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EFFECTS OF POLARITY PARAMETER ON MACHINING OF TOOL STEEL WORKPIECE USING ELECTRICAL DISCHARGE MACHINING

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ABSTRACT

Electrical discharge machining (EDM) has been recognized as an efficient production method for precision machining of electrically conducting hardened materials. This research studies the effect of polarity on the material removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR) of the tool steel work piece machining using EDM. Design of experiments (DOE) using L18 orthogonal arrays were being selected and the results being represents using response graph. Wrong polarity can have significant implications on speed, wear, and stability and to investigate this phenomenon using L18 orthogonal arrays design of experiment. The optimum parameters and the effects of polarity to the material removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR) are being discussed.

Keywords: EDM, Polarity, Electrode Wear Rate, Material Removal Rate, L_{18} Orthogonal arrays

INTRODUCTION

Electrical Discharge Machining (EDM) is a machining method primarily used for machining of metals or hard metals. The control parameters optimization for individual machining characteristic is concerned with separately maximize the material removal rate, separately minimize the tool wear ratio and separately obtained a good surface finish. Basic EDM process consists of electrode, work piece materials, dielectric and the range of pulse rate, current and voltage. Polarity is the designation of positive or negative electrical potential to the electrode. The polarity can affect the material removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR). It is very important to pay attention to the recommended polarity of various electrode work piece combinations because wrong polarity can have significant implications on speed, wear, and stability.

The major factor in the selection electrode is the ability of the electrode to resist thermal damage. However, some other factors that affect the selection of electrode material include material removal rate, wear resistance, desired surface finish, costs of electrode manufacture and material and characteristics of the material to be machined. Electrode density, polarity and frequency are the important factors in wear rates. Materials typically used for EDM electrodes are various forms of graphite, copper, tungsten, brass, silver and steel as reported by Lee et al (2007)**.**

The functions of the dielectric are: transportation of removal particles, to increase the energy density in plasma channel, recondition of the dielectric strength and cooling of the electrode as reported Dielectric fluid is pumped through the arc gap to flush away the eroded particles between the work piece and the electrode. Most common dielectric fluids are mineral oil, kerosene, paraffin, distilled water and deionised water. Recent trends involve the use of clear and low viscosity fluids to make cleaning easier. The elements considered in measuring EDM performance are MRR, electrode wear (EW), recast layer, surface quality (SQ) and effect of electrical and non-electrical parameter. Four electrical parameter that give major influences in EDM performance are pulse, electrode polarity, peak current and spark gap. Flushing pressure is considered as non-electrical parameter as reported by Kiyak and Cakir (2008).

METHODOLOGY

Clarify the Design Factor

For each parameter, apart from the polarity, three values or three levels were selected for the experiment. The range of values was identified empirically, taking into account on one hand the lowest power that can be supplied by the machine generator and on the other hand the highest power that the electrode can take before burning out. The eight selected design factors are in the Table 1:

Table 1: Controls Factors

	P	**i_e**	**u_i**	**t_i**	**T_o**	**C**	**gap**	**gain**
Lower limit	-	0.8	60	1	2.4	/	50	2
Middle value	+	1.4	80	2.4	13	2.7	65	5
Upper limit		1.8	100	5.5	56	19.4	80	9

Design the Experiment

For design the experiment, the orthogonal array was selected from the types of experimentation (orthogonal arrays, Greco-Latin squares, Placket-Burman Designs, full factorial). This because orthogonal arrays are the most versatile and are becoming more widely used. Table 2 shows the standard of orthogonal arrays.

Table 2: Design of the experiments

Orthogonal array	**Number of row**	**Number of factor**	**Number of columns**			
			2	3	4	5
L_4	3	3	3	-	-	-
L_8	8	7	7	-	-	-
L_9	9	4	-	4	-	-
L_{12}	12	11	11	-	-	-
L_{16}	16	15	15	-	-	-
L_{16}	16	5	-	-	4	-
L_{18}	18	8	1	7	-	-
L_{25}	25	6	-	-	-	6

Workpiece and Tool Preparation

For the workpiece preparation, the raw materials Alloy Steel (AISI P20 GRADE 1.2738) in form of block shape will be cut into smaller portion so that the workpiece can be prepared separately. The dimension of the workpiece is 8 mm x 25 mm x 25 mm. The workpieces were cut using wire EDM machine based on the standard parameters setting. For the tool preparation, copper in form of cylinder shape has 15 mm diameter and 40 mm length.

Material Removal Rate

Material Removal Rate (MRR) is the different weighted before and after rough cutting divide by time machining. So, the weight of the workpiece before and after the rough cutting must to take because to calculate the loss of mass for the material during the rough cutting at EDM machine. Below is the formula to calculate the MRR.

$$MRR = \frac{W_b - W_a}{t_m}(g/\min)$$

where:

W_b = weight of workpiece material before machining (g)
W_a = weight of workpiece material after machining (g)
t_m = machining times (min)

Electrode Wear Ratio (EWR)

The concept of electrode wear (EWR) can also be defined in many different ways, and in this study the EWR is defined according to the ratio in weight of the electrode and the workpiece, as this definition is the most commonly used among them. Minimum value of EWR always becomes an objective in many studies, where it indicates a minimum change in the shape of electrode, which leads to the better accuracy in the product.

$$EWR = \frac{EWW}{\mathrm{WRW}} \times 100\%$$

Surface Roughness (SR)

The surface roughness measurements for the machined surface are performed with a Surface Roughness Perthometer. The average surface roughness, Ra in μm unit was used to evaluate the surface roughness of machined surface.

RESULTS AND DISCUSSION

Table 3 shows the list of values for 3 machining characteristics i.e. MRR, EW and SR. This experiment uses design of experiment L_{18} Orthogonal Array to obtain the MRR, EWR and SR results. The criteria for optimum condition of every machining characteristic are being identified which quality characteristic for material removal rate (MRR) is higher-the-better, Electrode Wear Ratio (EWR) is lower-the-better and Surface Roughness (SR) is lower-the-better. Hence in relation with Taguchi method, the observed values of MRR, EWR and SR were set to maximum, minimum and minimum, respectively.

Table 3: Values of MRR, EWR and SR

No. expt.	Machining parameters								Machining efficiency		
	polarity	I [A]	u_l [V]	t_l [µs]	t_o [µs]	C [nF]	gap [-]	gain [-]	MRR [mm^3/min]	EWR [-]	R_a [µm]
1	+	0.8	60	1	2	-	50	2	0.0003	1.6162	0.34
2	+	0.8	80	2.4	13	2.7	65	5	0.0006	3.076	1.14
3	+	0.8	100	5.5	56	19.4	80	9	0.0008	2.0715	0.8
4	+	1.4	60	1	13	2.7	80	9	0.0003	3.0782	1.51
5	+	1.4	80	2.4	56	19.4	50	2	0.001	1.7383	0.72
6	+	1.4	100	5.5	2	-	65	5	0.0007	0.754	0.62
7	+	1.8	60	2.4	2	19.4	65	9	0.0016	0.7588	0.73
8	+	1.8	80	5.5	13	-	80	2	0.0004	1.9202	0.41
9	+	1.8	100	1	56	2.7	50	5	0.0004	3.6376	1.62
10	-	0.8	60	5.5	56	2.7	65	2	0.0011	0.2151	0.34
11	-	0.8	80	1	2	19.4	80	5	0.002	0.2847	0.56
12	-	0.8	100	2.4	13	-	50	9	0.0009	0.1247	0.46
13	-	1.4	60	2.4	56	-	80	5	0.0006	0.1988	0.22
14	-	1.4	80	5.5	2	2.7	50	9	0.0014	0.2124	0.97
15	-	1.4	100	1	13	19.4	65	2	0.0018	0.2954	1.36
16	-	1.8	60	5.5	13	19.4	50	5	0.0007	0.3916	1.07
17	-	1.8	80	1	56	-	65	9	0.0007	0.1941	0.58
18	-	1.8	100	2.4	2	2.7	80	2	0.0021	0.2584	0.44

Optimum Condition for MRR, EWR and SR

Relation with the mentioned quality characteristics, the optimum condition of machining characteristics for MRR, EWR and SR are shown in Figure 1, Figure 2 and Figure 3 response graphs.

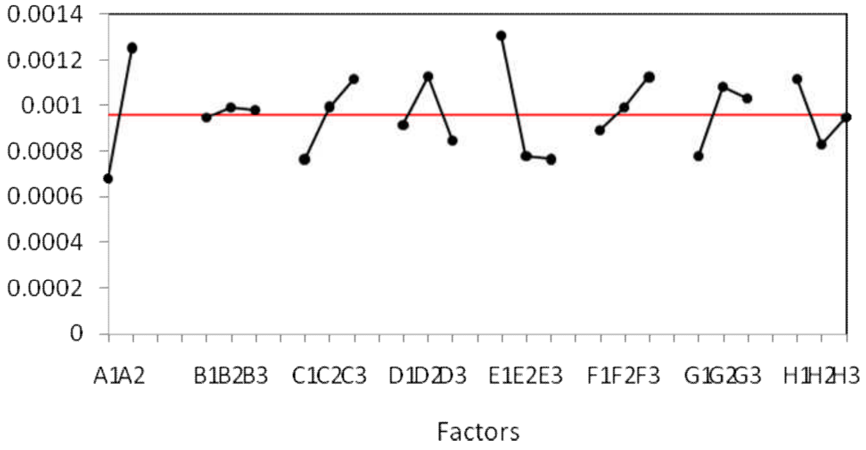

Figure 1: Response Graph for MRR

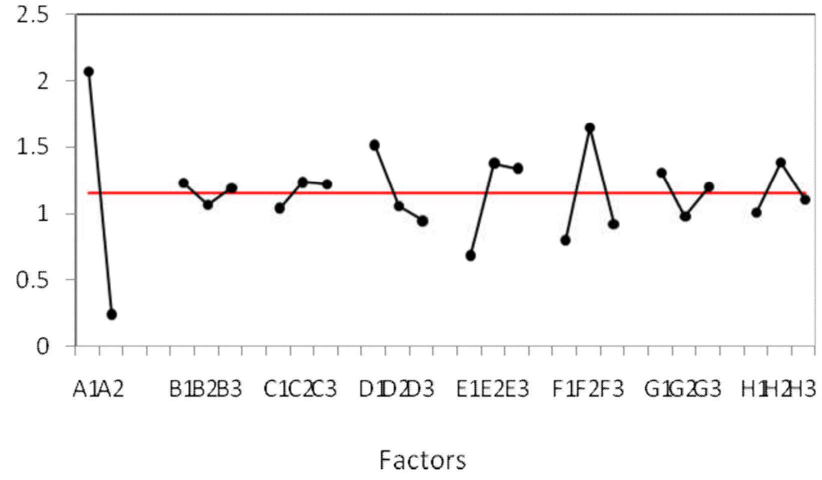

Figure 2: Response Graph for EWR

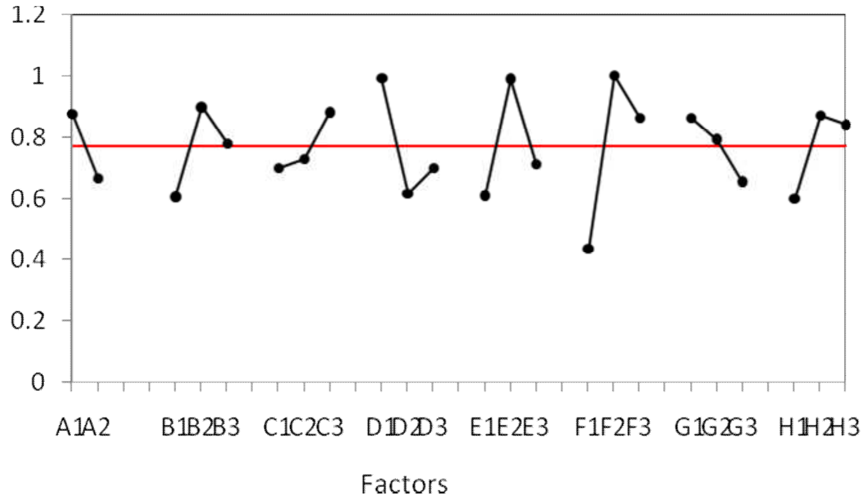

Figure 3: Response Graph for SR

Effects of Polarity to MRR, EWR and SR

Positive polarity (tool -, workpiece +) was found according to the MRR response graph shown. According to B.H. Yan, Saeki and Sunida, using a negative polarity in EDM caused higher MRR with a higher discharge energy (P>3A or A>5μs), in contrast a positive polarity caused a higher MRR with lower discharge energy (P<3A or A<5μs). The MRR increased when electrodes were used with positive polarity in all cases of semi-sintered electrodes. In the case of lower MRR, the electrode must spend more time to achieve machining. The positive polarity gives better MRR than negative polarity. Lee S.H. agreed that positive polarity factor decrease EWR rather than negative polarity factor. This is because relative heat dissipation on the workpiece is high at the end of discharge duration. During sparks occurs, few electrons impinge the tool rather than on the workpiece because electrons are normally react with positive polarity which is the workpiece. Kiyak and Cakir stated that with positive polarity with the condition that smaller current and pulsed were being used for the experiment. This is because small particle depth and particle will be produced to obtained the smooth surface of the workpiece. The positive polarity give effect on the spark stability as it is the normal condition for any EDM machining that contributes to the lower surface roughness result.

CONCLUSION

The positive polarity (tool -, workpiece +) is found optimum for the all analysis on the Material Removal Rate (MRR), Electrode Wear Ratio (EWR) and Surface Roughness (SR) when machining tool steel work piece using Electric Discharge Machine (EDM). Hence, this research might be useful to other researches in finding the best polarity and its effect on the tool steel AISI P20 GRADE 1.2738 workpiece using copper tool.

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