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Optimization of Control Parameters for EWR in Injection Flushing Type of EDM on Stainless Steel 304 Workpiece

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Abstract**—**The operating control parameters of injection flushing type of electrical discharge machining process on stainless steel 304 workpiece using copper tools are being optimized according to its individual machining characteristic i.e. Electrode Wear Ratio (EWR). Higher EWR would give bad dimensional precision for the EDM machined workpiece because of high electrode wear. Hence, the quality characteristic for EWR is set to lower-the-better to achieve the optimum dimensional precision for the machined workpiece. Taguchi method has been used for the construction, layout and analysis of the experiment for EWR machining characteristic. The use of Taguchi method in the experiment saves a lot of time and cost of preparing and machining the experiment samples. Therefore, an L18 Orthogonal array which was the fundamental component in the statistical design of experiments has been used to plan the experiments and Analysis of Variance (ANOVA) is used to determine the optimum machining parameters for this machining characteristic. The control parameters selected for this optimization experiments are polarity, pulse on duration, discharge current, discharge voltage, machining depth, machining diameter and dielectric liquid pressure. The result had shown that negative polarity machining parameter setting will decreases EWR.

Keyword**—**ANOVA, EDM, Injection Flushing, L18 Orthogonal Array, EWR, Stainless Steel 304

I. INTRODUCTION

THE electro-discharge machining is a non-traditional machining process for removing metals from workpiece without applying any physical cutting force by the tool. This is performed by a series of successive electrical sparks generated by an electrical potential between the submerged electrode and the workpiece in dielectric fluid. Flushing is the most important function in any electrical discharge machining operation. Flushing is the process of introducing clean filtered dielectric fluid into the spark gap. Flushing applied incorrectly can result in erratic cutting and poor machining. There are a number of flushing methods used to remove the metal particles efficiently while assisting in the machining process [1, 2].

Injection flushing or pressure flushing is the most common and preferred method for flushing, is where the dielectric fluid is forced down through a flushing hole in the electrode, or, up through a hole in the workpiece [7]. 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. There are many input parameters which can be varied in the EDM process which have different effects on the EDM machining characteristics [10].

The Taguchi Method using L18 orthogonal array is used in carrying out experiments for solving the optimization process. This approach can optimize the machining parameters with consideration of the multiple responses which is the machining characteristics (Electrode Wear Ratio (EWR) effectively [12].

II. EXPERIMENTAL PROCEDURE

A. Design of Experiments Using L18 Orthogonal Array

The experiment is executed using L18 Orthogonal Array which is the most suitable for one-2 level and six-3-level of control factors that were used for the experiment. The control factors are tabulated in the following table 1.

TABLE I CONTROL FACTORS

Factor	**Desc.**	**L1**	**L 2**	**L 3**	**Units**
A	Polarity	W/P(+) Tool (-)	W/P (-) Tool (+)	-	(+) (-)
B	Pulse on	4	6	8	µsec
C	Discharge Current	57	66	75	Ampere
D	Discharge Voltage	60	90	120	Volt
E	Machining Depth	1.5	2.0	2.5	mm
F	Machining Diameter	9.5	11.0	12.5	mm
G	Dielectric Liquid Pressure	1.0	1.5	2.0	bar

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B. *Workpiece Material*

Stainless Steel 304 is being selected as it is often used in producing springs. nuts, bolts and screws. Table 2 shows the physical properties.

TABLE II PHYSICAL PROPERTIES OF STAINLESS STEEL 304

Physical properties	Stainless Steel 304
Density [g/cm^3]	8.03
Electrical conductivity [x 10^5 / Ω cm]	11.6
Thermal conductivity [W/(cm K)]	0.162
Melting point [K]	1644
Boiling point [K]	1672

C. *Tool Material and Shape*

A pipe copper tool is being selected for the machining because it is a highly conductive tool, low cost, low wear ratio, good machinability and finishing. The initial cubic cylindrical copper tool is being drilled to produce a pipe copper tool. It is mainly for the purpose of the dielectric could be flow through and being injected to the workpiece during the machining and it is called injection flushing machining.

D. *EWR Calculation*

The Electrode Wear Ratio (EWR) is being calculated using the formula, EWR = (EWW/WRW) x 100. It is expressed by the ratio of the electrode wear weight (EWW) to the workpiece removal weight (WRW) in percentage form. The measurement is taken by using a weighing machine.

E. *Optimum Condition and Verification*

The optimum condition for the respective machining characteristic EWR is determined by using response graph. The EWR quality characteristic should be known to select which points exhibit the relation with its' quality characteristics. Hence, for EWR, the quality characteristic is lower-the-better where the minimum points are chosen from its' response graph.

The confirmation experiment is done to verify the optimum condition of EWR machining characteristics. The value should not be less than 90% difference with the predicted values to proof that the optimum condition obtained is acceptable.

F. *Significant Factor Analysis using ANOVA*

The significant factors that contribute to the optimized machining characteristic (EWR) was discussed in detail of its' relation with the overall process performance. Fig. 1 shows the response graph for EWR machining characteristic. According to the higher-the-better quality characteristic for EWR, based from the maximum point on the graph, the optimum condition for each factor indicated is A2 (negative polarity), B3 (8μs), C3 (75A), D3 (120V), E1 (1.0 mm), F1 (9.5 mm), G2 (1.5 bar). The confirmation experiment indicated that it has 9.93% difference from the predicted value, PV calculated.

The significant factors from the above graph were calculated using ANOVA equation and the result is shown on the following table 3.

III. RESULTS AND DISCUSSIONS

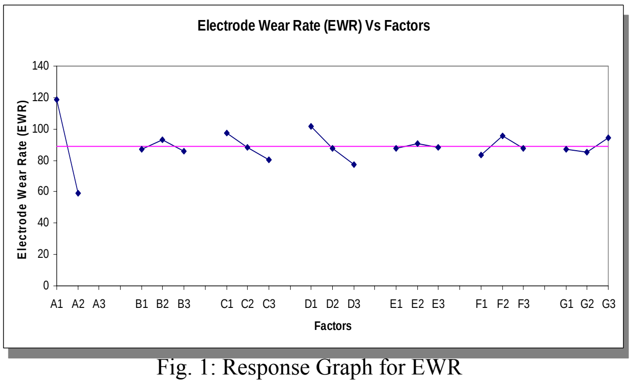

Fig. 1: Response Graph for EWR

TABLE III ANOVA FOR EWR

Factor	Description	F-ratio	% contribution ratio, ρ
A	Polarity, P	413.961**	80.725
B	Pulse-on-duration, τ_{on}	2.3287	0.519
C	Discharge Current, I_d	6.3246	4.037
D	Discharge Voltage, V_d	23.350*	8.737
E	Machining Depth, l_i	0.4451	0.217
F	Machining Diameter, d	5.617	1.805
G	Dielectric Liquid Pressure, P_l	3.737	1.070

The highest F-ratio contributes to be the most significant factor which is polarity, P followed with 2nd highest F-ratio to be the significant factor which is discharge voltage, V_d.

A. *EWR Most Significant Factor – Polarity, P*

The negative polarity (workpiece as negative and electrode as positive) is the most significant factor that affects EWR for this research. Li X.P. (2001) agreed that negative polarity factor decrease EWR rather than positive polarity factor (workpiece as positive and electrode as negative). Low electrode wear ratio occurs for setting using negative polarity (workpiece as negative and electrode as positive) because relative heat dissipation on the workpiece is high at the end of discharge duration.

During machining, when ionization occurs there are positive ions and electrons in the machining gap. Positive ions generate more heat because of its size are larger than electrons. This satisfy the heat transfer equation, heat transfer, Q = mass, m × coefficient of convection, C × (difference of temperature, ΔT). Higher mass contributes to higher heat transfer. Hence, in this case, more positive ions will attract and gather to the workpiece (negative polarity). Therefore, the electrode wear ratio is being minimized because the relative heat dissipation on the workpiece is high at the end of discharge duration.

B. EWR Significant Factor – Discharge Voltage, V_d

Discharge voltage is the significant factor that affects EWR for this research. This is in agreement with Li X.P. (2001) that voltage is an important parameter that will affect EWR. Improper setting of discharge voltage especially in higher settings of discharge voltage of above then 120 V may influence electrode wear. Too high a voltage will generate more potential difference where more sparks will be generated. Then, an unfavourable concentrated discharge due to insufficient cooling of workpiece will increase the electrode wear. Therefore, in this experiment, the discharge voltage of 120 V was the optimum having low electrode wear ratio.

IV. CONCLUSIONS

This research has investigated the optimization of control parameters for EWR in injection flushing type of electrical discharge machining on stainless workpiece. The main conclusions of this research are as follows:-

1. Machining performance in the EDM process can be improved effectively by using optimum factors that had been determined for EWR machining characteristic.

2. Polarity and discharge voltage are the most significant and significant factors that affect EWR.

3. Optimum condition for EWR are being set at negative polarity (workpiece negative and tool positive), 8 microseconds of pulse on duration, 75 Ampere of discharge current, 120 volt of discharge voltage, 1.0 mm of machining depth, 9.5 mm of machining diameter and 1.5 bar of dielectric liquid pressure.

4. For future research work, other single objective performance characteristic namely surface roughness (SR) could be made using the same method and other types of Advanced Taguchi methods such as Grey Relational Analysis, Response Surface Method could be made optimize performance characteristic made.

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