RESEARCH ARTICLE

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Investigation of Process Parameters for Optimum Thermal Energy Distribution in Spark Erosion Process

Mohd. Hasan Akhtar[1]*, Pankaj Jaiswal[2], Sarvesh Biyani[3], Nilesh Gowardipe[4]

[1-4] Department of Mechanical Engineering, S. B. Jain Institute of Technology, Management and Research, Nagpur, India; e-mail : [1*]mhasanakhtar27@gmail.com

Abstract

In the Spark Erosion machining process, the electrical energy in the inter-electrode gap gets converted into thermal energy. Whatever thermal energy generated in inter electrode gap gets distributed among anode, cathode and the dielectric fluid. The workpiece in spark erosion process is kept as anode and the fraction of the total energy which is going to the anode (workpiece) should be maximum. As this thermal energy is responsible for the melting of material on the workpiece. This fraction of energy is the important parameter used to predict the effective use of total heat energy generated between tool and workpiece. The fraction of energy that is going to workpiece changes with change in machine parameter. It has been observed from the literature that the researcher simply considered a variation of spark voltage in analysis as a significant parameter in deciding material removal rate.

In this work is variation of fraction of energy is experimentally determined with process parameters by using heat transfer equations during the spark erosion process of EN-31. The results showed that the ratio of amount of energy going to workpiece and total energy generated at inter electrode gap ranges from 9.56% to 18.97%. So, fraction of energy which is going to workpiece at different machining process parameter changes significantly, which proves that the it has significant impact on material removal rate and should be considered in study of spark erosion process.

Keywords: Electric discharge machining process, Fraction of energy, Inter electrode gap, EN-31.

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Introduction

Spark Erosion Process is the process of metal removal using the sparks that are generated in between tool and workpiece when both are immersed in dielectric fluid. There is no physical contact between tool and workpiece instead the gap between these is filled with a dielectric fluid, which acts as an insulator and breaks up when a high potential difference is applied. In the EDM process material removes if the material is electrical conductivity.

The models of the spark erosion process has been developed since the nineteen century by the use of thermal aspects Dibitonto et al. [1], Van Dijck and Dutre [2], Snoeys and Van Dijck[4], Beck [5], Jilani and Pandey[6], Joshi and Pande [7]. However, these models over-predict the material removal rate due to the assumptions that constant energy going to a workpiece [8]. A need, therefore, exists for accurate determination of energy transferred to the workpiece which will be used to evaluate material removal rate. So, this paper aims to find out a heat energy going to the workpiece at various machining parameters.

Corresponding Author : Mohd. Hasan Akhtar, Department of Mechanical Engineering, S. B. Jain Institute of Technology, Management and Research, Nagpur, India; e-mail : mhasanakhtar27@gmail.com

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Past Work

Since the development of the spark erosion process, several studies have been done on the dispersal of available energy and specifically for the spark erosion process is reported [1-7] though the study during process.

Dibitonto et al. [1] developed a point heat source approach cathode erosion and disk heat source for the anode. During the analysis thermophysical properties are kept constant.

Jilani and Pandey [6], utilized for a similar model to develop a model for molten metal by applying a disk heat source. considered insulated workpiece. Thermophysical properties of the both the electrode considered as again constant.

Joshi and Pande [7] considered a spark during a pulse and considered the spatial Gaussian dispersion of the heat energy. Latent heat of fusion which is responsible for melting of the material was considered for better result for calculating heat energy transferred to the workpiece. It was observed that maximum amount of energy is getting generated at positive terminal.

Over a wide range the fraction of energy going to workpiece found by the researcher. Whereas few researchers considered as 50% of the energy is going to workpiece and half of the energy going to tool and dialectic fluid DiBitonto and co-workers [1] obtained the data at different condition and by varying the processes parameters of the spark erosion process.

Calculation for Heat Transferred to Workpiece

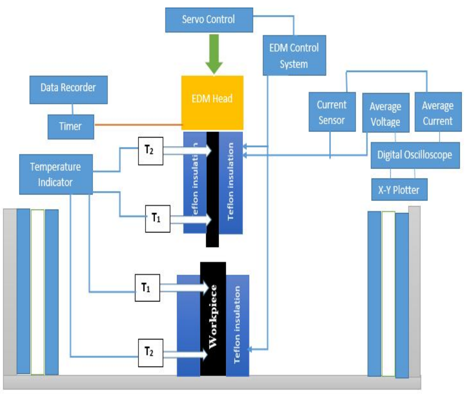

Figure 1: Schematic diagram of experimental Set-up

Figure 1 represents schematic diagram of experimental set-up and the actual set up. In the spark erosion process, thermal energy is generated form electrical energy. Furthermore, total thermal energy available between tool and workpiece is getting distributed among the tool (cathode), workpiece (anode) and the dielectric fluid. This thermal energy transferred to the workpiece is responsible for material removal and raise in temperature. It means that whatever heat energy supplied to the electrode and workpiece responsible is for material removal also the heat energy is getting stored and conducted through the electrode and workpiece respectively the sample calculation for these energies are as follows.

1. Total energy generated at the inter-electrode gap.

$$Total\ Energy\ at\ IEG = \frac{V_g I_p T_{on}}{T_{on} + T_{off}}$$

2. The total energy accountable for material removal in workpiece and tool can be calculated as

$$EMR = \frac{m}{t}\{c_s(T_m - T_0) + LHM + c_1(T_v - T_m) + LHV\}$$

3. The energy conducted through cathode and anode can be calculated as

$$Energy\ conducted = \frac{\pi d^2}{4} k \frac{(T_1 - T_2)}{L}$$

4. The absorbed thermal energy in the workpiece and tool during erosion process can be calculated as

$$Energy\ Stored = \frac{\pi\ \rho\ c\ \mathrm{r}^2 l}{t}\left(\frac{T_1 + T_2}{2} - T_0\right)$$

Observation Methodology

Experimental readings were taken by considering three levels of each control parameter as shown in the table-1. A total of 27 readings were taken by keeping one parameter constant and varying the other two parameters.

Table-1: Control Parameters

S. N.	Parameter	Symbol	Unit	Levels		
				1	2	3
1	Peak Current	I_p	A	10	12	14
2	Spark Voltage	V_s	V	35	40	45
3	Pulse on Time	T_{on}	µs	290	380	430

Table-2: Fixed Parameters

S. N.	Parameter	Symbol	Unit	Values
1	Flushing Pressure	F_p	Kgf/cm^2	3.2
2	Pulse Off time	T_{off}	Micro-Sec	35
3	Duty Cycle	T_{dc}	%	290

The parameters kept constant during the overall machining process are listed in table-2.

Experimental Procedure

The workpiece material is chosen as EN-31 as it is one the most widely used material for die manufacturing using spark erosion machining processes. Different material that have good properties to be a tool in electric discharge machining process, but copper is used during the present study as it is easily available and economical. EDM oil is used during the process a die electric fluid. It severe the three purposes (1) It act as a coolant. (2) It acts as a strong insulator and break down at discharge voltage. (3) It flushes away the removed material form inter electrode gap.

Figure 2: EDM Tool & Work Piece

During the spark erosion process in order to know the heat conducted in linear direction and heat absorbed by the tool and workpiece both are insulated using Glass wool and Teflon tape as shown in figure 2.

K-type of thermocouples was used to measure the temperature at different locations of workpiece and tool electrode. The readings of thermocouples are reflected on Temperature indicator with precision of 1 degree Celsius. On the workpiece thermocouples were embedded in the space provided in the Teflon insulation at points 1,2 and similarly on tool at 3,4 around at 20mm.

Variation of Total Heat Energy & MRR with Process Parameter

Consequence of Current on Total Thermal Energy and Material Removal Rate

The variation in total heat energy generated at IEG, Energy transferred to workpiece, and MRR at different current densities viz. 10A, 12A, and 14A when machining at a pulse duration of 290µs at a gap voltage of 35V is shown in the figure 3. It is observed that though the energy generated at IEG is very high, but heat transferred to the workpiece is very less because of significant energy losses to dielectric and radiation losses. As the value of current is increased by two unit's energy generated at IEG also increases but still energy transferred to the workpiece is very less as compared to energy generated at IEG further the same trend follows for 14A.

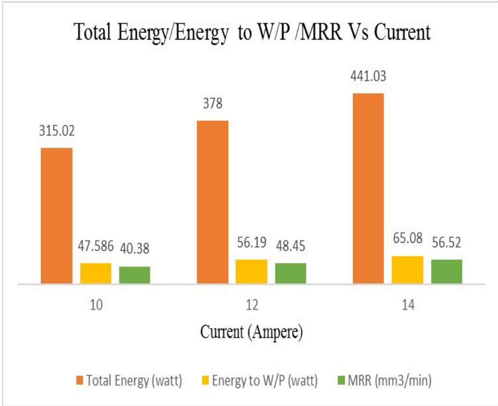

Figure 3: Total Energy/Energy to W/P /MRR Vs Current

The melting point of EN-31 is high and for machining the energy level should be high therefore machining current is kept a little higher side to produce high heat energy at the inter-electrode gap. The increase in current leads to an increase in MRR as well because energy transfer to workpiece also increases which is consumed for removal of material from a work piece.

From the figure 4, for this range of current, MRR is in linear relation with increase in current material removal rate also increases. A similar trend follows

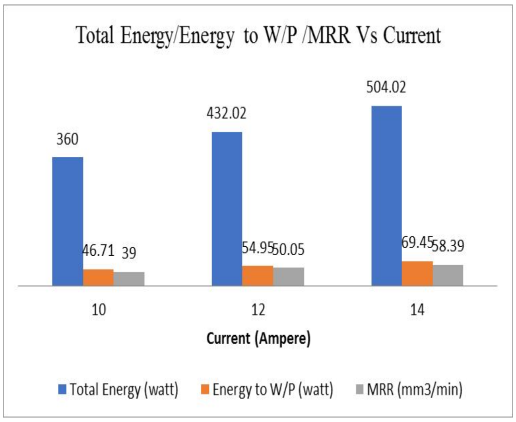

Figure 4: Total Energy/Energy to W/P /MRR Vs Current at 380µs & 40V

at different gap voltage and pulse duration for the same current see figure.

The same trend is followed when machining at a current density of 10A, 12A, and 14A by keeping pulse duration of 380μs, at gap voltage of 40V is shown in the figure 4. The increase in current does not lead to an increase in surface roughness in this range so it is preferable to EDM the component at a slightly higher current.

Consequence of Voltage on Total Energy and Material Removal Rate

The consequence of voltage on total heat energy generated at IEG then transferred to workpiece, and MRR is shown in figure 5. The experiments were conducted at different gap voltage viz. 35V, 40V, and 45V, when machining at a pulse duration of 290μs at a peak current of 10 A is shown in figure 5. It has been seen and observed that though the energy generated at IEG is very high, but energy transferred to the work piece is very less because of significant energy losses to dielectric and radiation losses. As it is expected that a surge in the value of gap voltage leads to an improvement in material removal because by doing so total energy is increases but on contrary to this any increase in gap voltage reduces the MRR.

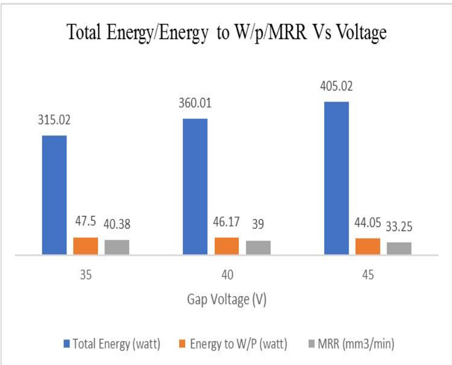

Figure 5: Total Energy/Energy to W/P /MRR Vs gap voltage at 10A & 290μs

In EDM, an increase in gap voltage is facilitated by an increase in the inter-electrode gap by the gap control knob. As by increasing voltage, the gap between electrode and workpiece increases the plasma channel which is due to spark at IEG get enough space to expand and due to this expansion specific energy of the plasma decreases. Due to the expansion of the plasma channel energy content of plasma decreases and hence less energy is imparted by the plasma channel to the workpiece and this causes a reduction in MRR. An increase in gap voltage influence the quality characteristics drastically, machining at higher voltage tends to increase in surface roughness and affect the dimensional accuracy as well i.e. over cut.

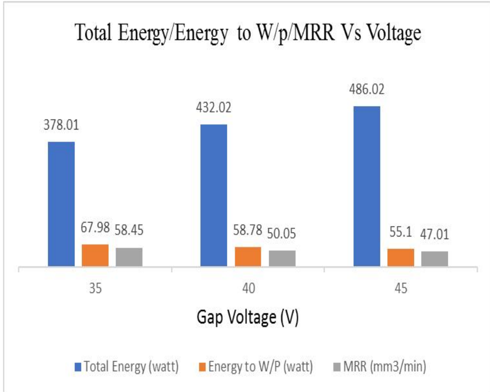

Figure 6: Total Energy/Energy to W/P /MRR Vs gap voltage at 12A & 380μs

A similar trend of decrease in MRR is followed when machining at gap voltage of 35V, 40V, and 45V and keeping pulse duration of 380μs at a peak current of 12A as shown in figure 6. Gap voltage is one of the prominent process parameters of EDM and inappropriate selection of gap voltage may lead to a greater decrease in MRR.

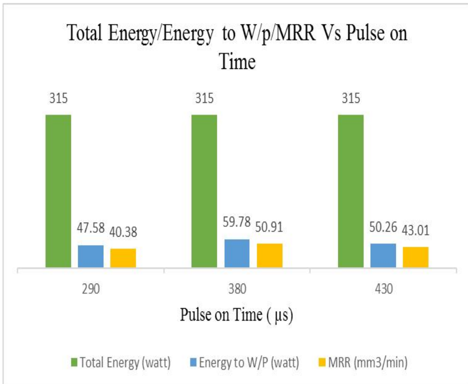

Figure 7: Total Energy/Energy to W/P /MRR Vs gap voltage at 10A 35V

Effect of Pulse on Time on Total Energy and MRR

The total heat generated at inter electrode gap and consequent material removal from the workpiece is proportional to pulse on time, so it is important to study the influence of pulse on time on performance measures. The significance of various of pulse on-time versus total energy at IEG and MRR, at a gap voltage 35V and different at 10A are plotted on the figure 7.

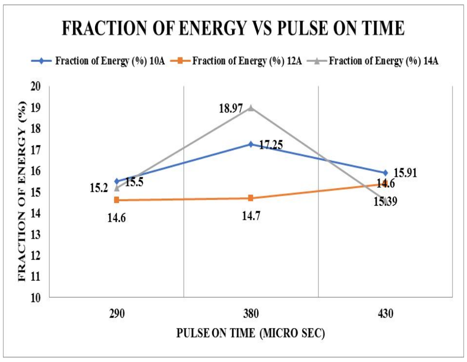

Figure 8: Fraction of energy versus Pulse on time at 40 V

It is observed from Figure 7 increasing pulse on time increases the energy transferred to the workpiece, which is further consumed to remove the metal from the workpiece. It is expected that a further increase

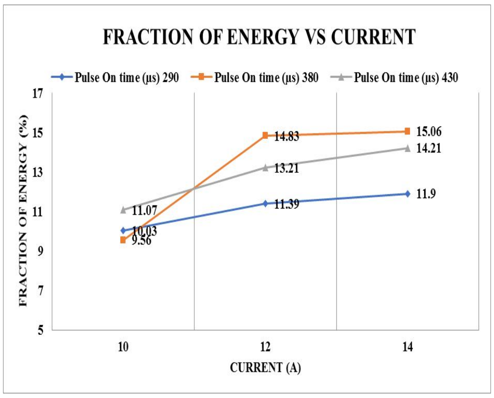

Figure 9: Fraction of energy versus Current at 45 V

in pulse on time will increase the MRR but as a pulse on time is increased from 380μs to 430 μs a clear decrease in energy transfer to the workpiece is observed which ultimately tends to reduce the MRR. This is because pulse on time is the duration up till then plasma channel is maintained in IEG.

[D] Fraction of Energy transferred to the Workpiece

The variation among the fraction of energy transferred to workpiece with respect to input parameters are depicted in the figure 8 at 40V.

It is evident from the figure 8, that value of fraction of energy going to the workpiece depends upon the pulse on time significantly. It increases with pulse on duration and maximum at 380 microseconds than decreases.

It can be observed from the figure 8 that as current increases the fraction of energy going to the workpiece increases and it is maximum as 14 A.

Conclusions

1. As input current is increased the total energy generated at the inter-electrode gap also increases and higher energy generation at IEG leads to higher energy transferred to the workpiece and it is manifested in terms of an increase in MRR.
2. An increase in gap voltage leads to an increase in the total energy at IEG but as the voltage increase, IEG also increases because that plasma column expands and loses its energy to the dielectric, and hence less energy is supplied to the work piece which is reflected in terms of decrease less energy transferred to workpiece followed by a reduction in MRR.
3. Pulse on duration which utilization of total energy generated is maximum at 380μs and then decreases with further increase in MRR but here it interesting to observe that for a constant duty cycle, voltage and current any changes in pulse on time doesn't lead to any change in total energy generated at inter-electrode gap but energy going to the workpiece is first increases and then decreases.
4. The ratio of amount of energy going to workpiece and total energy generated at inter electrode gap ranges from 9.56% to 18.97%. It can be concluded that fraction of energy which is going to workpiece at different machining process parameter changes significantly, therefore, the fraction of thermal energy which is going to workpiece shall be considered in spark erosion models.

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