Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 06, June-2018

Effect of Different Dielectric Fluids on Material Removal in machining of Steel (EN31) with Electrolytic Copper Electrode in Sinker EDM

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***Abstract* - This research work analyzes the effect of process parameters in the machining of Steel (EN 31) in Sinker EDM. Performance parameter selected for the investigation is Material Removal (MR). Input parameters taken are Dielectric Fluids (Distilled Water, Kerosene Oil, EDM Oil), Pulse On Time, Current and Voltage. Here, material of the electrode is electrolytic copper. Taguchi L_9 orthogonal array is selected for Design of Experiments to optimize the process parameters. The results have revealed that dielectric fluid and voltage are the major contributors as compared to pulse on time and current, towards the effect on material removal. Optimum values for maximum MR are; Dielectric Fluid is Kerosene oil, Ton = 60µs, Current = 16A and Voltage = 10V.**

Keywords: EDM, Dielectric Fluid, Distilled Water, Kerosene Oil, EDM Oil, EN31, Material Removal

I. INTRODUCTION

Electric Discharge Machine (EDM) is a non-traditional machine in which material from the workpiece is removed by electrical discharges (sparks). The electrodes are separated by dielectric fluid and a voltage is applied across it. One of the electrodes is tool and other is workpiece In Sinker EDM, tool is produced according to the desired shape required for the workpiece. Materials most commonly used for the electrode are Graphite, Brass or Copper tungsten [8]. Sinker EDM process is commonly used in the production of dies and molds. Dielectric fluid in EDM enables spark discharge to pass between the tool and the work. It also acts as a coolant. Besides this, it is a flushing medium i.e. it removes wear debris present in the spark gap.

Chen et al. [2] carried out experimentation on Ti-6Al-4V. MRR was found to be higher in distilled water than kerosene. George et al. [3] found that the process variables affecting EWR and MRR, according to their relative significance are gap voltage, peak current and pulse on time respectively. Hascalik and Caydas [4] observed that for titanium alloy, as peak current and Ton get larger, more amount of heat energy gets transferred which leads to more amount of material removal. Kathiresan and Sornakumar [6] presented that for LM24 Al-SiC metal matrix composite, both the MRR and surface roughness were increasing with the increasing magnitude of current. Banker et al. [1] observed that for AISI 304L, copper electrode showed highest MRR, brass electrode exhibited highest TWR and aluminium electrode showed maximum surface roughness. According to Khanna and Garg [7], the factor which mostly influenced MRR was voltage, followed by current, pulse on time and pulse off time. Reddy and Valli [10] found that for Steel (EN 31), the parameters such as peak current, Ton, duty factor, supply voltage and their interactions have a significant effect on material removal rate. Sahani et al. [11] presented that for mild steel, MRR increased upto a certain limit with increase in current and then, it decreased with further rise in current. Similar trend was seen for Ton as well. MRR increased with increase in voltage. Jeykrishnan et al. [5] studied that for AISI D2 die steel, MRR decreased when current is increased and it rose with further increase in current. MRR decreased with increase in Ton whereas it increased when T_{off} increased.

II. EXPERIMENTATION

A. Experimental setup

The machine used for experimentation was Sinker EDM, with model OSCARMAX 645, as shown in figure 1. Steel (EN 31) was chosen as the work material. As it is very hard, therefore, non-conventional machining processes are better suited for its machining as compared to conventional processes. A pool of EN 31 pieces was created to conduct the experiments. Dimensions of each piece: 47 mm × 49 mm × 19 mm. Electrolytic copper electrode with square cross-section having dimensions 23 mm × 23 mm was chosen as the tool electrode. It is the most common copper. Magnitude of T_{off} and dielectric fluid pressure was kept constant at 45µs and 0.5 Pound respectively.

Fig. 1. Sinker Electric Discharge Machine

B. Design of Experiments (DOE)

For this study, the Taguchi method was used to design the experimental process parameters. Four parameters namely Dielectric Fluid, T_{on}, Voltage and Current were

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 06, June-2018

varied in order to investigate the influence on material removal. Here, all the four parameters were of three levels, denoted by 1, 2, 3 as shown in table 1. Orthogonal array L_9 was chosen to design the experiments, as shown in table 2. To obtain more accurate results, experiments were repeated two times.

TABLE 1. MACHINING PARAMETERS AND THEIR LEVELS

Parameters	Units	Level 1	Level 2	Level 3
Dielectric Fluid (DF)	Nil	Distilled Water (DW)	Kerosene Oil (KO)	EDM Oil (EO)
Pulse On time (T_{on})	μs	60	90	120
Voltage (V)	Volt	10	15	20
Current (C)	Amp.	8	16	24

TABLE 2. ORTHOGONAL ARRAY PARAMETER TRIAL CONDITIONS

Expt. No.	Dielectric fluid	T_{on}	Voltage	Current
1.	DW	60	10	8
2.	DW	90	15	16
3.	DW	120	20	24
4.	KO	60	20	16
5.	KO	90	10	24
6.	KO	120	15	8
7.	EO	60	12	24
8.	EO	90	20	8
9.	EO	120	10	16

Material removal (MR) was calculated from following mathematical formula:-

$$MR = \text{Initial weight} - \text{Final weight}$$

S/N ratio was calculated using higher the better characteristic. Table 3 shows the experimental results of MR for EDM of steel (EN 31) by electrolytic copper electrode.

TABLE 3. RESULTS OF EXPERIMENTS

Expt. No.	MR			S/N ratio (dB)
	R1	R2	R3	
1.	2.83	3.45	3.01	9.82
2.	2.00	2.36	3.20	8.03
3.	2.78	3.21	2.69	9.23
4.	3.33	3.50	3.88	11.05
5.	3.28	3.52	3.48	10.70
6.	2.98	2.67	3.13	9.33
7.	2.69	3.08	2.96	9.28
8.	3.19	3.89	3.00	10.53
9.	3.45	2.99	3.87	10.72

III. RESULTS AND DISCUSSIONS

A. Effect of dielectric fluid on MR

Figure 2 shows the variation of MR with change in dielectric fluid. It can be seen from the figure that MR is less for distilled water as compared to kerosene oil. This may be because of the reason that arcing phenomenon is prominent in distilled water due to early decomposition of water molecules. This was similar to the result obtained by Niamat et al. [9]. Material removal for EDM oil was slightly lesser than kerosene oil because its viscosity is high. As a result, its movement is slow which hinders flushing of the debris. Therefore, arcing gets effected and hence, MR gets reduced for EDM oil.

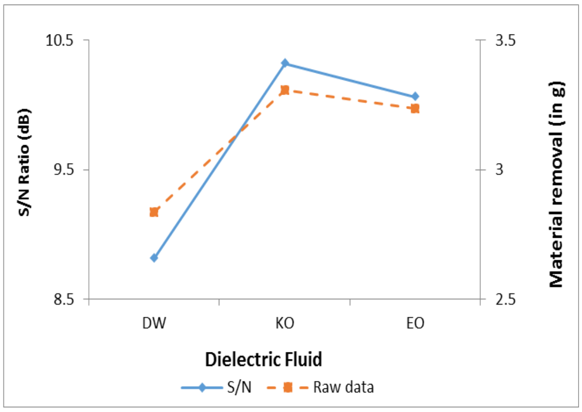

Fig. 2. Effect of dielectric fluid on MR

B. Effect of T_{on} on MR

Figure 3 shows the variation of MR with change in the value of T_{on}. MR has been decreased when T_{on} is increased from 60μs to 90μs. This may be due to the reason that with increase in T_{on}, ignition delay increased in each cycle which reduced the machining rate. Ignition gets "postponed", due to which removal of material decreased. Now, when magnitude of T_{on} is further changed to 120μs, heat energy got available for longer time. The dielectric fluid utilized some energy to get decomposed and the rest of energy got used for removal of the material. Hence, MR increased when T_{on} was changed from 90μs to 120μs.

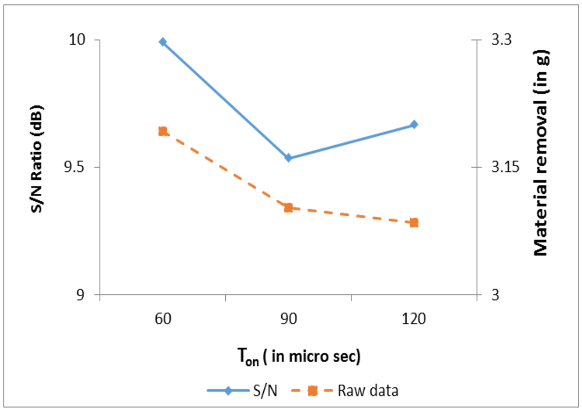

Fig. 3. Effect of T_{on} on MR

C. Effect of current on MR

Figure 4 shows variation in magnitude of MR with change in current. It can be seen that as the magnitude of current increased from 8A to 16A, material removal increased. This may be due to the reason that with rise in value of current, strong sparks got produced. This helped in eroding more material, thereby increasing MR. Now, when current further rose to 24A, more material should be eroded but high amount of current got utilized by the dielectric fluid to get decomposed. As a result, part of energy got lost over there, thereby MR decreased.

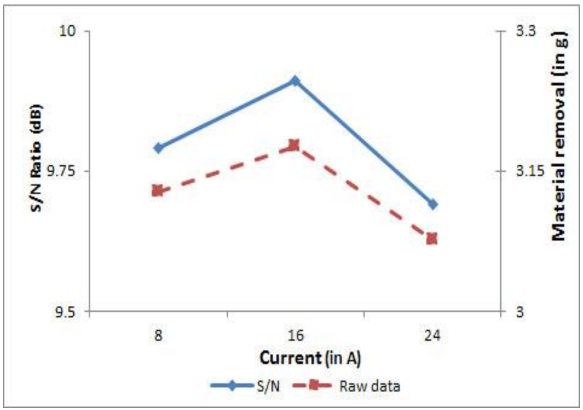

Fig. 4. Effect of current on MR

4. Effect of voltage on MR

Figure 5 shows the change in MR with respect to variation in voltage. When voltage increased from 10V to 15V, MR decreased. This may be due to the reason that discharge gap rose with increase in voltage. Hence, flushing efficiency reduced. The increase in spark energy was dominated by reduction in spark efficiency. Now, when voltage rose to 20 V, material removal increased due to rise in spark energy with increase in voltage. Hence, number of positive ions attacking the surface of workpiece increased. Therefore, temperature of work rose, helping in melting and evaporating of material from the work's surface.

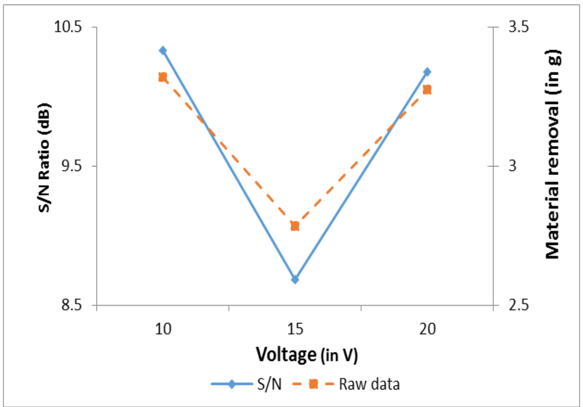

Fig. 5. Effect of voltage on MR

To study the significance of process parameters towards MR, Analysis of Variance (ANOVA) had been performed. Pooled version of ANOVA of S/N ratio for MR is given in table 4.

From the figures, optimum values for maximum MR are; Dielectric fluid (DF_2) is Kerosene, T_{on1} = 60µs, Current (C_2) = 16A and Voltage (V_1) =10V.

TABLE 4. POOLED ANOVA (S/N RATIO FOR MR)

Source	SS	DOF	V	P	F-Ratio
Dielectric fluid	3.90	2	1.95	42.43	235.65
T_{on}	0.33	2	0.16	3.55	19.72
Current	POOLED				
Voltage	4.95	2	2.47	53.84	299.05
Error	0.02	2	0.01	0.18	
T	9.20	8		100	
Significant at 95% confidence level, Critical = 4.46					
SS-Sum of squares, DOF-Degrees of freedom, V-Variance					

IV. CONCLUSIONS

The major conclusions drawn are as follows:

- It was found that output parameters are significantly affected by the dielectric fluids. Maximum amount of material was removed in case of kerosene oil than that of distilled water and EDM oil.
- For pulse on time, it was seen that at the first level of Ton i.e. 60µs, MR is largest. MR decreased when Ton changed from 60µs to 90µs and when it is increased to 120µs, MR increased.
- When current was changed from 8A to 16A, MR increased and when current was further increased to 24A, there was a reduction in MR
- For voltage, when it was changed to 10V to 15V, a rapid decrease in MR was observed and when the voltage further rose to 20V, there was rapid increase in MR. Here, maximum MR was obtained at 10V.

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