ISSN : 2455-9679
Impact Factor : 3.340

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INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"OPTIMIZATION OF SURFACE ROUGHNESS & MATERIAL REMOVAL RATE THROUGH TAGUCHI STATISTICAL TECHNIQUE"

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ABSTRACT

EDM has become an important and cost-effective method of machining extremely tough and brittle electrically conductive materials. It is widely used in the process of making moulds and dies and sections of complex geometry and intricate shapes. The work piece material selected in this experiment is AISI 304 Stainless steel, taking into account its wide usage in industrial applications. In today's world, AISI 304, contributes to almost half of the world's production and consumption for industrial purposes. The input variable parameters are discharge current, duty cycle and discharge voltage. Taguchi method is applied to create an L9 orthogonal array of input variables using the Design of Experiments (DOE). The effect of the variable parameters mentioned above upon machining characteristics such as Material Removal Rate (MRR), Surface Roughness (Ra) are studied and investigated. The tool material is copper. Confirmation tests are carried out to investigate the results obtained using Taguchi algorithm. Discharge current is found contributing the most in both the cases of surface roughness to be minimized and MRR to be maximized.

Keyword: *Electrical Discharge Machining (EDM), Design of Experiments (DOE), Materia Removal Rate (MRR), Taguchi, Optimization, Surface Roughness, Copper, Steel, Array, Orthogonal.*

I. INTRODUCTION

Electrical Discharge Machining, generally known as EDM is a non-conventional machining technique used to expel material by various tedious electrical discharges of little term and high current thickness between the work piece and the instrument. EDM is a significant and cost-powerful strategy for machining very extreme and weak electrically conductive materials. In EDM, since there is no immediate contact between the work piece and the electrode, consequently there are no mechanical forces existing between them. Any kind of conductive material can be machined utilizing EDM regardless of the hardness or sturdiness of the material. Electric discharge machining (EDM) is a non-conventional procedure dependent on electro-thermal vitality and is utilized for machining of assorted materials with complex geometrical shapes just as exact dimensional cuttings. EDM process is particularly very much perceived for assembling of hard-to-machine materials. By conquering specialized challenges related with the conventional machining, EDM innovation discovers its proper applications in the aviation and car ventures as well as in the careful and therapeutic embed creation. Moreover, shape and pass on creation, burr free micro gap or space fabrication4 likewise misuse the EDM innovation because of the hardness issue of the materials and bigger cutting force associated with the conventional machining. Notwithstanding, EDM process additionally endures regarding execution. A considerable amount of examinations have been sought after to improve the machining procedure of EDM, particularly

ISSN : 2455-9679
Impact Factor : 3.340

concentrating on the accompanying angles, for example, expanding material removal rate, upgrading surface quality and decreasing device wear rate..

II. LITRATURE REVIEW

B.S. Reddy et al. completed an investigation on the impact EDM parameters over MRR, TWR, SR and hardness. Blended factorial plan of trials and numerous relapse investigation procedures had been utilized to accomplish the ideal outcomes. The parameters in the diminishing request of significance for; MRR: servo, duty cycle, current and voltage; WR: current, servo and duty cycle; SR: current; HRB: servo as it were. M.M. Rahman et al. [2] researched the impact of the pinnacle current and heartbeat term on the presentation qualities of the EDM. The ends drawn were: the current and heartbeat on time significantly influenced the MRR, TWR and SR, the MRR increments directly with the expanding current, the SR increments straightly with current for various heartbeat on schedule, TWR expanded with expanding top current while diminished when the beat on time was expanded.

Puertas et al, completed outcomes which indicated that the force and heartbeat time factor were the most significant if there should be an occurrence of SR while the duty cycle factor was not huge by any means. The power factor was again persuasive if there should arise an occurrence of TWR. The significant factors if there should be an occurrence of MRR were the force followed by duty cycle and the beat time.

S.H. Tomadi et al, examined the machining of tungsten carbide with copper tungsten as electrode. The full factorial plan of investigations was utilized for examining the parameters. In the event of SR, the significant factors were voltage and heartbeat off time while current and heartbeat on time were not critical. For MRR the most compelling was beat on time followed by voltage, current and heartbeat off time. At last in the event of TWR the significant factor was beat off time followed by top current.

Iqbal and Khan et al, reasoned that the voltage and rotational speed of the electrode are the two critical parameters for EDM processing. Enhancement is worried about amplifying the MRR and limiting EWR alongside an ideal Ra..

III. EXPERIMENTATION

The experiments were conducted using the Electric Discharge Machine, model ELECTRONICA -ELECTRAPLUS PS 50ZNC (die sinking type) the polarity of the electrode was set as positive while that of work piece was negative. The dielectric fluid used was EDM oil (specific gravity-0.763).

Selection of the work piece

AISI 304 Stainless Steel is one of the most widely used materials in all industrial applications and accounts for approximately half of the world's stainless steel production and consumption. Because of its aesthetic view in architecture, superior physical and mechanical properties, resistance against corrosion and chemicals.

Tool Design

The tool material used in Electro Discharge Machining can be of a variety of metals like copper, brass, aluminum alloys, silver alloys etc. The material used in this experiment is copper. The tool electrode is in the shape of a cylinder having a diameter of 21mm

Fig. 1 Machined work piece and Tool

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Table 1 Machining parameters and their level

Factor (s)	Notation/ Units	Code	Level of Factors		
			1	2	3
Discharge Current	I_P (A)		3	5	7
Duty Facor	%		50	70	90
Discharge Voltage	V (Volt)		30	45	60

For Taguchi analysis of the machining parameters like Discharge current, Duty factor and Discharge voltage, 3 levels are taken with the parameter values as shown in table 1.

Table 2 Design of Experiment (DOE)

S.No.	**Design of Experiment (L9orthogonal array)**		
01	3	50	30
02	3	70	45
03	3	90	60
04	5	50	45
05	5	70	60
06	5	90	30
07	7	70	60
08	7	50	30
09	7	90	45

To design the orthogonal array for the optimization of parameters using Taguchi analysis, Degree of freedom is calculated using the number of levels of the parameters.

$$\text{Degree of Freedom} = \text{No. of Level} - 1$$

$$\text{Total Degree of Freedom} = 3 \text{ x } (\text{No. of Level} - 1) = 6$$

Since the cumulative DOF = 6, hence the number of trial experiments required must be greater than or equal to 6. As per Design of Experiments (DOE), L9 orthogonal array is required to be designed.

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Table 3 Experimental Data

S.No	Experimental Data	
	MRR (mm3/min)	Ra(μm)
01	8.4	8.66
02	8.7	8.38
03	7.72	8.42
04	13.2	9.88
05	14.1	10.72
06	11.7	8.1
07	18.9	13.27
08	15.44	11.68
09	13.22	9.02

Table 4 S/N Ratios of MRR and Surface Roughness

S.No	S/N Ratio	
	MRR (Higher-the-Better)	Ra (Lower-the-Better)
01	18.4856	-18.7504
02	18.7904	-18.4649
03	17.7523	-18.5062
04	22.4115	-19.8951
05	22.9844	-20.6039
06	21.3637	-18.1697
07	25.9292	-22.9999
08	23.7729	-21.3489
09	22.4246	-19.1041

Table 4 shows the signal-to-noise ratio for material removal rate and surface roughness of the test samples. S/N ratio is the value of ratio of controllable and uncontrollable factors involved in the experimentation. It shows the parameters which can be controlled by the observer during the experimentation.

IV. RESULTS & DISCUSSION

Results for S/N ratio of Surface Roughness

It can be seen from the fig. 2 that the surface roughness is better for lower values of the S/N ratio obtained. As per the above figure A3;B2;C3 is the optimized combination for the best obtained surface roughness on the samples with the cost effectiveness during the machining operation. As per table 5 it is observed that discharge current has utmost

ISSN : 2455-9679
Impact Factor : 3.340

impact on the machining operation followed by duty factor and the discharge voltage. Discharge current contributes maximum to lower the surface roughness of the sample and hence its observation should be prioritized.

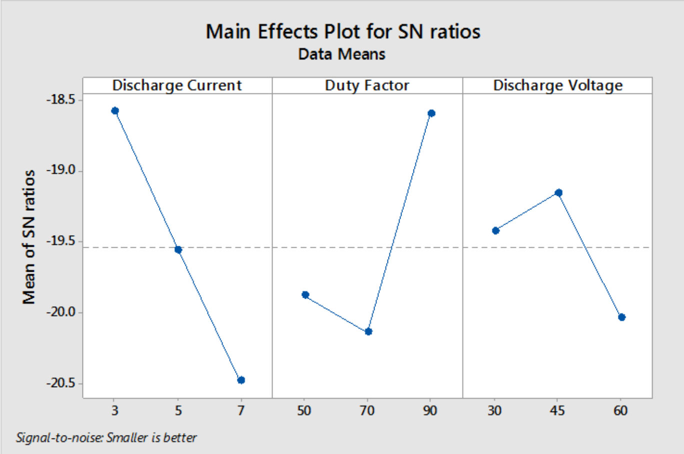

Fig.2. S/N ratio graph for Surface Roughness

Results for S/N ratio of Material Removal Rate (MRR)

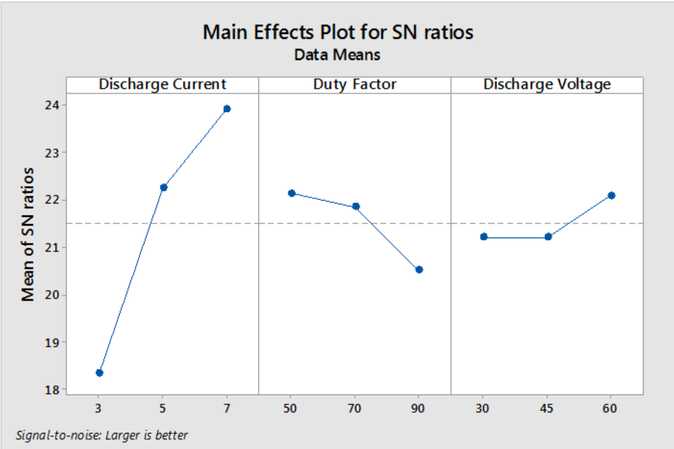

Fig. 3. S/N ratio graph for Material Removal Rate (MRR)

It can be seen from the fig. 3 that the MRR is better for higher values of the S/N ratio obtained. As per the above figure A3;B1;C3 is the optimized combination for the best obtained MRR on the samples with the cost effectiveness during the machining operation.

Confirmation Test

Predicted Value of Surface Roughness against the optimized experiment

$$\eta_{opt} = m + \sum_{j=1}^{n} [(m_{i,j})_{\max} - m]$$

where,

m= overall mean of η with nine trials;

(m_{ij})max= S/N ratio at optimal level and parameter;

'n' is the number of main designing parameters that affect the machining process.

$$\text{mA3} = \frac{-22.99 - 21.35 - 19.10}{3} = -21.15$$

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$$\mathrm{mB2} = \frac{-18.47 - 20.60 - 22.99}{3} = -20.69$$

$$\mathrm{mC3} = \frac{-18.51 - 20.60.22.99}{3} = -20.68$$

$$\mathrm{m} = \frac{-18.75 - 18.46 - 18.50 - 19.89 - 20.60 - 18.16 - 22.99 - 21.34 - 19.10}{9} = -19.76$$

$$\eta\mathrm{opt.} = -19.76 + (-21.15 + 19.76) + (-20.69 + 19.76) + (-20.68 + 19.76)$$

$$\mathbf{Ra} = \mathbf{10^{23.04/20} = 14.19}$$

Predicted Value of MRR against the optimized experiment

$$\mathrm{mA3} = \frac{25.93 + 23.78 + 22.42}{3} = 24.04$$

$$\mathrm{mB1} = \frac{18.48 + 22.41 + 25.92}{3} = 22.27$$

$$\mathrm{mC3} = \frac{17.75 + 22.98 + 25.92}{3} = 22.22$$

$$\mathrm{m} = \frac{18.48 + 18.79 + 17.75 + 22.41 + 22.98 + 21.36 + 22.92 + 23.77 + 22.42}{9} = 21.55$$

$$\eta\mathrm{opt.} = 21.55 + 2.49 + 0.72 + 0.67 = 25.43$$

$$\mathbf{MRR} = \mathbf{10^{25.43/20} = 18.69}$$

By the use of above methods we can be able to maintain temperature PV panel at a certain level to achieve desired efficiency.

V. CONCLUSION

In the experiment Taguchi L9 design was used to study the effect of Discharge current, Duty factor and Discharge voltage on surface roughness and material removal rate in machining operation

The Surface roughness is mainly affected by Discharge current, Duty factor and Discharge voltage. From the Taguchi orthogonal array design it is seen that discharge current affects the surface roughness most and thus it has a huge impact on lowering down the roughness of the samples. Experiment with parameters set A3;B2;C3 is the optimum set verified by Taguchi design and confirmation tests both. Furthermore, A3;B1;C3 is the optimum set of experiment parameters for the MRR obtained as suggested by the confirmation test values.

Confirmation test exhibits a minimal deviation of about 2% in case of material removal rate but in case of surface roughness it has considerable impact on the surface roughness with optimized sets of experiments.

Predicted v/s Observed Surface Roughness			
Optimized Experiment	**Predicted Value**	**Observed Value**	**Percentage Deviation**
A3B2C3	14.19 µm	13.27 µm	6.48%
Predicted v/s Observed Material Removal Rate (MRR)			
Optimized Experiment	**Predicted Value**	**Observed Value**	**Percentage Deviation**
A3B1C3	18.90 cu. mm./min.	18.69 cu. mm./min.	1.12 %

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