Electric Discharge Machining- An overview

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Abstract: Electrical Discharge Machining (EDM) is a non conventional manufacturing process in which desired shape is obtained by using electrical discharges. Material is removal from the work piece is carried out by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. The EDM process has many advantages over conventional machining processes, key among them being the capability to machine very hard materials and cut complex internal profiles. It is also used to machine micro-parts with high dimensional accuracy and surface finish.

Key words: Electrical Discharge Machining(EDM),Tool Wear Rate(TWR),Material removal rate (MRR), Surface Roughness (SR).

INTRODUCTION

Electrical discharge machining has been proven as an alternative process for machining complex and intricate shapes from the work piece. It is a nonconventional machining method. In this process electrical energy is used to cut the material to desired shape and size. Efforts are made to utilize the whole energy by applying it at the exact point where the operation needs to be carried out. There is no mechanical contact between work piece and electrode thus there is mechanical pressure. Any hard or tough conductive material can be machined using EDM [2].

PRINCIPLE OF EDM

Working principle of EDM is based on removal of material from the workpiece is done due to erosion caused by rapidly recurring electrical spark discharge between the workpiece and the tool electrode.This process is demonstrated in Figure1. It shows the tool and workpiece form the electrodes, one of which is positive and the other one is negative., A pulsed DC voltage is applied across the electrodes. The workpiece is submerged in dielectric fluid.

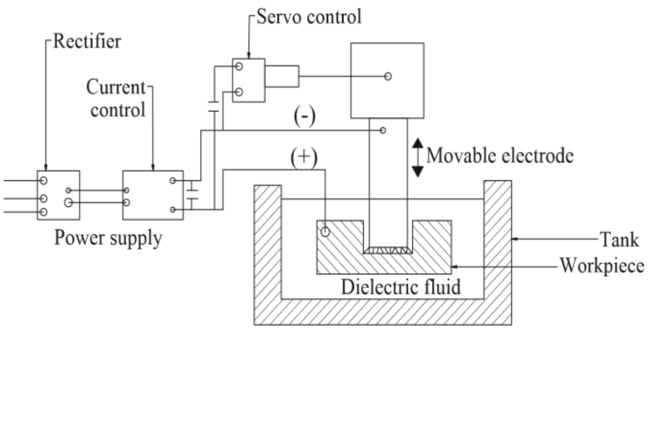

Fig:1 Electric Discharge Machining setup

The erosion process due to a single electric spark in EDM generally passes through the following phases Figure 2 and Figure 3 shows these phases:

1. **Pre-breakdown**: In this phase the electrode comes in proximity to the workpiece and at the same time voltage is applied between the electrodes i.e. open circuit voltage Vo.
2. **Breakdown:** When the voltage is applied beyond boundary limit of dielectric strength of used dielectric fluid, it causes beginning of the breakdown of the dielectric medium. Generally the dielectric initiate to break near the closest point between tool and work piece, but it also depend on conductive particles present in between the gap [9]. When the breakdown occurs the voltage falls and a current rises suddenly. During this process the dielectric gets ionize and plasma channel develops between the tool and work piece also there is possibility of presence of current.
3. **Discharge:** The discharge current is maintained at constant level during this phase for a continuous bombardment of ions and electrons on the electrodes. This will cause strong heating of the work-piece material (and also of the electrode material), rapidly creating a small molten metal pool at the surface. Also a small amount of metal is directly vaporized due to the large amount of heat. At the same time, the plasma channel grows; thus the radius of the molten metal pool also increases with time. Therefore some portion of the work-piece will be evaporated and some will be remain in molten state. The Inter Electrode Gap (IEG) is an important parameter throughout the discharge phase. It is estimated to be around 10 to 100 micrometers (IEG increases with the increase in discharge current).
4. **End of the discharge**: In this phase, the current and supply voltage is shut down. The plasma collapses (since current supply is stopped, there will be no more spark) under the pressure imposed by the surrounding dielectric.

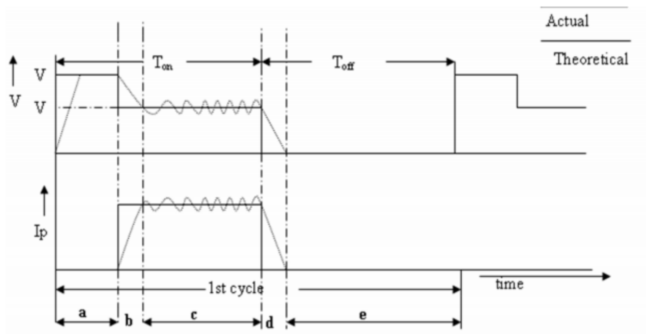

Figure2: Variation of Ip and V in different phases of a spark [10]

5. **Post-discharge:** In post discharge phase there will be no plasma available. Here a small portion of metal is removed along with deposition of a small thin layer because of collapsing and cooling of plasma. This layer is (approx 20 to 100 microns) is known as white layer. Consequently, the molten metal pool is strongly sucked up into the dielectric, leaving a small crater on the work-piece surface (typically 1-500 micrometer in diameter, depending on the current).

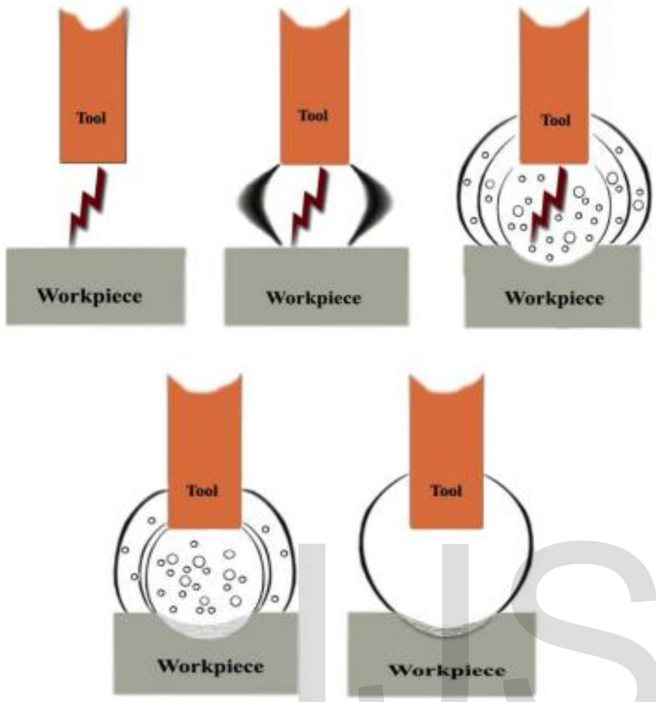

Figure 3: (a) Pre-breakdown phase (b) Breakdown phase (c) Discharge phase (d) End of the discharge and (e) Post-discharge phase [10]

Types of EDM

Basically there are two types of EDM: Die-sinking EDM and Wire-cut EDM as shown in fig 2

a. Die-sinking EDM-

Die-sinking EDM, also known as Volume EDM or cavity type EDM consists of an electrode and a workpiece which is submerged in an insulating fluid such as oil or other dielectric fluids.When the current is switched on, an electric tension is created between the two metal parts. If the two parts are brought together to within a fraction of an inch, the electrical tension is discharged and a spark jumps across. Where it strikes, the metal is heated up so much that it melts.

b. Wire-cut EDM-

Wire EDM Machining (also known as Spark EDM) is an electro thermal production process in which a thin single-strand metal wire (usually brass) in conjunction with de-ionized water (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, usually brass, is fed through the workpiece, submerged in a tank of dielectric fluid, typically deionized water. 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.

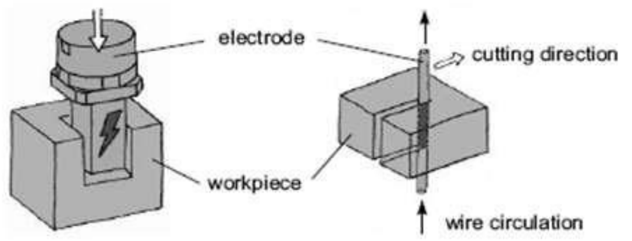

Fig:2Die sinking & wire cut EDM Process [7]

EDM PROCESS PARAMETERS

The EDM process involves multiple parameters like gap voltage, discharge current, spark gap, discharge frequency that vary more often during machining process along with material properties for the electrodes and the dielectric medium. As a result of different combinations of these varing parameters, the output parameters like, electrode wear, material removal rate and quality of the workpiece surface are different for different workpiece and electrode materials. In order to reduce the wear of the electrodes and enhance the material removal rate, there is need for proper selection of optimum machining input parameters. This can be achieved by development of accurate process model for use in conventional control [3–6].

The process parameters that influence while electric discharge machining are listed below:

1. **Discharge current** - It points out the different levels of power that can be supplied by the generator of the EDM machine and represents the mean value of the discharge current intensity.
2. **Pulse-on time** - It is 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 pulse-on time. This energy is controlled by the discharge current and the duration of the pulse-on time.
3. **Pulse-off time** - It is the duration of time (μs) between the two successive sparks (pulse-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.
4. **Duty cycle** - It is a percentage of the pulse-on time relative to the total cycle time. This parameter is calculated by dividing the pulse-on time by the total cycle time (pulse-on time plus pulse-off time). The result is multiplied by 100 for the percentage of efficiency, called duty cycle
5. **Dielectric pressure** - This is the flushing pressure of the dielectric jet which removes the chip or debris produced during the EDM process away from the gap zone. This value of pressure is measured by pressure gauge existing in the EDM machine.
6. **Polarity** - The machine can run either in normal polarity or reverse polarity.The polarity normally used is straight (normal polarity) in which the tool is negative and work piece is positive, while in reverse polarity the tool is positive and work piece is negative.[8]

The effectiveness of EDM process is evaluated in terms of its machining characteristics. The short product development cycles and growing cost pressures have forced the die and mould making industries to increase the EDM efficiency. The EDM efficiency is measured in terms of its machining characteristics viz. material removal rate, surface roughness and tool wear rate. The most important machining characteristics considered in the present work are:

i) Surface Roughness (Ra): Surface finish is an essential requirement in determining the surface quality of a product. The average surface roughness is the integral absolute value of the height of the roughness profile over the evaluation length (L) and was represented by the equation given below.

$$R_{a=\frac{1}{L}}\int_0^L |Y(x)dx$$

Where 'L' is the length taken for observation and 'Y' is the ordinate of the profile curve.

ii) Material removal rate (MRR): Material removal rate is a desirable characteristic and it should be as high as possible to give least machine cycle time leading to increased productivity. Material removal is the difference of weight of work-piece before machining and after machining. It is calculated by the formula as given below.

$$MRR = \frac{W_i\_W_f}{\rho_w t} \quad mm^3/min$$

Where,Wi is the initial weight of work-piece in g;Wf is the final weight of work-piece after machining in g; t is the machining time in minutes and ρ is the density of work piece material.

iii)Tool Wear Rate (TWR): Tool wear rate is the difference of electrode weight before and after machining and is expressed as:

$$TWR = \frac{E_i - E_f}{\rho_e\ t}$$

Where,E_i is the initial weight of electrode in g; E_f is the final weight of electrode after machining in g; and*t* is the machining time in minutes [12].

Fundamental EDM settings

The polarity, pulse duration, pulse interval and peak current are the basic machine settings. These parameters can also be expressed as average current, pulse frequency and duty factor.

1. **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 (%) × Peak Current
2. **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.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 (µs) [11]
3. **Duty Factor:** -Duty factor is a percentage of the pulse duration relative to the total cycle time. Generally, a higher duty factor means increased cutting efficiency. It is calculated in percentage by dividing pulse duration by the total cycle time (pulse on- time + pulse off-time). Duty Factor (%) = [Pulse duration (µs)/Total cycle time (µs)] × 100 [11]

Advantages of EDM

1. Any material that is electrically conductive can be cut using the EDM process.
2. Hardened work pieces can be machined eliminating the deformation caused by heat treatment.
3. X, Y, and Z axes movements allow for the programming of complex profiles using simple electrode.
4. 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.
5. 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
6. 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.
7. Thin fragile sections such as webs or fins can be easily machined without deforming the part.

Limitation of EDM

1. 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.
2. 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.
3. Low material removal rate- The material removal of the EDM-process is rather low, especially in the case of die-

$$MRR = \frac{W_i\_W_f}{\rho_w t}$$

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.

4. 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 [13]

Applications 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.[13]

CONCLUSION

This article presents a overview of research work carried out in the determination and optimization of the process parameters for EDM. In the metal cutting, edm has been a viable machining option for producing highly complex parts, independent of the mechanical properties of work piece material. This is by virtue of the capability of edm to economically machine parts, which are difficult to be carried out by conventional material removal processes.The capacity of machining hard and difficult to machine parts has made EDM as one of the most important machining processes.

REFERENCES

[1] S. Chen, B. Mulgrew, and P. M. Grant, “A clustering technique for digital communications channel equalization using radial basis function networks,” *IEEE Trans. on Neural Networks*, vol. 4, pp. 570-578, July 1993.

[2] J.P.Nobre ,J.C.Outeiro ,Evaluating Residual Stresses Induced By Drilling Of Ti-6Al-4V Alloy By Using Experimental-Numerical Methodology ,15th CIRP Conference on Modelling of Machining Operations ,Procedia CIRP 31 (2015) 215-220.

[3] Tarng Y. S., Tseng C. M. and Chung L. K., “A fuzzy pulse discriminatingsystem for electrical discharge machining,” *International Journal of Machine Tools and Manufacture*, vol. 37, pp. 511–522, 1997.

[4] Tarng Y. S. Ma S. C. and Chung L. K., “Determination of optimal cuttingparameters in wire electrical discharge machining,” *International Journal of Machine Tools and Manufacture*, vol. 35, no 12, pp. 1693–1701, 1995

[5] Sandeep K., “Status of recent developments and research issues of electrical discharge machining (EDM),” *International Journal of Latest Trends in Engineering and Technology (IJLTET)*, vol. 2 Issue 3, pp. 242–248, 2013.

[6] A. Cichocki and R. Unbehaven, *Neural Networksfor Optimization and Signal Processing*, 1st ed. Chichester,U.K.: Wiley, 1993, ch. 2, pp. 45-47.

[7] Dewangan S.K., Experimental Investigation of Machining parameters for EDM using U-shaped Electrode of AISI P20 tool steel, M-Tech Thesis 2010, http://ethesis.nitrkl.ac.in/2071/1/Thesis_EDM.pdf

[8] V. S. Nimbalkar,Prof. M. T. Shete*Electric Discharge Machining (EDM) of Titanium Alloys: A Review*;International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 6 Issue 04, April-2017

[9] Antoine Descoeudres, Characterization of electrical discharge machining plasmas, Ph.D. Thesis (2006), School PolytechniqueFederale de Lausanne, Thèse EPFL, no 3542.

[10] Shiba Narayan Sahu “Neural Network Modelling and Multi-Objective Optimization of EDM Process”,MTech Thesis, Department of Mechanical Engineering National Institute of Technology Rourkela, Orissa 2012

[11] Pandey, P.C., Shan, H.S., 1999, Modern Machining Process, Tata McGraw- Hill Publishing Company Ltd, Page 84-113

[12] A.W.S.Ram.Prasad,KoonaRamji,G.L.Dutta,An Experimental Study Of Wire EDM On Ti-6Al-4V Alloy, International Conference On Advances In Manufacturing And Materials Engineering.AMME 2014,Procedia Materials Science 5 (2014)2567-2576.

[13] TrinkleYuvarajSaindane, H. G. Patil, “Electrical Discharge Machining – A State of Art,” in *IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 2, February 2016.*

[14] G. W. Juette and L. E. Zeffanella, “Radio noise currents n short sections on bundle conductors,” presented at the IEEE Summer Power Meeting, Dallas, TX, June 22-27, 1990.