I J C T A, 9(37) 2016, pp. 353-359

Influence of Energy Distribution and Process Parameters on Tool Wear in Electrical Discharge Machining

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Abstract: In the present scenario, the complex shapes of moulds and dies is being fabricated using electrical discharge machining process. Since the tool wear affects the surface quality of the machined specimens, it is very important to enhance the tool electrode machinability in such machining process. In the present study, an attempt has been made to analyze the influence of energy distribution on tool wear rate and surface roughness of machined AISI 202 stainless steel with different pulse generators such as transistor pulse generator and iso energy pulse generator. The experimental investigation has been done under L_9 Taguchi orthogonal array with various process parameter selection as open circuit voltage, peak current and duty factor. Brass electrode has been utilized as the tool electrode to investigate the performance measures such as tool wear rate and surface roughness of machined workpiece. From the experimental results, it has been observed that iso energy pulse has produced 13.1 % less tool wear with good surface quality. It has also been observed that open circuit voltage has most significant nature on determining tool wear rate.

Index Terms: Discharge, Taguchi, Surface, Wear.

1. INTRODUCTION

Electrical Discharge Machining (EDM) is one of the modern machining, in which thermal energy is used for removing the material from the work piece. Both the tool and the work piece are separated by small standoff distance in term of air gap. The electrical energy is supplied between tool and work piece in the form of DC pulse. When the air gap is short, a spark is initiated due to the ionization of dielectric medium. This causes to produce excess amount of heat energy [1]. The material is melted and vaporized due to the thermal energy. The flushing process is utilized for removing melted material. Figure 1 show the arrangement of EDM process. It has been found that duration of energy has significant contribution on performance measures in EDM process [2]. The thermal energy dissipated during the EDM process is directly proportional to the electrical energy discharged between tool and electrode. This discharge energy is characterized by the DC pulses applied across the EDM setup.

The discharge energy is mostly influenced by the pulse duration in electro erosion process [3]. The quality of the machined surface is mainly influenced by the tool electrode surface at any instant in EDM process [4]. It has been inferred that it has been very important to analyze the effect of discharge energy distribution on tool wear in EDM process [5]. Han et al. (2004) discussed about nature of electrical discharging process and need for iso duration pulse generator [6].

From the above literatures, it has been found that only little attention has been given for finding the influence of energy distribution on performance measures such as tool electrode wear (TWR) in EDM process. In the present study, a modified uniform energy approach has been proposed an modified iso energy pulse generator by controlling the discharge current and duty factor to enhance the process mechanism.

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The uniform current duration has been chosen as 50μs for better surface finish [7]. It is possible to control the duration of the discharge current pulse by changing the width of the drive pulse [8]. This causes for uniform and smaller crater volume over the tool electrode and machined workpiece surface in EDM process.

Figure 1: Die-sinking EDM arrangement

2. SIGNIFICANCE OF PULSE GENERATOR IN EDM PROCESS

Since the performance of EDM process is determined by applying DC pulses, pulse generator plays a key role on determining the machinability in EDM Process [9]. Figure 2 shows the schematic arrangement of conventional transistor pulse generator (TPG). In such pulse generator, the electrical energy supplied between tool and electrode can be realized a high frequency switching operation especially MOSFET. Owing to the stochastic nature of EDM process, conventional transistor pulse generators does not produce uniform discharge energy distribution over the machined surface and tool surface. Figure 3 shows the schematic arrangement of modified iso energy pulse generator (IPG). It can produce the uniform energy distribution by producing equal duration of discharge current. This can be obtained by the variable pulse width modulation using current sensing element [5].

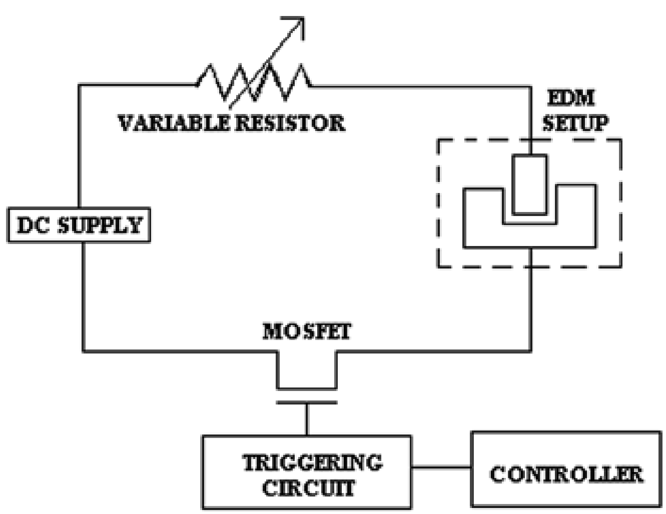

Figure 2: Schematic arrangement of Transistor pulse generator

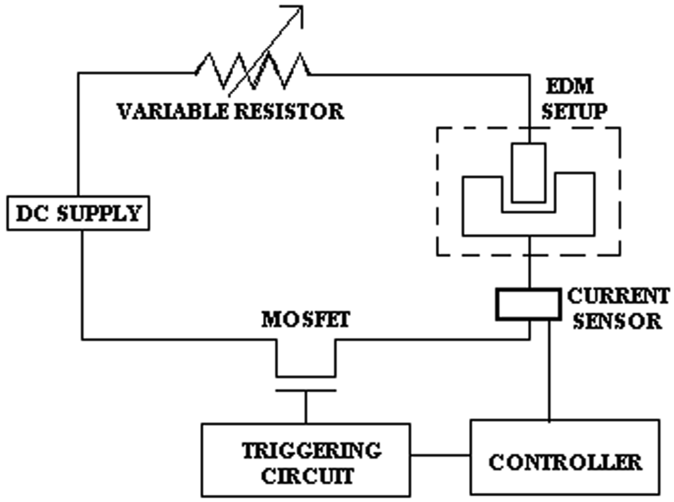

Figure 3: Schematic arrangement of Iso energy pulse generator

3. EXPERIMENTAL METHODOLOGY

There are many parameters involved in EDM process. Gap voltage (V_g), discharge current (I_p) and duty factor (DF) have been taken as the input parameters for this study, since they have most influent nature in EDM process. Brass tool has been selected as tool electrode for machining AISI 202 stainless steel with 5mm thickness in EDM process. The EDM drilling process has been conducted for making 2mm blind hole. Since the machining process have three input factors, L_9 orthogonal array has been selected as per Taguchi design of experiments. Since the experiments have to be conducted in smaller, medium and larger level rating of electrical energy, open circuit voltage has been selected as 40 V, 60 V and 80 V with duty factor of 0.4, 0.6 and 0.8. The peak current has been chosen as 9A, 12A and 15A [9].

The tool wear rate has been calculated by finding the weight percentage of tool electrode before and after machining process. It is normally denoted in mm^3/min. The three dimensional view of machined surface by EDM process with conventional and modified pulse generators has been acquired using Keyence VHX 2000 microscope. The two dimensional view of the machined tool surface has been acquitted using SIPCON SVI107 vision measurement system [7].

4. RESULTS AND DISCUSSION

The AISI 202 stainless steel specimens have been machined using EDM process with conventional transistor pulse generator and modified iso energy pulse generator under L_9 based different process parameters combinations. The effects of the pulse generators on tool wear rate (TWR) have been given as Table 1.

Table 1
Effects of pulse generators on TWR

S.No	*Process parameters combination*			*Tool Wear Rate (mm^3/min)*	
	V_g	*DF*	I_P	*TPG*	*IPG*
1	40	0.4	9	1.0641	0.7746
2	40	0.6	12	1.5830	1.0403
3	40	0.8	15	1.7326	1.3419
4	60	0.4	12	1.3892	1.1237
5	60	0.6	15	2.0963	1.9714

S.No	*Process parameters combination*			*Tool Wear Rate (mm^3/min)*	
	V_g	*DF*	I_P	*TPG*	*IPG*
6	60	0.8	9	2.1951	1.9613
7	80	0.4	15	2.0798	1.8816
8	80	0.6	9	2.0660	1.9224
9	80	0.8	12	2.8858	2.6900

A. Influence of Energy Distribution on TWR

The effect of the energy distribution on tool wear rate is shown in Figure 4. Tool wear rate depends on the discharge current and pulse duration as per Eq.1. [7]

$$TWR = (11 \times 10^3)\, I_d T_t^{-2.38} \quad (1)$$

where I_d is the discharge current in ampere (A) and T_t is the melting point of the tool electrode in °C. The modified iso energy pulse generator has produced smaller and uniform pulse duration; it has created the lower spark energy and smaller craters over the tool surface. Hence it has produced 13.1 % lower tool wear rate. Since the transistor has produced higher discharge energy with random energy distribution, it has removed more material from tool electrode during the machining process [7].

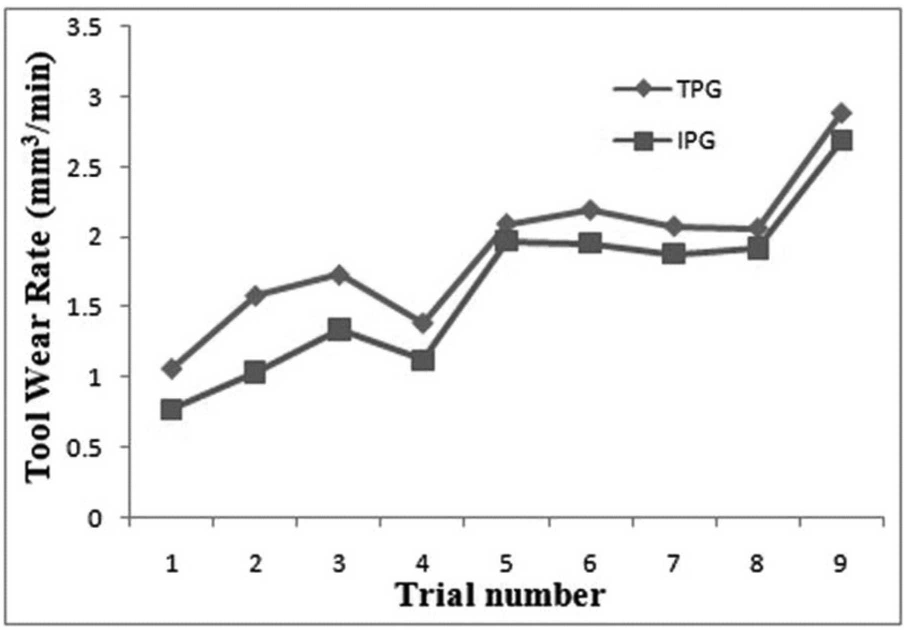

Figure 4: Influence of energy distribution on TWR

B. Surface Topography Analysis

The pulse generator of EDM process has to produce sparks with uniform discharge energy to create similar craters on the workpiece surface for enhancing the surface quality. The surface roughness of machined surface can be enhanced by uniform energy distribution with tiny crater size. Owing to the stochastic nature of the discharge current duration during the EDM process, the conventional transistor pulse generator has not produced uniform energy distribution [4]. The modified iso energy pulse generator has been designed to produce lower energy pulses with uniform spark energy distribution. This approach has created the similar and tiny craters over the tool electrode and workpiece surface [5]. Figure 5 shows the spark distribution on the surface of tool electrode workpiece with various pulse generators in the EDM process.

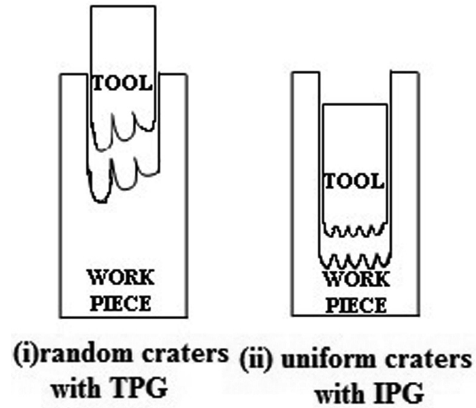

Figure 5: Mechanism of energy distribution over tool electrode surface

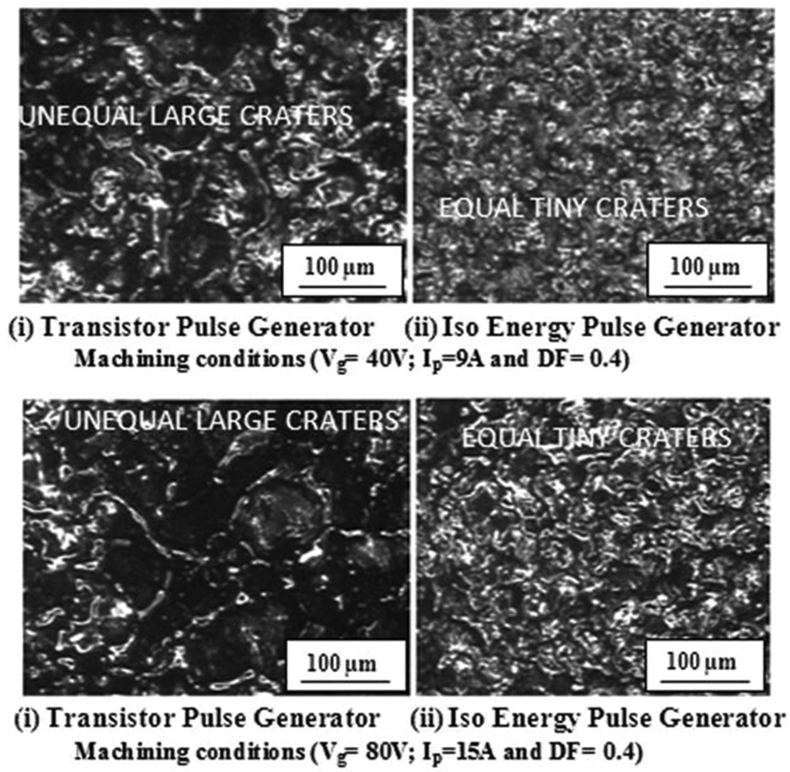

Figure 6: Surface topography of tool electrode surface in EDM process

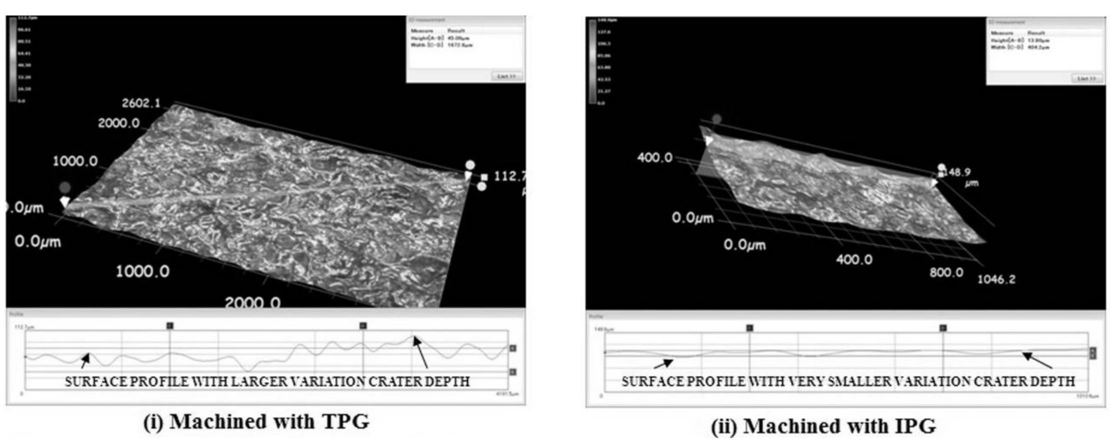

Figure 7: Surface topography of machined workpiece surface in EDM process with Machining conditions (V_g = 60V; I_p = 12 A and DF = 0.6)

Figure 6 shows the surface topography of tool electrode after the machining process. It has been observed that iso energy pulse generator has produced tiny and identical craters over the surface of machined tool electrodes owing to the nature of producing lower discharge energy pulses with uniform energy distribution. Whereas the transistor pulse generator has produced larger craters with different sizes due to ability of producing higher discharge energy pulses with random energy distribution during the machining process. Figure 7 shows the machined workpiece with TPG and IPG in EDM process. The surface roughness of the machined workpiece is the replica of tool electrode surface. It has been realized that the surface roughness has been influenced by the surface topography of the tool electrode surface at any instant in EDM process. Since the tool electrode surface has the significant nature on determining surface roughness of the machined workpiece, it has been observed that the iso energy pulse generator has produced lower surface roughness than the transistor pulse generator owing to the surface of the less tool electrode wear with identical and tiny craters [6].

C. Main effect plot Analysis

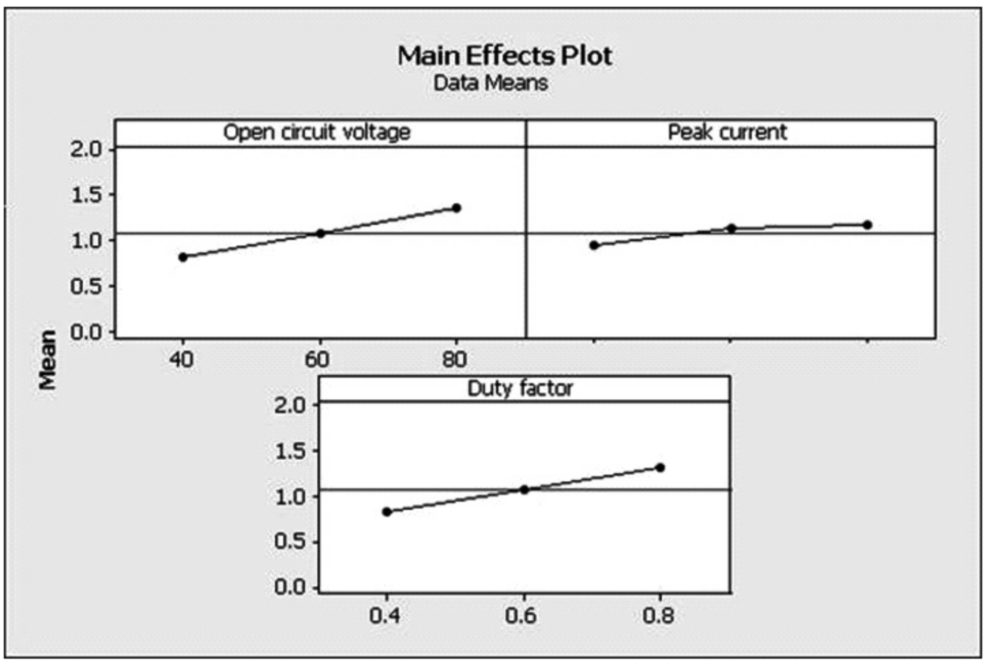

Figure 8: Main effect plot on tool wear rate

In the main effect plot, the deviation from horizontal line indicates the greater influence of process parameter on response variables. In the present study, the main effect plot has been developed with the help of Minitab software package. Figure 8 shows the main effect plot of input process parameters on tool wear rate in EDM process.

From these plots, it has been inferred that the open circuit voltage is the most influencing process parameters on determining tool wear rate owing to its importance of determining discharge energy during the material removing mechanism in EDM process [9].

5. CONCLUSIONS

With the view of knowing about the influence of energy distribution on tool wear rate in EDM process, a detailed experimental investigation has been conducted on AISI 202 stainless steel. The effects of transistor pulse generator and iso current pulse generator on tool wear rate have been compared and analyzed. Based on those results, the following conclusions have been made.

(i) Iso energy pulse generator can produce less tool wear rate with good surface quality owing to its uniform energy distribution nature.

(ii) Open circuit voltage current is the most influencing process parameters on determining tool wear rate owing to its importance of determining discharge energy.

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