, MRR, Surface finish, Tool wear rate*

I. INTRODUCTION

A. Principles of EDM

Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion between tool and work-piece. In this process an electric spark is used as the cutting tool to cut (erode) the workpiece to produce the finished part to the desired shape. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the workpiece. This removes (erodes) very tiny pieces of metal from the workpiece at a controlled rate.

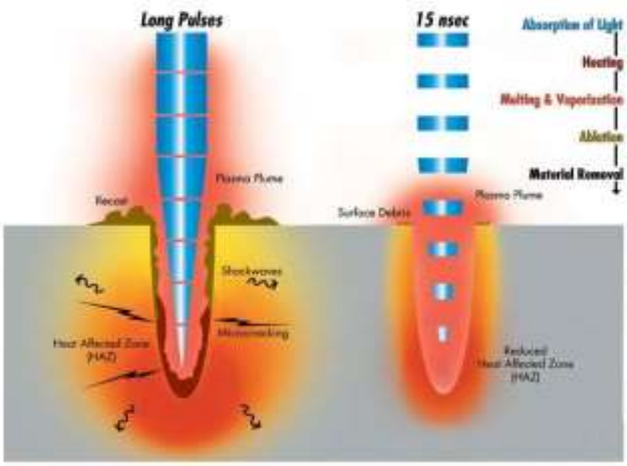

Fig. 1 (Principle of material removal in EDM) [1]

B. EDM Process

EDM spark erosion is the same as having an electrical short that burns a small hole in a piece of metal it contacts. With the EDM process both the workpiece material and the electrode material must be conductors of electricity.

The EDM process can be used in two different ways:

1. Conventional EDM - A preshaped or formed electrode (tool), usually made from graphite or copper, is shaped to the form of the cavity it is to reproduce. The formed electrode is fed vertically down and the reverse shape of the electrode is eroded (burned) into the solid workpiece

2. Wire-Cut EDM - A continuous-travelling vertical-wire electrode, the diameter of a small needle or less, is controlled by the computer to follow a programmed path to erode or cut a narrow slot through the workpiece to produce the required shape.

C. Important Parameters of EDM [2]

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

b) Spark Off-time (pause time or Toff): The duration of time between the sparks (that is to say, on-time). This time allows the molten metal 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.

c) Arc gap (or gap): The arc gap is distance between the electrode and work piece during the process of EDM. It may be called as spark gap. Spark gap can be maintained by servo system of the machine.

d) Discharge current (Ip): Current is measured in amp Allowed to per cycle. Discharge current is directly proportional to the MRR.

e) Duty cycle (τ): It is 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).

$$\tau = Ton$$

F) Voltage (V): It is potential that can be measure by volt it is also effect to the material removal rate and allowed to per cycle. Voltage is given by in this experiment is 50 V.

g) Diameter of electrode (D): It is the electrode of CU-tube there are two different size of diameter 4mm and 6mm in this experiment. This tool is used not only as an electrode but also for internal flushing.

h) Over cut: It is a clearance per side between the electrode and the work piece after the marching operation.

D. Independently/Dependently controlled parameters of EDM

EDM specification by mechanism of process, MRRR and other function that shown in table. 1.1

Open circuit voltage	50 to 300 V
Frequency	50 Hz to 500 kHz or equivalent duty-cycle setting of on and off times per pulse
Dielectric type	Hydrocarbon oils, deionized water kerosene, gas (dry)
Dielectric flow pressure	711 mm vacuum to 480 kPa pr.
Electrode materials	Graphite, copper, brass, zinc-tin, steel, copper-tungsten, copper-graphite, silver-tungsten, tungsten
Servo drive gap	0.013 to .13 mm
Sensitivity control Capacitance	(on some style M/Cs) from trial cuts
Polarity	“standards is positive on workpiece, negative on electrode”
Average current	0.1 to 500 A

Spark gap	0.013 to 0.13 mm
Overcut	0.005 to 0.5 mm per side
MRR	0.05 to 24.5 cm^3/hr.
WR(ratio of w/p erosion to electrode erosion)	0.5:1 to 100:1
Source roughness	$R_{0,}$ 0.2 to 6.3 µu
Depth of recast and affected zone	0.005 to 0.13 mm
Corner radius	0.025 mm or equal to overcut
Taper	0.0005 to 0.005 mm/mm/side. With proper tooling taper can be eliminated.

Table. 1 (Parameters of EDM) [2]

II. LITERATURE SURVEY

Krishna Mohana Rao *et al* [3] have experiments are conducted by varying EDM parameters such as current, pulse-on-time, and duty factor. The performance measures like Material removal rate, surface roughness, and hardness are assessed. It is concluded that metal removal rate, and surface roughness increases with increase in current, duty factor. But, as the pulse-on time increases MRR and surface roughness decreases. Hardness value increases as the current value increases from 5A to 10A amps and then decreases as the current increases from 10A to 15A. When current Increases, high material removal rate and surface roughness are also increased. When current increases, hardness will decrease. When current is increased, the crack length, crack widths are also increased due to the high temperature generation at high currents. When duty factor increases, the MRR and SR are also increases. Due to increase in duty factor, the spark intensity, machining time also increases resulting in the increase of MRR and SR. When duty factor increases, hardness will decrease. When duty factor is increased, the crack length, crack widths are also increased due to the high temperature generation. When pulse-on-time increases, the MRR is decreased. The higher the pulse-on-time, intensity of spark decreases due to expansion of plasma channel and results in less metal removal. When Pulse-on-time is increased, surface roughness is decreased. When Pulse-on-time increases.

Amandeep Singh *et al* [5] in this paper includes the new trend of adding the fine abrasive particles into electrolyte, hence mixing the powders in the EDM process is called as hybrid machining process. By this kind of process, EDM process becomes quite more stable and improves the various factors such as machining efficiency, material removal rate and surface quality. By the study obtaining their properties the following materials can be considered and used as powder mixing in die-electric fluid are as follows:

1. Graphite,
2. Silicon (Si),
3. Aluminum (Al),
4. Crushed glass,
5. Silicon carbide (SiC)
6. Molybdenum Sulphide,
7. Chromium (Cr),
8. Copper (Cu).

The study and research claims that the smallest particle (70– 80 nm) generates and produces best surface finish and among them the Aluminum (Al) powder gives the best surface finish Results

EDM in Water: The approach towards Water as a dielectric fluid to promote safe and toxic free environment while working with EDM. This happens because die electric fluid such as kerosene decomposes and release harmful gases such as CO & CH_4. Machining in distilled water generates higher MRR and creates lower wear ratio than in kerosene and other dielectric fluids when high pulse energy range is used. Hence concluding that water based EDM is more environment friendly and harms less to atmosphere as compared to other conventional based dielectric fluids.

Tool Vibration: The study of ultrasonic vibration and their effects on the electrode in electric discharge machine has been undertaken since many years. The higher efficiency is achieved by deploying ultrasonic vibration which mainly adds to the better circulation of dielectric fluid and quicker debris / scrap removal from work piece and later from the tank. This enhances the tool wear ratio and also the surface quality of the work piece. It also increases the material removal rate (MRR) form 35% to 45%.

Vineet Srivastava *et al* [6] have studied the process of sintered copper (Cu)–titanium carbide (TiC) electrode tip in ultrasonic assisted cryogenically cooled electrical discharge machining has been studied. The performance parameters studied are electrode wear ratio (EWR), material removal rate (MRR), surface roughness (SR), out of roundness and surface integrity. The process parameters considered in this study are discharge current, pulse on time, duty cycle and gap voltage. Copper (Cu) is the most commonly used commercial EDM material due to its excellent electrical and thermal conductivity However, it is required to add another material with high melting point because the low melting point of Cu increases the electrode wear rate.
Hence in this work, electrode tip of sintered copper (Cu) - titanium carbide (TiC) was successfully fabricated and brazed with copper rods to perform as electrodes.

J.A. Sanchez *et al* [7] the methodology defined requires the number of EDM tests, in which the surface finish of each intermediate stage must be assured and measured.

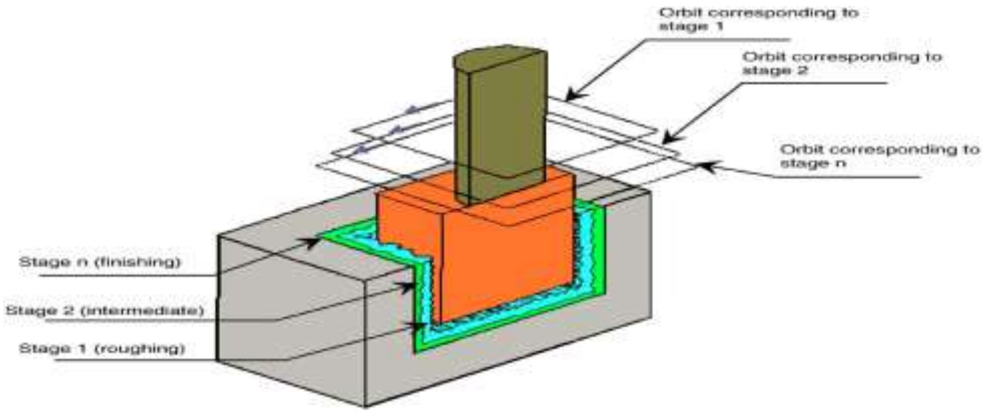

FIG.2.27. Schematic of a multi-stage planetary EDM operation. Regimes from roughing to finishing are involved.

Small electrodes are associated to larger gap variations. In the experiments carried out, the difference with respect to larger electrodes was as high as 48% in roughing regimes. Copper electrodes produce larger gap variations than graphite electrodes. The roughness of the cavity is strongly influenced by flushing conditions within the working gap. Gap variation increases with the increase of the radius of the first orbit until a limit value is reached. Hence concluding that the steepest decreases in gap variation occur at the regimes where both discharge current and pulse time decrease.

Kumar Sandeep [8] basically reviewed in this review paper so all the type of basics related to EDM is in this paper. EDM is unconventional electro thermal machining process which is used to making geometrically hard or complex material or shape which cannot be done by conventional machining processes. Electro Discharge Machining (EDM) is an electro-thermal nontraditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. In this process the metal is removing from the work piece due to erosion case by rapidly recurring spark discharge taking place between the tool and work piece. Show the mechanical set up and electrical set up and electrical circuit for electro discharge machining. A thin gap about 0.025mm is maintained between the tool and work piece by a servo system. Both tool and work piece are submerged in a dielectric fluid. As this is the review paper, in this they have include some parameters and some basic definitions related to terms which are connected to EDM and they are as follows:

On Time or Pulse Time: - It is the duration of time for which the current is allowed to flow per cycle.

Off Time or Pause Time: - It is the duration of time between the sparks. This time allows the molten material to solidify and to be washout of the arc gap.

Arc Gap: - It is the distance between electrode and the work piece during the process of EDM.

Duty Cycle: **-** It is the percentage of on time relative to total cycle time. This parameter is calculated by dividing the on time by the total cycle time (On time plus off time).

Conclusion which comes from this paper is when current increase MRR will also increase and SR (surface roughness) will also be in increasing form. And if Pulse on time will increase than MRR will decrease.

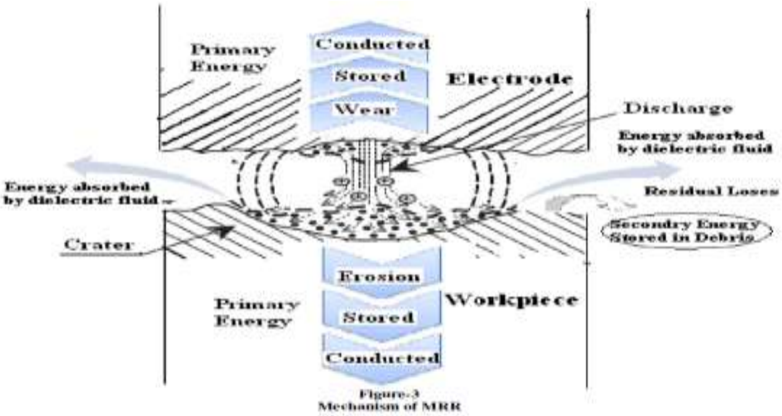

FIG.2.29. Mechanism of MRR

B. Mohana *et al* [9] have seen the machining characteristics of SiC/6025 Al composite using rotary electro-discharge machining (EDM) with a tube electrode were investigated in this study. Brass was used as the electrode material to EDM SiC/6025 Al composites.

Three observed values: material removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR) are adopted to evaluate the machinability.
Peak current, polarity, volume fraction of SiC reinforced particles, pulse duration, hole diameter of the tube electrode, and speed of electrode rotation were used as the input variables to assess the machinability.
Peak currents of EDM drilling were confirmed to have positive effects on the MRR, EWR and SR. The MRR, EWR and SR were more with positive polarity of the electrode than at negative. The feasibility of machining Al–SiC composites by EDM drilling with tube electrode has been evaluated. From the results of this experiment, following conclusions can be drawn:

1. The effect of EDM drilling with the rotating tube electrode has produced higher material removal rate than the rotating solid electrode.
2. The electrode tube hole diameter significantly affects the MRR, EWR and SR. The decrease in hole diameter has produced a better MRR, SR and higher EWR.
3. The increase in volume percentage of SiC has resulted in decrease in MRR, SR and increase in EWR.

M. M. Pawade *et al* [10] have experienced electrical discharge machine (EDM) is especially used for the manufacturing complex design and hard materials which are hard to machining by conventional machining processes. In this paper authors have researched the various techniques to improve Material removal rate (MRR), Surface Roughness (R_a) and Tool wear ratio (TWR) as well. In this paper various techniques reported by researchers for improving the machining characteristics which have been described as follows:

A) Influencing Process Parameters: EDM process is not only limited to capacities of the machines only but it also includes various process parameters which highly influence the process of EDM. There are many parameters that affects the Electro Discharge Machining, some of the major influencing process parameters like:

1. Discharge voltage
2. Frequency of current
3. Gap between tool electrode & work piece
4. Ignition delay time
5. Pulse on time, pulse off time
6. Polarity
7. Flushing type
8. Properties of dielectric media

9. Conductivity of electrodes
10. Eroding area

All these process parameters play a vital role in deciding machining characteristics like $R_{a,}$ MRR and TWR. Researchers have researched that most influencing process parameters are:

1. Discharge current
2. Pulse on time
3. Pulse off time
4. Dielectric liquid pressure.

B) Multi Spark: Conventional EDM has only one discharge point for each pulse. To have multi spark in single pulse tool electrode was divided into two and more parts. These electrodes were electrically insulated to obtain optimum O/P from multi spark. Power consumption is same in both ways of sparking but in multi spark power is generated is "n" times an electrodes were used for machining. Because of this R_a and MRR is higher in multi spark EDM as compared to that conventional EDM at the same energy consumption.

C) Powder Mixed EDM: Instead of using conventional dielectric fluid, Powder mixed electrical discharge machining (PMEDM) is suggested as in the powder of aluminum (Al), Chromium (Cr), graphite (Gr), Copper (Cu), and silicon (Si) were mixed with dielectric fluid and experimentation were performed.

D) Servo Control: An adaptive control system maintains a desired gap that gives healthy spark and also poised to prevent harmful arcing and short circuit between workpiece and electrode. A new technology was developed so that it can detect the undesirable machining and abrupt changes in surface and it also helps to improve the efficiency of EDM radially.

E) Pulse Discriminating
EDM pulse is generally classified into several types they are:

1. Open pulse
2. Spark pulse arc pulse
3. Short pulse
4. Off pulse

For higher MRR, Sparking pulse is so useful because it gives better R_a than other pulse type. Whereas, arc and short pulses gives rough surface finish and EDM gets unstable caused as particles were poised between W/P and Electrode.

Proposed Automated System: The functionability of the PLC has evolved over the years to include capabilities beyond typical relay control:

1. Sophisticated motion control
2. Process control
3. Distributive control systems
4. Complex networking
5. Reduce operator dependency.
6. Higher MRR with better SR.

Muslim Mahardikaa *et al* [11] have noticed that in older day's **λ θ** theory, which is the product of the thermal conductivity (l) and melting point (y) of the workpiece function of the machining time. A new theory referred to as **λ θ ρ** theory, is proposed, where ρ is the electrical resistivity of the workpiece.

Twelve different workpiece materials were used in this study:

1. Aluminum (Al)
2. Brass (Br),
3. Copper (Cu)
4. Steel (Fe)
5. Molybdenum (Mo)
6. Nickel (Ni)
7. Platinum (Pt)

8. Silver (Ag)
9. Stainless steel (SS)
10. Tantalum (Ta)
11. Titanium (Ti)
12. Tungsten (W)

The diameter of the workpiece was 300 mm.

Tungsten–silver (Ag–W) square plates with dimensions of 10×10×1.2 mm. Ag–W was used because it has a good wear resistance.

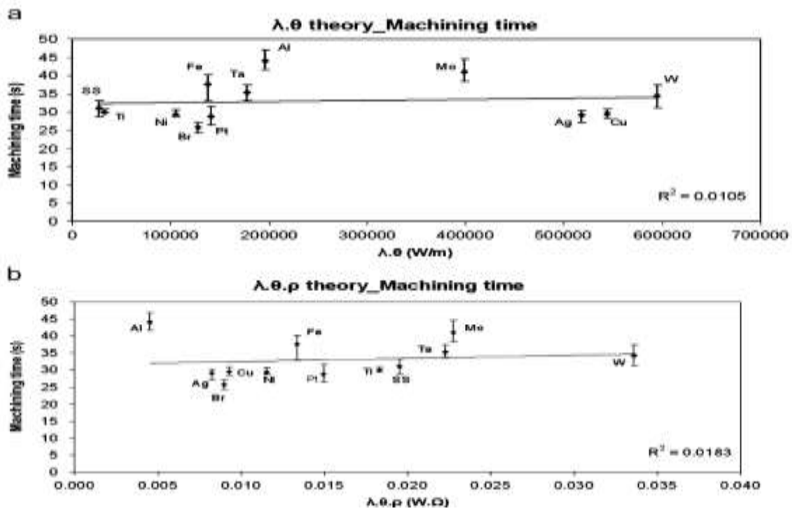

FIG.2.35. Machining time for different workpiece materials, according to (a) the **λ θ** theory and (b) the **λ θ ρ** theory.

Two comparisons were shown in the two graphs. 12 different materials were used all of them were shown in the graph as by their effects on Machining time and Electrode wear as per the theory

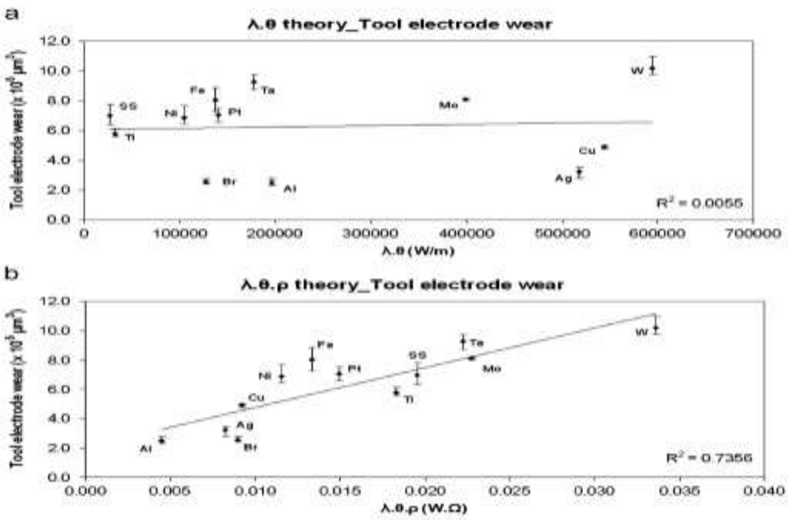

FIG.2.36. Tool electrode wear for machining of different workpiece materials, according to (a) the λ θ theory and (b) the λ θ ρ theory

OUTCOMES:

1. A fundamental study of the total energy of discharge pulses required to machine different workpiece materials was calculated with good results.
2. The machining time cannot be used as a parameter because it is affected by many complications, such as adhesion, cavitation, and short-circuiting.
3. Al should be the easiest material to machine; however, its machining time was the highest.

Jose Marafona *et al* [12] studied in this paper as an investigation into the optimisation of the process which uses the effect of carbon which has migrated from the dielectric to tungsten–copper electrodes. To achieve this Two-stage EDM is used in easy stage different settings were used to gain optimum MRR and TWR.

The input parameters by use of Taguchi method which were varied here were:

1. Ram speed (SI): Speed at which the tool moves with respect to the work piece
2. Current intensity (S2): Peak electrical current
3. Pulse duration (S3): Time during which the discharge takes place
4. Duty factor (S4): Ratio of pulse duration to total pulse time
5. Compression (SS): Gap compression
6. Gain (S6): Sensitivity of the servo controlling the movement of the ram
7. Relative withdrawal (S7): Distance by which tool is withdrawn each time
8. Cycle timer (S8): Time interval between successive ram cycles

A Taguchi L18 orthogonal array was used taking into account the number of variables (7+1) and levels at which the variables can be set (3+2). Taguchi results, where the optimum settings of the input parameters for TWR, MRR, and Ra are given. It can be seen that, in many instances, the optimum value of a given control factor for MRR is not the same as that for TWR.

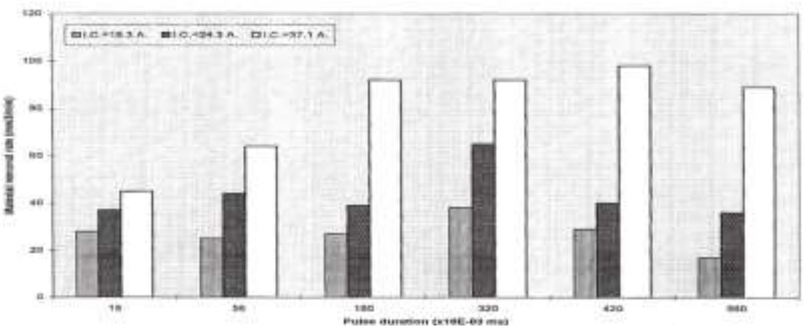

FIG.2.37. Variation in material removal rate for different current intensities and pulse durations

The proposed new method is as follows:

1. A lower current intensity and long pulse duration are used for the first part of the erosion to create a wear inhibitor carbon layer on the surface of the tungsten–copper tool electrode.
2. A higher current intensity and long pulse duration are used in the remaining part of the erosion cycle, to improve the material removal rate and maintain a lower tool wear ratio due to the inhibitor carbon layer.

Shyam Kumar Karna1, Dr. Ran Vijay Singh, Dr. Rajeshwar Sahai [13] have noticed the objective of the present study is to optimize the process by applying the Taguchi method with orthogonal array robust design.
Step1: Identify the main function, side effects, and failure mode
Step2: Identify the noise factors, testing conditions, and quality characteristics
Step3: Identify the objective function to be optimized
Step4 Identify the control factors and their levels
Step5: Select the orthogonal array matrix experiment
Step6: Conduct the matrix experiment
Step7: Analyse the data; predict the optimum levels and performance
Step8: Perform the verification experiment and plan the future action.

III. CONCLUSION

The above literature survey infers there is a need to study on how to increase material removal rate and surface finish by using a range of various process parameters like voltage gap, pulse on time pulse off time, discharge current etc. This literature survey also indicates:

(a) With the increase in Pulse On-time MRR and Surface Roughness decreases respectively.

(b) It is noticed that Pulse On time, Voltage gap and Discharge current has highest impact on EDM MRR and Surface roughness.

(c) Material removal and flushing of dielectric medium significantly increased when UACEDM is used.

(d) Powder mixed dielectric fluid can be used to increase machining in EDM. Despite all the other particles Aluminum (Al) powder gives great surface finish and fine surface texture. It is also notices that small grains of powder gives great results.

(e) Tool vibration and rotation enhances the tool wear ratio and also the surface quality of the work piece. It also increases the material removal rate (MRR) form 35% to 45%.

(d) Copper and Graphite is widely used electrodes in EDM because of ecomic and availability consideration. Copper electrodes produce larger gap variations than graphite electrodes.

(e) The steepest decreases in gap variation occur at the regimes where both discharge current and pulse time decrease.

(f) When current increase MRR will also increase and SR (surface roughness) will also be in increasing form.

(g) The various applications can be used for ease of machining in EDM as multi spark, power mixed EDM, servo control, pulse discriminating, automated system and DRY EDM.

(h) Al is the best material to be used for machining but it also takes higher machining time.

(i) The machining time cannot be used as a parameter because it is affected by many complications, such as adhesion, cavitation, and short-circuiting.

(j) Taguchi method made easy for parameters selection and design of experiments. L9, L18 and L27 array can be brought out for ease of experiments and carry out best in results.

IV. ACKNOLEDGEMENT

The completion of this review would not have taken place without the contribution of many key people. The progress of the review was supervised by **Asst. Prof. Samarth D. Bhaduwala** from Mechanical Engineering Department of ITM UNIVERSE, VADODARA. A special thanks to our **Head of Department Prof. Minesh Patel** their guidance, advice and wisdom throughout this work are also greatly appreciated

REFERENCES

1. *Google-images-principle of EDM spark generation.*
2. P. K. Mishra, *Non-Conventional Machining.*
3. G Krishna Mohana Rao, S. Satyanarayana, M Praveen, *Influence of Machining Parameters on Electric Discharge Machining of Maraging Steels – An Experimental Investigation.*
4. Vineet Srivastava, Pulak M. Pandey, *Effect of process parameters on the performance of EDM process with ultrasonic assisted cryogenically cooled electrode.*
5. Amandeep Singh, Neel Kanth Grover, Rakesh sharma, *Recent Advancement in Electric Discharge Machining.*
6. Vineet Srivastava, Pulak M. Pandey, *Study of ultrasonic assisted cryogenically cooled EDM process using sintered (Cu–TiC) tooltip.*
7. J.A. Sanchez_, L.N. Lopez de Lacalle, A. Lamikiz, U. Bravo, *Study on gap variation in multi-stage planetary EDM.*
8. Kumar Sandeep, *Current Research Trends in Electrical Discharge Machining: A Review*
9. B. Mohana , A. Rajadurai , K.G. Satyanarayana, *Electric discharge machining of Al–SiC metal matrix composites using rotary tube electrode.*
10. M. M. Pawade, S. S., *A Brief Review of Die Sinking Electrical Discharging Machining Process towards Automation.*
11. Muslim Mahardikaa, Takayuki Tsujimotoa, Kimiyuki Mitsuib, *A new approach on the determination of ease of machining by EDM processes.*

12. Jose Marafona, Catherine Wykes, *A new method of optimising material removal rate using EDM with copper–tungsten electrodes.*

13. Shyam Kumar Karna1, Dr. Ran Vijay Singh2, Dr. Rajeshwar Sahai, *Application of Taguchi Method in Indian Industry.*