Trends In Electrical Discharge Machining: A Review

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Abstract- *EDM is an unconventional electro thermal machining process used for manufacturing geometrically complex or hardmaterial parts that are extremely difficult-to-machine by conventional machining process. The process involves a controlled erosion of electrically conductive materials by the initiation of rapid and repetitive spark discharges between the tool and work piece separated by a small gap of about 0.01 to 0.50. This gap is either flooded or immersed in a dielectric fluid. The controlled pulsing of direct current between the tool and the work piece produces the spark discharge. The EDM process that we know today is a result of various researches carried out over the years. EDM researchers have explored a number of ways to improve the sparking efficiency with various experimental concepts. Despite a range of different approaches, every new research shares the same objectives of achieving high metal removal rate with reduction in tool wear and improved surface quality. This paper reviews the vast array of research work carried out within past decades for the development of EDM. This study is mainly focused on aspects related to surface quality and metal removal rate which are the most important parameters from the point of view of selecting the optimum condition of processes as well as economical aspects. It reports the research trends in EDM.*

Keywords- Electrical discharge machining, EDM parameters, machining characteristic.

I. INTRODUCTION

Electrical discharge machining is basically a non-conventional material removal process which is widely used to produce dies, punches and moulds, finishing parts for aerospace and automotive industry, and surgical components. This process can be successfully employed to machine electrically conductive parts irrespective of their hardness, shape and toughness.The review presented in this paper is on different techniques proposed and investigated by researchers resulting in improvement in material removal rate in EDM. Being an important performance measure, MRR improvement has always been a major area of focus for researchers and scrutiny of the published research work emphasized the need for such a review paper reporting all the available literature and suggesting the future direction for research. The end of the paper identifies the major EDM academic research area and suggests future direction for the EDM research as a novel contribution to the archival literature

1.1-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 fig 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

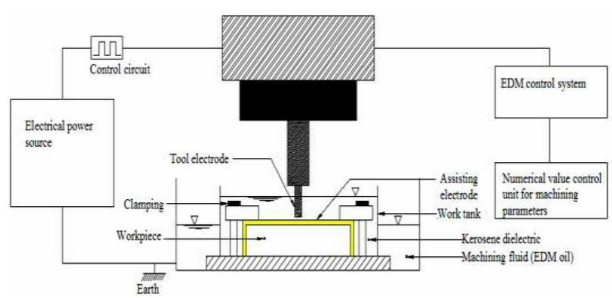


Figure 1: Working principle of EDM

This fig.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. The molten metal is not removed completely but only partially

1.2-Electric setup of the Electric Discharge Machining

The tool is made up of cathode and work piece is of 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. The molten metal is not removed completely but only partially. As the potential difference is withdrawn, the plasma channel is no longer sustained. As the plasma channel collapse, it generates pressureor shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark.

II. DEVELOPMENT OF EDM

With the help of different advances in the EDmachine has increased the applications of EDM process. It is used in the automotive industry, aerospace industry, nuclear industry, mould, tool and die making industries. EDM is also used in machining of medical, dental, optical equipments, jewellery industries. For this we need the machining req. such as the machining of HSTR materials, which generate strong research interest and increase the EDM machine manufacturers to improve the machining characteristics. One of the unique options of improving the machining performance involves the HMP combining EDM process with other material removal processes. The most popular and highly effective arrangement includes the USM delivering ultrasonic vibration to the electrode, which assists the sparking and flushing operations. However, Taylan et al. [2001] noted that the current trend in tool and die manufacturing is towards replacing the EDM process with new machining techniques such as HSM. HSM process is just as capable as the EDM process in machining hardened materials with 40–60 HRC. Therefore, HMP involving EDM will continue to draw intense research interests seeking innovative ways of improving the machining performance and expanding the EDM applications

2.1-Monitoring and control of the process-

The monitoring and control of the EDM process are often based on the identification and regulation of adverse condition occurring during the sparking process. Most of the approaches measure pulse and time domain parameters to differentiate the arc pulses from the rest EDM pulses. The option of using emitted RF has also been experimented but generates very little research. The application of fuzzy logic to the adaptive control system provides a reliable pulse discriminating role during the EDM process. Several authors claimed that the fuzzy logic control implements a control strategy that is adopted by a skilled operator to maintain the desired machining process. Tarng et al. [1997] suggested a fuzzy pulse discriminator established on the linguistic rules acquired from the knowledge of experts and expressed mathematically through the theory of fuzzy sets. However, the definition of membership functions for each fuzzy set is not straightforward and is based on exploratory means to classify various discharge pulses. Radio frequency (RF) or HF signal generated during EDMhas been used to monitor and control the sparking process. Radio Frequency monitoring system providing a pulse control to the machine power generator by examining the RF signal created from the spark gap. The RF monitoring system detects any drop in the intensity of signals to a threshold value whenever the discharge changes from sparking to arcing.

III. 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 theon-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 istoo 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

(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.

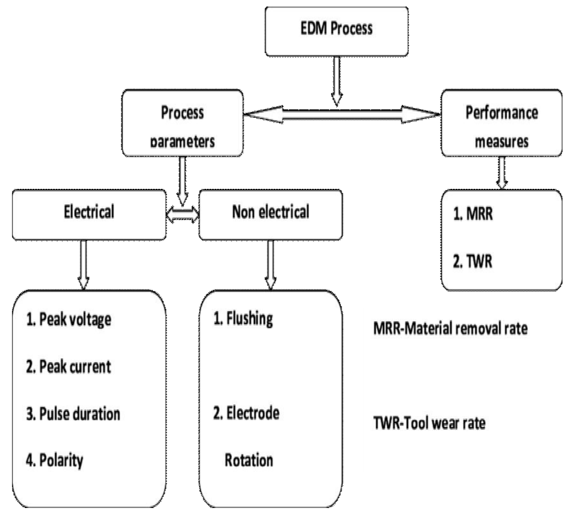
(f) **Voltage (V):** It is a potential that can be measure by volt it is also effect to the material removal rate and allowed to per cycle. Voltage is given by in this experiment is 50 V.

(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 alsoforinternalflushing

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

3.1-Process Parameters and Performance Measures-

The process parameters and performance measures are shown in Fig. The process parameters can be divided into two categories i.e. electrical and non-electrical parameters. Major electrical parameters are discharge voltage, peak current, pulse duration and pulse interval, electrode gap, polarity and pulse wave form. The EDM process is of stochastic thermal nature having complicated discharge mechanism. Therefore, it is difficult to explain all the effect of these parameters on performance measures. However, researchers now rely on process analysis for optimization of parameters to identify the effect of operating variables on achieving the desired machining characteristics. Lin et al. applied grey relational analysis for solving the complicated interrelationships between process parameters and the multiple performance measures. Taguchi approach has also been used by many other researchers to analyze and design the ideal EDM process. Main non-electrical parameters are flushing of dielectric, workpiece rotation and electrode rotation. These non electrical parameters play a critical role in optimizing performance measures. Researches on flushing pressure reveal that it affects the surface roughness, tool wear rate, acts as coolant and also plays a vital role in flushing away the debris from the machining gap . Workpiece rotary motion improves the circulation of the dielectric fluid in the spark gap and temperature distribution of the workpiece yielding better MRR and SR. Similarly, electrode rotation results in better flushing action and sparking efficiency . Therefore, improvement in MRR and SR has been reported due to effective gap flushing by electrode rotation.
Vol.9, No.8 MRR Improvement in Sinking Electrical Discharge Machining



IV. MECHANISM OF MRR

The first serious attempt of providing a physical explanation of the material removal during electric discharge machining is that of Dijck [48]. In his Ph.D. thesis, he presented physic mathematical analysis of the process. He presented a thermal model together with a computational simulation to explain the phenomena between the electrodes during electric discharge machining. However, as he himself admitted in his thesis, the number of assumptions made to overcome the unavailability of experimental data at that time was quite significant. Further enhanced models were developed in the late eighties and early nineties trying to explain the phenomena that occur during electric discharge machining in terms of heat transfer theories. Probably the most advanced explanation of the EDM process as a thermal process was developed during an investigation carried out at Texas A&M University: this stream of research resulted in a series of three research papers. In the first paper, a simple cathode erosion model for the process was presented. This point heat-source model differed from previous conduction models in the way that it accepts power rather than temperature as the boundary condition at the plasma/cathode interface. Optimum pulse times were predicted to within an average of 16% over a two-decade range after the model is tuned to a single experimental point. In this model, a constant fraction of the total power supplied to the gap was transferred to the cathode over a wide range of currents. A universal, dimensionless model was then presented which identifies the key parameters of optimum pulse time factor (*g*) and erodibility (*j*) in terms of the thermo physical properties of the cathode material. Compton's original energy balance for gas discharges was amended for EDM conditions. Here it was believed that the high density of the liquid dielectric causes plasmas of higher energy intensity and pressure than those for gas discharges. These differences of macroscopic dielectric properties affect the microscopic mechanisms for energy transfer at the cathode. In the very short time frames of EDM, the amended model uses the photoelectric effect rather than positive-ion bombardment as the dominant source of energy supplied to the cathode surface. As a second in a series of theoretical models, an erosion model for the anode material was presented [50]. As with the point heat-source model in the previous article, this model also accepts power rather than temperature as the boundary condition at the plasma/anode interface. A constant fraction of the total power supplied to the gap is transferred to the anode. The power supplied was assumed to produce a Gaussian-distributed heat flux on the surface of the anode material. Furthermore, the area upon which the flux is incident was assumed to grow with time. As a third in a series of theoretical models a variable mass cylindrical plasma model (VMCPM) was developed for the sparks created by electrical discharge in a liquid media. The model consists of three differential equations-one each from fluid dynamics, an energy balance, and the radiation equation-combined with a plasma equation of state. A thermo physical property subroutine allows realistic estimation of plasma enthalpy, mass density, and particle fractions by inclusion of the heats of dissociation and ionization for a plasma created from demonized water. Problems with the zero-time boundary conditions are overcome by an electron balance procedure. Numerical solution of the model provides plasma radius, temperature, pressure, and mass as a function of pulse time for fixed current, electrode gap, and power fraction remaining in the plasma. However, from a careful reading of these three papers, it emerges that for small discharge energies the presented models are quite inadequate to explain the experimental data. Also, allthese models are based on a number of assumptions. Later, many alternative models have been reported in the literature for material removal mechanism in the EDM process. Singh and Ghosh re-connected the removal of material from the electrode to the presence of an electrical force on the surface of the electrode that would be able to mechanically remove material and create the craters. They proposed thermo-electric model as a general method of calculating the electrostatic force on the surface of the cathode and the stress distribution inside the metal during the discharge. The result obtained for the stress distribution deep inside the metal, where the surface stress acts as a point force, can be extended for any kind of discharge. The model can explain the experimental results for short pulses. The model proposes that the electrostatic forces are the major cause of metal removal for short pulses and melting becomes the dominant phenomenon for long pulses. The model explains the reason for constant crater depth with varying discharge duration, for short pulses. Erden proposed that material removal mechanism relating to three phases of sparking, namely breakdown, discharge and erosion. Also, it was found that reversing the polarity of sparking alters the material removal phenomenon with an appreciable amount of electrode material depositing on the workpiece surface. Gadalla and Tsai investigated the material removal of WC–Co composite. They attributed the material removal to the melting and evaporation of disintegrated Co followed by the dislodging of WC gains, which have a lower electrical conductivity. However, Lee and La indicated that thermal spalling contributes to the material removal mechanism during the sparking of composite ceramics. This is because the physical and mechanical properties promote abrupt temperature gradients from normal melting and evaporation. A number of researchers have reported that the surface material of eroded electrode differ considerably from initial one in composition and properties. This surface material consists of dielectric pyrolysis products and an alloy between matrix and electrode. The workpiece material may diffuse into electrode surface and influence its wear resistance. Several other researchers have also reported presence of considerable quantity of opposite electrode material in the surface treated and debris produced. Roethel proposed a mechanism of mass transfer of electrode material and determined the change in thermally influenced zone. Pandey and Jilani proposed a thermal model on plasma channel growth and thermally damaged surface layer. The change in chemical composition of material was found to be confined within re-solidified layer. Although several researches have tried to explain the material removal mechanism (MRM) but in the light of the many available models, it appears that this mechanism is not yet well understood. Further investigations are necessary to clarify the MRM. Especially the available models are based on several assumptions and also there is lack of enough experimental scientific evidence to 716 Kuldeep Ojha, R. K. Garg, K. K. Singh Vol.9, No.8 build and validate them. This is due to stochastic thermal nature having complicated discharge mechanism.

V. CHARACTERISTICS OF EDM

STANDARD MACHINE SPECIFICATION			
CAPACITY	Height of centers	mm	380
	Swing over bed	mm	760
	Max. turning diameter over guide ways for lathes with turret head	mm	760
	Swing over cross slide	mm	520
	Swing in gap	mm	1000
	Distance between centers	mm	5000
SPINDLE	Spindle nose DIN 55027	mm	11
	Spindle bore	mm	132
	Spindle taper	Metric 120	Metric 140
HEAD STOCK	Number of spindle speed	-	Infinitely variable in 4 sub-ranges
	Spindle range	rpm	5.5-22, 22-88, 65-255, 255-1070
	Main motor power	kW	20
FEEDS	Z-axis feed	m/min	0-10
	X axis feed	m/min	0-10
CNC SYSTEM	Fanuc - FS 0i Mate-TD, B12is, B22is, MOP, MPG I/O 48/32	-	Fanuc
TOOL HOLDER / TURRET HEAD	Tool section	mm	32 x 32
	Diameter of boring bar	mm	32
	Turret head position number	mm	4
TAIL STOCK	Quill diameter	mm	95
	Quill taper		Morse No.6
	Quill traverse	mm	225
WEIGHT	Weight	kg	5300

VI. CONCLUSION

When current increases, the MRR also increases. The higher the current, intensity of spark is increased and results in high metal removal rate. When the current is increased, surface roughness is also increased.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. With increase in pulse-off time, the MRR increases as with long pulse off time the dielectric fluid decreasing the cutting speed. Surface Roughness improves with increasein pulse-off time. The MRR first increase with increase in sevovoltage and then starts to decrease. At low value of pulse duration, the SR increases with increase in servo voltage up to 30 v and then decreases with increase in servo voltage while at high value of pulse duration SR decreases continuously with increase in servo voltage. The MRR first increases with increase in wire feed rate and then decreases with further increase in wire feed rate. The SR decreases with increase in wire feed rate. produces the cooling effect on wire electrode and work material,

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