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Optimization of Electrical Discharge Machining Process Parameters Using Flushing and Drilled Tool

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Abstract - *Electric Discharge Machining (EDM) is a thermo-electric non-traditional machining process in which material removal takes place between a pair of electrodes which are submerged in a dielectric medium. In present study the effect of Flushing discharge and tool hole diameter on MRR has been studied along with current, voltage and spark on time. The optimization was done using Design of Experiments (DOE). It is observed experimentally that increase in flushing discharge increases the MRR. Also increase in tool hole diameter increases MRR up to a certain value and decreases with further increase in diameter.*

Key Words: EDM, Flushing, Dielectric medium, MRR, DOE.

1. INTRODUCTION

Electro Discharge Machining (EDM)[1] is a non-conventional machining process which is more efficient than conventional machining process due to ease of machining of difficult-to machine materials with complex shapes. It is also used for machining the materials which are hard enough to cut by traditional processes. It has many applications in industries like aerospace, automobile, general engineering, etc. EDM performance is mainly dependent on factors like flushing discharge, pulse on time, current, voltage, tool geometry.

Flushing [6] is the greatest key role which provides correct circulation of dielectric liquefied in any electrical discharge machining operation. If removed particles are not flushed thoroughly, they act as obstacles in the small gap between tool and work piece. Flushing is the procedure of presenting clean strained dielectric liquid into the spark gap. Fig-1.1 shows the basic principal of flushing.

By scrutiny of the published research work, the paper addresses the issue that an alternate type of tool like hollow tube electrode may have a positive impact on MRR with low tool wear rate due to improved flushing conditions. Hollow tool is particularly useful for drilling holes with low tool wear rate. It was found that while machining the same length of Inconel718 with a solid tool it takes approximately 40% more machining time than taken by a hollow tool [7]. Hollow tool also helps in minimizing the dielectric fluid degradation. Consequently, the approach light is cost effective with higher yield, and reduced material and energy loss. The work will be carried out using Drilled tool varying the diameters[9] of the hole and finding the optimum combination of parameters and experimentally conform the results [3].

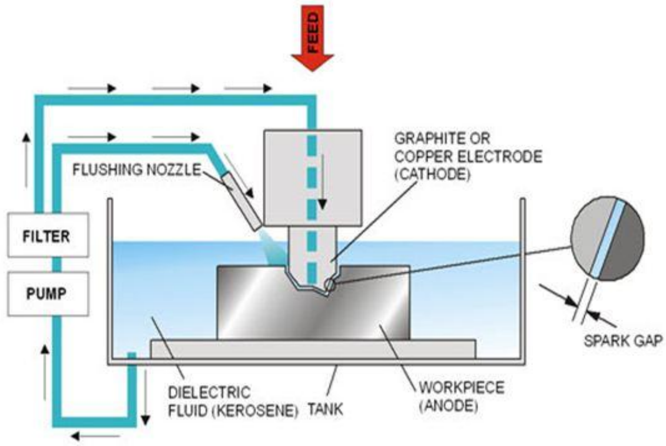

Fig -1.1: Flushing [10]

1.1 Experimental Setup

The Experiment set was conducted on an EDM machine, CHMER 50-EZ using 16mm diameter copper tool[2] electrode and variable flushing discharge for studying the effect of flushing discharge on MRR.

For studying the effect of tool hole diameter on MRR the tool was drilled by 4mm, 6mm and 8mm diameter. The experiment was conducted on EN-353[7] steel using EDM-30 oil as dielectric. The properties of work piece and tool electrode are listed in the following table:

Table -1.1.1: Properties of Cu Electrode [2]

Property	Description
Density	8960 kg/m³
Melting point	1083C
Thermal conductivity	401 W/mK
Electrical resistivity	1.673e-008 ohm
Bulk modulus	137.8 GPa

Table -1.1.2: Properties of EN-353 [7] steel work piece

Property	Description
Density	8904 kg/m³
Melting point	1510C
Thermal conductivity	51.9 W/mK
Hardness	260 HB
Dimension	130mm*50mm*30 mm

Table -1.1.3: Properties of Dielectric EDM-30

Property	Description
Density	826 kg/m³
Flash point	102⁰C
Burn Rate	150 A
Boiling Point	149⁰c
Viscosity at 40⁰c	3.5 cst

Fig-1.1.1 and Fig-1.1.2 shows the different copper tool electrode and work piece EN-353 steel respectively.

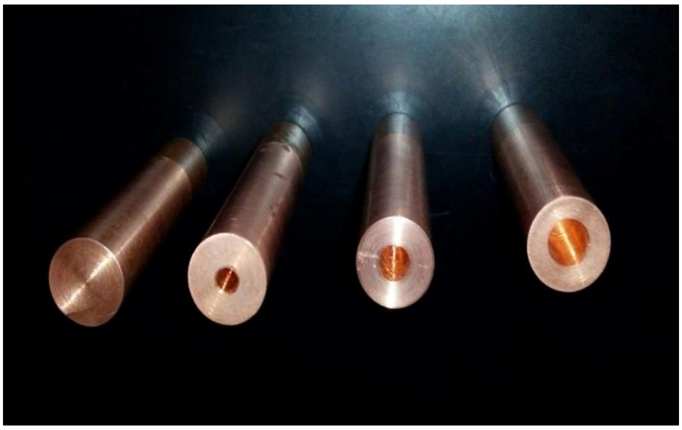

Fig -1.1.1: Solid and drilled Cu electrode

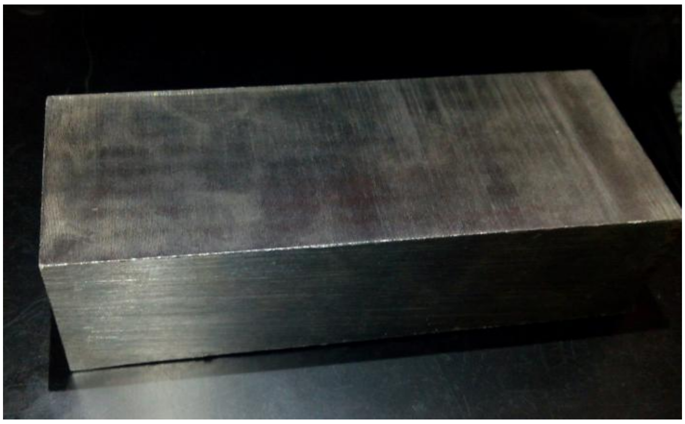

Fig -1.1.2: Work piece EN-353 steel

Design of experiments was conducted using Taguchi's approach [4]. The value of input parameters with their levels are shown in Table 1.1.4.Since the number of parameters is three and each parameter has three levels, using the orthogonal array selector, the L9 array is selected. The array obtained is shown in Table 1.1.5 and Table 1.1.6.

Table -1.1.4: Value of Input Parameters

Parameters	Level		
	1	2	3
Discharge Current (A)	8	10	12
Spark ON Time (μs)	100	150	200
Flushing Discharge (mm³/min)	2631	3946	5260
Hole Diameter of Electrode (mm)	4	6	8

Table -1.1.5: L9 Array for Flushing

Sr.No.	Current (amp)	Pulse ON time (μs)	Flushing (mm³/min)
1	8	100	2631
2	8	150	3946
3	8	200	5260
4	10	100	3946
5	10	150	5260
6	10	200	2631
7	12	100	5260
8	12	150	2631
9	12	200	3946

Table -1.1.6: L9 Array for Drilled Electrode

Sr.No.	Current (amp)	Pulse ON time (μs)	Hole Diameter (mm)
1	8	100	4
2	8	150	6
3	8	200	8
4	10	100	6
5	10	150	8
6	10	200	4
7	12	100	8
8	12	150	4
9	12	200	6

As the process of removing work piece to measure weight after each reading is cumbersome, the MRR was calculated by determining volume of the material removed, after performance of the entire experiment. Following formulae are used for calculation:

$$MRR = \frac{\text{Volume of material loss (mm^3)}}{\text{Machining time (min)}}$$

Volume of material loss (mm³) = $V = A*d_c$ .... (1.1)

Material Removal Rate (mm³/min) = V / T .... (1.2)

Where,

A= Area of the impression

d_c = Depth of cut (mm),

T_m = machining time (min)

1.2 Observation

The MRR for each combination of experiments is calculated using equation 1.1 and 1.2. The observation table for Flushing discharge and Tool hole diameter are as shown in Table 1.2.1 and Table 1.2.2 respectively.

Table -1.2.1: Observation table for Flushing discharge

Sr. No.	Current (amp)	Pulse ON time (µs)	Flushing (mm^3/min)	MRR(mm^3/min)
1	8	100	2631	9.6504
2	8	150	3946	11.1179
3	8	200	5260	9.8871
4	10	100	3946	21.1630
5	10	150	5260	19.3008
6	10	200	2631	16.3013
7	12	100	5260	22.7600
8	12	150	2631	22.6600
9	12	200	3946	19.4560

Table -1.2.2: Observation table for Drilled Electrode

Sr.No.	Current (amp)	Pulse ON time (µs)	Hole Diameter (mm)	MRR (mm^3/min)
1	8	100	4	8.9600
2	8	150	6	12.6460
3	8	200	8	9.0470
4	10	100	6	20.3260
5	10	150	8	13.4000
6	10	200	4	13.7000
7	12	100	8	18.2700
8	12	150	4	16.4800
9	12	200	6	18.0200

Figure 1.2.1, 1.2.2, and 1.2.3 shows the flushing arrangement for different discharge.

Fig -1.2.1: Flushing arrangement for discharge =2631 mm^3/min

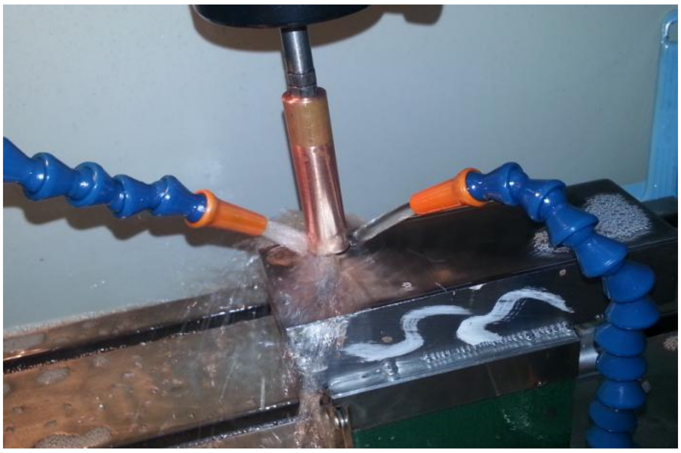

Fig-1.2.2: Flushing arrangement for discharge=3946 mm^3/min

Fig-1.2.3: Flushing arrangement for discharge =5260 mm^3/min

2. Result and Analysis

The experimental results are analyzed for MRR to the flushing discharge and tool hole diameter. For analysis MINITAB-17 software was used. The subsequent graphs are plotted by implementing DOE. Table displays the result obtained, along with the combination of input parameters. Two types of subsequent graphs are plotted.

2.1 Main Effect Plot

This plot considers the effect of all the input parameters on the output and plots the means of output (MRR) against each level of input for each parameter. Below chart-1 and chart-2 shows the main effect plots for flushing and drilled electrode respectively.

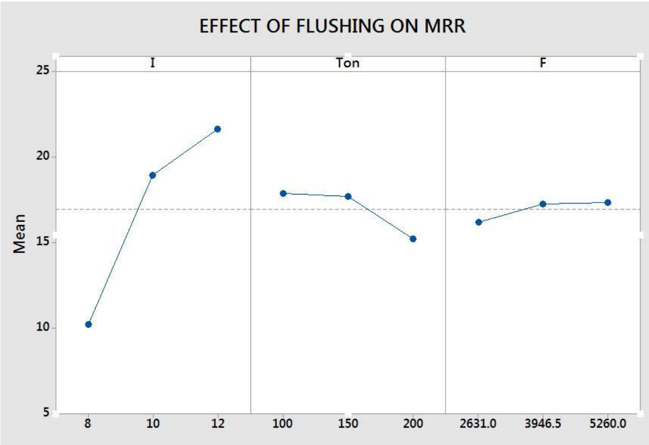

Chart -2.1.1: Main Effect Plot for flushing discharge

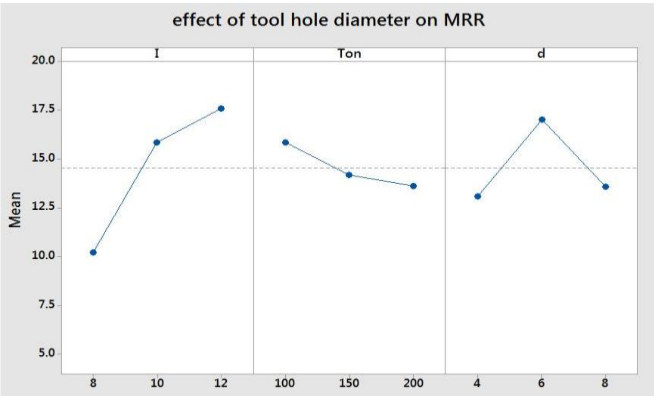

Chart -2.1.2: Main Effect Plot for flushing discharge

From the main effects plot, it can be inferred that within experimental limits, the following combination will give the best value of MRR:

For Flushing:-

1. Current: 12 amp
2. Pulse ON time: 100 µs
3. Flushing Discharge : 3946 mm³/sec

For Drilled Electrode:-

1. Current: 12 amp
2. Pulse ON time: 100 µs
3. Hole Diameter: 6 mm

2.2 Individual Value Plot

This graph takes all the possible combinations and plots each result accordingly. From Table 1.1.5 it is clear that each set of readings has a unique combination of input parameters. It gives graph for each value separately. This is especially useful when numbers of observations are relatively less.

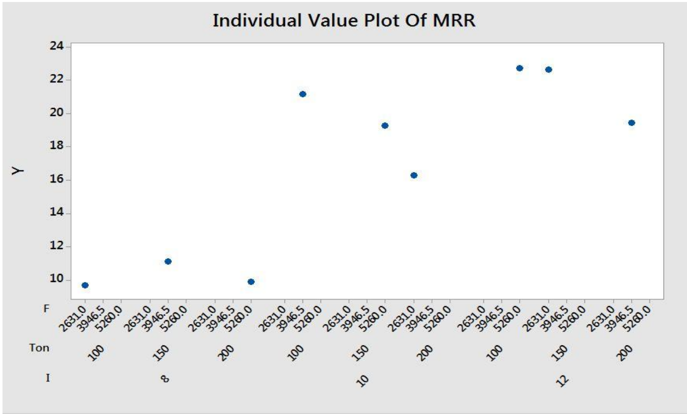

Chart -2.2.1: Individual Value Plot for flushing discharge

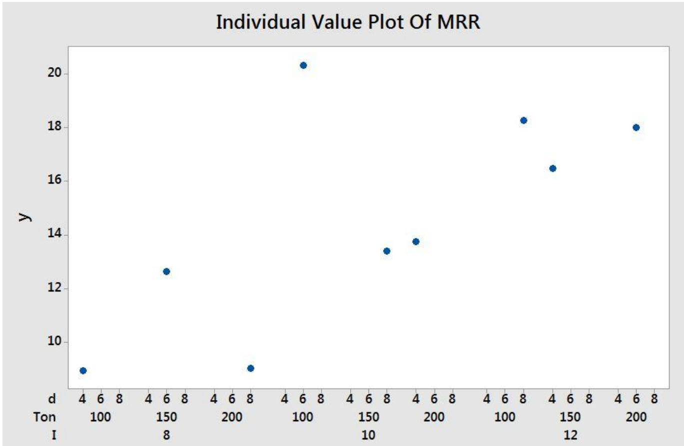

Chart -2.2.2: Individual Value Plot for drilled electrode

2.3 Validation

The optimum combination obtained from main effect plot must be verified in order to validate the experiment. Hence the experiment is performed again but for a small set of readings and only considering the parameter values in the obtained optimum combination. The results of validation are listed in Table 2.3.1.

Table -2.3.1: Validation

	Current (amp)	ON time (µs)	Discharge/Hole Dia.	MRR (mm3/min)
Flushing	12	100	5260	22.76
Drilled Electrode	12	100	6	21.24

3. CONCLUSIONS

1. From the observation, as the flushing discharge increases the Metal Removal Rate also increases gradually.

2. Experimental result shows that factor of flushing is important to remove gaseous and solid debris generated during EDM process also the MRR tend to increase gradually with increase of tool hole diameter up to 6mm and further increase in diameter results in decrease of MRR.

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