IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 2, February 2016.

www.ijiset.com

ISSN 2348 – 7968

Electrical Discharge Machining – A State of Art

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Abstract

With the advent of newer materials and intricate shapes of components, unconventional methods of material removal have been developed. Electrical Discharge Machining (EDM) is one of such processes of material removal. This paper briefly describes the basic features of EDM, such as, its mechanism of material removal, advantages, disadvantages and application possibilities.

EDM is now more economical non convectional machining process. It is used widely used on small scale as well major industries. EDM process is affect by so many process parameter which are electrical and non electrical. The machining parameters selected as a variables are discharge current, pulse on-time, pulse off-time, dielectric level and flushing pressure. The output measurement includes surface roughness.

Keywords: *Electrical Discharge Machining*

1. Introduction

Electrical Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive.

The operating regime and usage environment of machinery components in modern manufacturing industries are becoming more hostile. The demand for advanced materials with high strength, high toughness and high hardness is now urgent. Therefore, the new species of advanced materials have been invented for diverse industrial applications. These advanced materials ordinarily have excellent mechanical properties to satisfy the requirements of applications that are commonly used in harsh environments.

Machining newly developed materials with excellent mechanical properties faces critical problems. Conventional processes for machining advanced materials encounter several obstacles, so the conventional processes, such as cutting and forming, are becoming unsatisfactory as they are associated with poor machining efficiency, precision and quality in current industrial applications. Hence, non-conventional processes, such as water-jet machining, laser beam machining, electron-beam machining and electrical-discharge machining (EDM), provide attractive alternatives for difficult-to-machine materials. Numerous researchers have thus performed intensive works on the non-conventional processes, so the machining performance associated with non-conventional processes has been markedly improved, when the technique is intended for modern manufacturing[1].

2.1 Principle of EDM

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 shown in Figure 2.1. Both tool and work piece are submerged in a dielectric fluid. Kerosene/EDM oil/deionized water is very common type of liquid dielectric although gaseous dielectrics are also used in certain cases.

This Figure 1 is shown the electric setup of the Electric discharge machining. The tool is mead cathode and work piece is anode. When the voltage across the gap becomes sufficiently high it discharges through the gap in the form of the spark in interval of from 10 of micro seconds. And positive ions and electrons are accelerated, producing a discharge channel that becomes conductive. It is just at this point when the spark jumps causing collisions between ions and electrons and creating a channel of plasma.

A sudden drop of the electric resistance of the previous channel allows that current density reaches very high values producing an increase of ionization and the creation of a powerful magnetic field. The moment spark occurs sufficiently pressure developed between work and tool as a result of which a very high temperature is reached and at such high pressure and temperature that some metal is melted and eroded. Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting[1-2].

ISSN 2348 – 7968

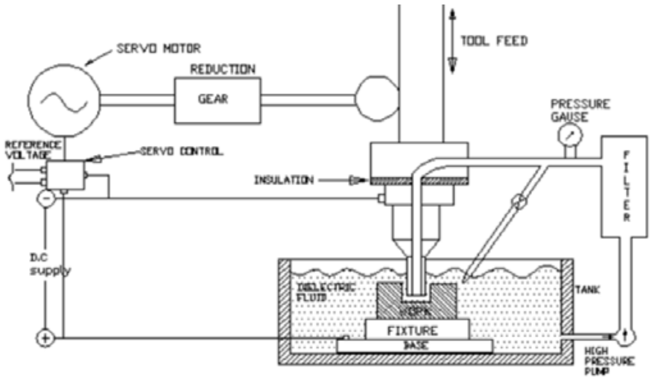


Figure 1 Set up of Electric Discharge Machining

The molten metal is not removed completely but only partially as the potential difference is withdrawn as shown in Figure 2, the plasma channel is no longer sustained. As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark.

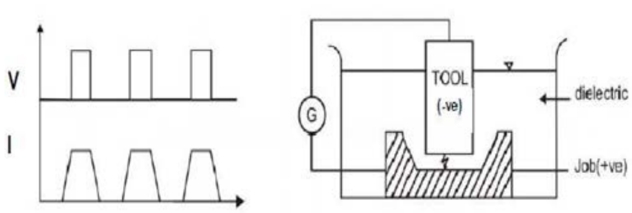


Figure 2 Working Principle of EDM Process

2.2 Advantages of EDM

(a) Any material that is electrically conductive can be cut using the EDM process.
(b) Hardened work pieces can be machined eliminating the deformation caused by heat treatment.
(c) X, Y, and Z axes movements allow for the programming of complex profiles using simple electrode.
(d) Complex dies sections and molds can be produced accurately, faster, and at lower costs. Due to the modern NC control systems on die sinking machines, even more complicated work pieces can be machined.
(e) The high degree of automation and the use of tool and work piece changers allow the machines to work unattended for overnight or during the weekends
(f) Forces are produced by the EDM-process and that, as already mentioned, flushing and hydraulic forces may become large for some work piece geometry. The large cutting forces of the mechanical materials removal processes, however, remain absent.
(g) Thin fragile sections such as webs or fins can be easily machined without deforming the part.

2.3 Limitation of EDM

(a) The need for electrical conductivity – To be able to create discharges, the work piece has to be electrically conductive. Isolators, like plastics, glass and most ceramics, cannot be machined by EDM, although some exception like for example diamond is known. Machining of partial conductors like Si semi-conductors, partially conductive ceramics and even glass is also possible.
(b) Predictability of the gap - The dimensions of the gap are not always easily predictable, especially with intricate work piece geometry. In these cases, the flushing conditions and the contamination state of differ from the specified one. In the case of die-sinking EDM, the tool wear also contributes to a deviation of the desired work piece geometry and it could reduce the achievable accuracy. Intermediate measuring of the work piece or some preliminary tests can often solve the problems.
(c) Low material removal rate- The material removal of the EDM-process is rather low, especially in the case of die-sinking EDM where the total volume of a cavity has to be removed by melting and evaporating the metal. With wire-EDM only the outline of the desired work piece shape has to be machined. Due to the low material removal rate, EDM is principally limited to the production of small series although some specific mass production applications are known.
(d) Optimization of the electrical parameters - The choice of the electrical parameters of the EDM-process depends largely on the material combination of electrode and work piece and EDM manufactures only supply these parameters for a limited amount of material combinations. When machining special alloys, the user has to develop his own technology [3-4].

2.4 Important Parameters of EDM

(a) **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.
(b) **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.
(c) **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 (fig 2.2).

ISSN 2348 – 7968

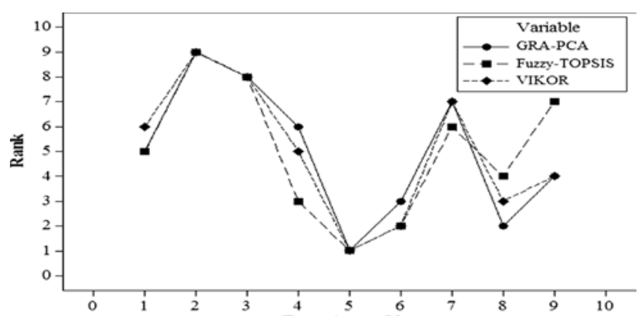
(d) **Discharge current (current Ip):** Current is measured in amp Allowed to per cycle. Discharge current is directly proportional to the Material removal rate.
(e) **Duty cycle (τ):** It is a percentage of the on-time relative to the total cycle time. This parameter is calculated by dividing the on-time by the total cycle time (on-time pulse off time).
(f) **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. 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 a electrode but also for internal flushing.
(h) **Over cut –** It is a clearance per side between the electrode and the workpiece after the marching operation.
(i) **Dielectric level** - Dielectric level is measured in mm.

2.4 Application of EDM

1. 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.
2. It is used to machine extremely hard materials that are difficult to machine like alloys, tool steels, tungsten carbides etc.
3. It is used for forging, extrusion, wire drawing, thread cutting.
4. It is used for drilling of curved holes.
5. It is used for internal thread cutting and helical gear cutting.
6. It is used for machining sharp edges and corners that cannot be machined effectively by other machining processes.
7. Higher Tolerance limits can be obtained in EDM machining. Hence areas that require higher surface accuracy use the EDM machining process.
8. Ceramic materials that are difficult to machine can be machined by the EDM machining process.
9. 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.
10. 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.

3. Literature Survey

Jagadish et al [5] have defined the experimental study multi response parameter optimization problems of green manufacturing. A combination of gray relational analysis (GRA) associated with principal component analysis (PCA) method has been developed and has optimized the process parameters of green electrical discharge machining (EDM). The major performance characteristics selected are process time, relative tool wear ratio, process energy, concentration of aerosol, and dielectric consumption. The corresponding machining parameters are peak current, pulse duration, dielectric level, and flushing pressure. Initially, Taguchi (L9) orthogonal array has been used to perform the experimental runs and the optimal process parameters using the GRA approach. The weighting values corresponding to various performance characteristics are determined using PCA. Thereafter, analysis of variance (ANOVA) is applied to determine the relative significant parameter and percentage of contribution of machining parameters; the peak current is the most influencing parameter having 52.87 % of contribution followed by flushing pressure, dielectric level, and pulse duration with 22.00, 21.52, and 3.55 %, respectively. Finally, multiple regression analysis is performed to determine the relationship between machining parameters and performance characteristics. The Fuzzy-TOPSIS and VIKOR methodologies have been used to compare the results of the proposed methodology, and the optimum process parameters obtained are peak current (4.5 A), pulse duration (261 µs), dielectric level (80 mm), and flushing pressure (0.3 kg/cm2).



Graph No. 01 Comparison Chart of Proposed Results

Jagadish et al [6] have defined the experimental study integrated approach of Entropy–Technique for Order Preference by Simulation of Ideal Solution (TOPSIS) method for the determination of the optimal process parameters in green electrical discharge machining. In this work, initially, an experiment is performed using Taguchi experimental technique. Thereafter, Entropy-TOPSIS is used to convert multiresponse parameters into single response parameter. Finally, the ranking of the parameter decides the best experimental set up and optimized the input process parameters. In this research, the weight of the quality characteristics of each of the output parameters are determined by the entropy method which influences the closeness coefficient values for finding the optimal experimental set up using TOPSIS method.On the basis of optimization results it has been found that peak current (4.5 A), pulse duration (261 _s), dielectric level (80 mm) and flushing pressure (0.3 kg/cm2), which are the best combinations of this analysis.

Optimization parameters for EDM drilling were also developed to summarize the effect of machining characteristic such as MRR, TWR and SR. The effects of the machining parameters (MRR, TWR and SR) in EDM on the machining characteristics of SKH 57 high-speed steel were investigated by Yan-Cherng et.al [7]. Experimental design was used to reduce the total number of experiments. Parts of the experiment were conducted with the L18 orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios associated with the observed values in the experiments were determined by ANOVA and F -test. The relationship of MRR and SR with pulse duration graph in different peak current is as shown in Graph 2.3. During the experiment MRR increases with peak current MRR initially increased to a peak at around 100 µs, and then fell.

Lee and X.P.Li [8] showed the effect of the machining parameter in EDM of tungsten carbide on the machining charatercteristics. The EDM process with tungsten carbide better machining performances is obtaining generally with the electrode as the cathode and the workpiece is anode. Tool with negative polarity give the higher material removal rate, lower tool wear and better surface finish. High open circuit voltage is necessary for tungsten carbide due to its high malting point and high hardness value and cupper tungsten as the tool electrode material with tool electrode material with negative polarity. This study confirms that there exists an optimum condition for precision machining of tungsten carbide although the condition may vary with the composing of martial, the accuracy of the machine and other other external factor.

Wang and Lin [10] discuss the optimization of W/Cu composite martial are used the Taguchi method. W/Cu composites are a type of cooling material highly resistant to heat corrosion produced through powder metallurgy. The Taguchi method and L18 orthogonal array to obtain the polarity, peak current, pulse duration, duty factor, rotary electrode rotational speed, and gapload voltage in order to explore the material removal rate, electrode wear rate, and surface roughness. The influenced of each variable and optimal processing parameter will be obtained through ANOVA analysis through experimentation to improve the process.

Sohani et al. [11] discussed about sink EDM process effect of tool shape and size factor are to be considering in process by using RSM process parameters like discharge current, pulse on-time, pulse off-time, and tool area. The RSM-based mathematical models of MRR and TWR have been developed using the data obtained through central composite design. The analysis of variance was applied to verify the lack of fit and adequacy of the developed models. The investigations revealed that the best tool shape for higher MRR and lower TWR is circular, followed by triangular, rectangular, and square cross sections. From the parametric analysis, it is also observed that the interaction effect of discharge current and pulse on-time is highly significant on MRR and TWR, whereas the main factors such as pulse off-time and tool area are statistically significant on MRR and TWR.

Balasubramanian et al [12] has work two different materials have been used as work pieces. These EN8 and D3 steel materials have been machined in an Electrical discharge machine which has wide application in Industry fields. The important process parameters that have been selected are peak current, pulse on time, die electric pressure and tool diameter. The outputs responses are material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR). The Cast Copper and Sintered Powder Metallurgy Copper (P/M Copper) have been considered as tool electrodes to machine the fore said work pieces. Response surface methodology (RSM) has been used to analyze the parameters and analysis of variance (ANOVA) has been applied to identify the significant process parameters. The influences of interaction of parameters have also been studied. Scanned electron microscope (SEM) images have been taken after machining on the work pieces for both electrodes to study the structure property correlation. The input parameters were optimized in order to obtain maximum MRR, minimum TWR and minimum SR.

4. Conclusion

A variety of materials can be cut by EDM process. EDM is a safer and more effective tool for quality cutting. This paper is use to comparative study of EDM with other traditional and non traditional machining processes. In this paper advantages and disadvantage of EDM meson.

After a comprehensive study of the existing literature, gap has been observed in EDM. Literature review reveals that the researchers have carried out most of work on EDM. However, relatively few researcher studied the effect of discharge current, pulse on-time, pulse off-time, dielectric level and flushing pressure; all together on surface roughness for machining AISI H13 tool steel.

ISSN 2348 – 7968

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