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OPTIMIZATION OF CONTROL PARAMETERS FOR SURFACE ROUGHNESS OF DIE SINK EDM USING TAGUCHI METHOD

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ABSTRACT

Electrical Discharge Machining (EDM) is a well-established machining option in many industries. Researcher have been undertaken to explore a number of ways to improve the efficiency including some unique experimental concepts. The operating performance measures of side flushing type of electrical discharge machining process on AISI D2 Cold Work Tool Steel using copper electrode are being optimized according to one of its effective machining parameter i.e. Surface roughness (SR). An L_9 orthogonal array of Taguchi methodology has been used to recognize the effect of process input factors (viz. current, pulse on time and flushing pressure) on surface roughness. Hence, the quality characteristic for SR is set to lower-the-better to attain the optimum dimensional precision. Using Taguchi's parameter design, significant machining parameters affecting the performance measures are identified as discharge current, pulse on time and flushing pressure. The results are further verified by conducting confirmation experiments.

Keywords: *EDM, Optimization, Taguchi Methodology and Surface Roughness*

1. Introduction

In the present scenario, the technology of electrical discharge machining (EDM) has been enhanced considerably to meet the requirements in various manufacturing fields, especially in the die manufacturing industry. Electrical discharge machining is widely used non-traditional machining method for removing material from the work-piece without applying any physical cutting force by the tool. EDM is a thermo-electrical process in which material is eroded from the work-piece by a series of successive electrical sparks between the work-piece and the electrode (tool) separated by a thin film of dielectric fluid (deionized water) that is continuously fed to the machining zone to flush away the eroded particles. Flushing is the most vital function in any electrical discharge machining operation. Flushing is the process of introducing clean filtered dielectric fluid into the spark gap. Incorrect flushing can result in inconsistent cutting and poor machining [1]. A comprehensive study of various parameters (current, pulse on time and flushing pressure) on the surface roughness has been carried out. Taguchi Method using L_9 orthogonal array has been used in carrying out experimentations for solving the optimization process [2-4].

In the past, manufacturers have tried to enumerate the control parameters to improve machining quality. Literature review indicates that a number of input parameters affect the quality of machined component in die sink EDM. The main concern of the work is to identify the parameters affecting the surface roughness [5-7]. During EDM, the main output parameters are the material removal rate (MRR), wear ratio (WR), electrode wear (EW), and job surface finish (Ra) [8-9]. It is desirable to obtain the maximum material removal rate with minimal electrode wear. Phase of sparking of material removal mechanism (breakdown, discharge and erosion) is highly influenced by the types of eroded electrode and work-piece elements together with disintegrated products of dielectric fluid [10]. Yu et al. (1998) introduced a uniform tool wear machining method compensating the longitudinal tool wear by applying an overlapping to-and-fro machining motion [11]. Bleys et al. (2002), Osyczka et al. (1982) addressed multi-criterion optimization in EDM process to improve the quality of metal removal rate, surface roughness and electrode wastage [12]. Lin et al. (2000, 2001) analyze the best factors combination by using Taguchi method in conjunction with fuzzy logic, to improve the quality features of MRR and electrode wastage[13-14], Lin et al. (1999, 2002) developed a set of algorithm to improve MRR, surface roughness and electrode wastage in electric discharge process through Taguchi method and grey relational analysis[15-16].

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2. Experimental Procedure

Experimental trials were performed on Sparkonix SN-35 ZNC die sink EDM machine. The experimental setup is as follows: Copper as tool electrode in the shape of round bar of 20 mm diameter and 30mm length (Properties: Density= 8.9 gms/cc, Melting point= 1083 °C, Electrical conductivity= 57.59 ohm/mm, Thermal conductivity= 268-389 Watt/m-Kelvin, Coefficient of linear expansion=16.5 $m10^{-6}K^{-1}$) and EN-31 die steel (Composition: C = 0.95- 1.20%, Si = 0.10-3.35%, Mn = 0.30-0.75%, Cr = 1.0-1.6%, S = 0.025%, P = 0.025%) was chosen as the work-piece material. Work-piece dimensions were kept as 800 mm x 500 mm x 500 mm for all the experiments. Experiments were conducted to determine the surface roughness of the work-piece with variation in input parameters. Taguchi method using L27 Orthogonal Array was used to determine optimal machining parameters for surface roughness. In this work, the behavior of six process parameters i.e. Discharge Current (I), Pulse On Time (Ton), Spark Gap (X), Voltage (Vg), Duty cycle(ζ), Flushing Pressure (P) were studied. Table 1 reports the selected process parameters and their levels based on review of literature and pilot experiments.

Table 1: Process Parameters and their Levels

Process Parameters	Parameter Designation	L1	L2	L3
Discharge Current (A)	A	3	4.5	6
Pulse On Time (μSec)	B	60	90	120
Flushing Pressure (Kgf/cm^2)	C	0.1	0.15	0.2

The process parameters are used to select the best conditions for stability in the Design of Experiments process, whereas the noise factors denote all factors that cause variation. The experimental observations are further converted into a signal-to-noise (S/N) ratio using Eq. (1). Lower value represents better machining performance; hence "Lower the better" is selected for obtaining optimum machining performance for surface roughness. The signal-to-noise (S/N) ratio for "Lower the better" is calculated as follows [3].

$$(S/N)_{LB} = -10\log\left[\frac{1}{R}\sum_{j=1}^{R}\frac{1}{y_j^2}\right] \quad (1)$$

Where y_j are the individual surface roughness measurements and R denotes number of experiment.

3. Results and Discussion

The mean effects plots of raw data and S/N ratios for the output measures are obtained using Minitab software. The mean response or average value of quality characteristics for each parameter at different levels (L1, L2, and L3) has been calculated from the experimental data. The ANOVA (Raw Data and S/N Data) tables in unpooled form are presented in table 2 and 3 to identify the significant parameters and to quantify their effects on quality characteristics. Associated with each response curve (raw data) is S/N response curve which has been used to select optimal levels of process parameters for the individual quality characteristics. Figures 1(a, b, c, d, e, f) and Figure 2(a, b, c) show graphically the effect of three control factors on SR

Table 2: ANOVA for Raw Data of SR

SOURSE	SS	DOF	V	F- RATIO	P
A	2.6190	2	1.3095	33.5500*	64.475
B	0.4120	2	0.2060	5.2783*	10.144
C	0.2504	2	0.1252	3.2073	6.164
T		26			100
e error	0.781	20	0.3903		19.217

Tabulated F ratio at 95% confidence level
F 0.05;2,20=3.49
*Significant at 95% confidence level

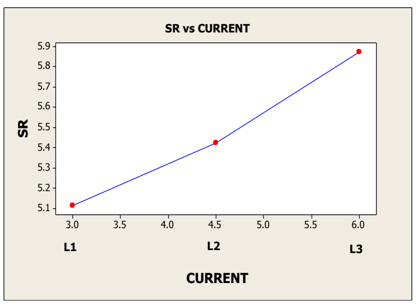
Table 3: ANOVA for S/N Data of SR

SOURSE	SS	DOF	V	F- RATIO	P
A	2.4498	2	1.2249	650.434*	70.08
B	0.3719	2	0.1860	98.744*	12.00
C	0.2721	2	0.1361	72.247*	8.78
T		8			100
e error	0.0038	2	0.00188		9.14

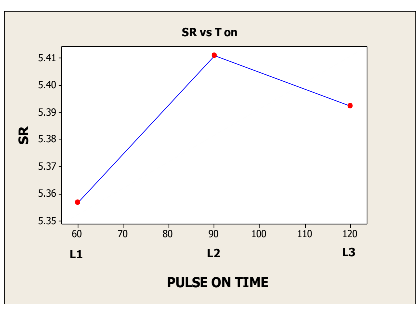
Tabulated F ratio at 95% confidence level
F 0.05;2,2=19.0
*Significant at 95% confidence level

Table 2 shows that the significant parameters affecting surface roughness are current and pulse on time. Figure 1(a) shows the effect of current on the selected quality characteristic i.e. surface roughness, there is a rapid increase in surface roughness with increase in current. Figure 1(b) shows that first there is a increase in SR with increase in pulse on time up to level 2 and further increase in pulse on time results in a slight decrease in SR. Figure 1(c) shows a decreasing trend in surface roughness with increase in flushing pressure.

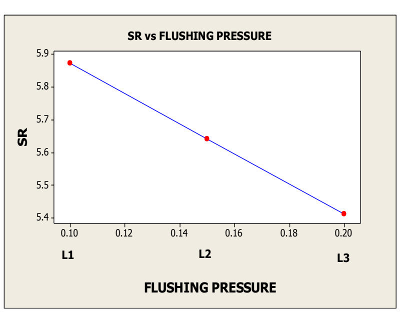
Table 3 shows that the significant parameters affecting SR depending upon S/N data are current and pulse on time. The S/N ratio response (optimum) plotted in Figure 2 (a,b,c) suggests the same level of the parameters i.e, third level of current (A_1) and second level of pulse on time (B_1) as the best levels, since these represent the highest points on the S/N response graphs. From a relative comparison of the steepness of the average response curves raw and S/N ratio, it is reveal that the current has strongest influence on surface roughness followed by pulse on time. The flushing pressure seems to have a slightly weaker influence on SR.



(a)

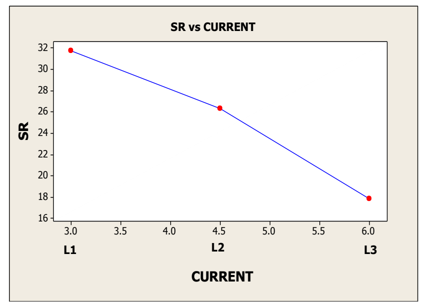


(b)

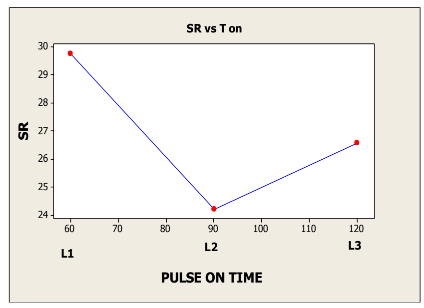


(c)

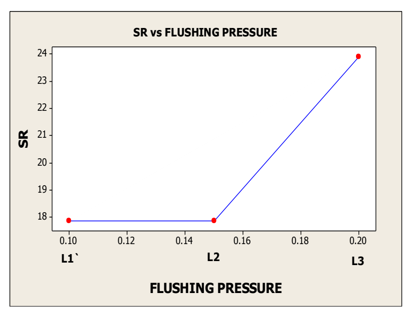
Fig. 1 (a, b & c) Effects of Process Parameters on SR (Raw Data)



(a)



(b)



(c)

Fig. 2 (a, b & c) Effects of Process Parameters on SR (S/N Data)

4. Analysis and Confirmation

The predicted ranges of optimal surface roughness are obtained at optimal values of process parameters i.e. Current (A_1): 3A, Pulse on time (B_1): 60μs.

Three Confirmation experiments for each of the quality characteristics have been performed at the optimal settings of the process parameters and the average values have been reported. Confirmation experiment was performed at average values of A_1 and B_1 levels of the parameters for minimum SR as suggested by the mean effect plot of SR. The predicted optimal surface roughness (μ_{SR}) is calculated as [3]:

$\mu_{SR} = \bar{A}_1 + \bar{B}_1 - \bar{T}_1$
$= 5.8485\ \mu m$

These predicted ranges of optimal surface roughness are obtained at optimal values of process parameters i.e. Current (A_1): 3A, Pulse on time (B_2): 60µs. The predicted optimal range of surface roughness ($\mu_{(SR)}$) at 95% confidence level for the mean of the population and confirmation of experiments is:

$CI_{POP} = 5.6908 < \mu_{SR}\ (\mu m) < 6.006$
$CI_{CE} = 5.591 < \mu_{SR}\ (\mu m) < 6.106$

For confirmation three experiments were performed to get the average value of Surface roughness using levels of significant parameters i.e. A_1 and B_1 and the obtained value of surface roughness i.e μSR=5.912µm is observed that it falls within the range of CI_{POP} and $CI_{CE.}$

6. Conclusion

This paper represents the findings of an experimental investigation on the effect of current, pulse on time and flushing pressure on surface roughness when using EDM on AISI D2 Cold Tool Steel using copper as electrode. It is found from the results that good surface finish is obtained at lower values of current and pulse on time and also observed that high flushing pressure give better surface finish. The optimum current, pulse on time and flushing pressure for good surface finish is 3A (A_1), 60µs ($B_{1)}$ and 0.20kgf/cm^2 (C_3) respectively.

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