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Optimization of Control Parameters for MRR 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 with copper tools are being optimized according to its individual machining characteristic i.e. material removal rate (MRR). Lower MRR during EDM machining process may decrease its' machining productivity. Hence, the quality characteristic for MRR is set to higher-the-better to achieve the optimum machining productivity. Taguchi method has been used for the construction, layout and analysis of the experiment for each of the machining characteristic for the MRR. 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 the higher the discharge voltage, the higher will be the MRR.

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

I. INTRODUCTION

ELECTRICAL discharge machining is a non-traditional manufacturing process based on removing material from a part by means of a series of recurring electrical discharges (created by electric pulse generators at short intervals) between a tool called electrode in the presence of a dielectric fluid [1]. This fluid makes it possible to flush eroded particles (mainly in the form of hollow spheres) from the gap and it is really important to maintain this flushing continuously. Side flushing is the least effective or inefficient method of removing suspended particles from the spark gap. The moving of tool electrode, up and down, in Z axis only introduces new dielectric fluid into the cavity of the workpiece. When the electrode is cycled down, it pushes out the contaminated oil. Injection flushing is where the dielectric fluid is forced down through a flushing hole in the tool electrode [11].

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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 (Material Removal Rate (MRR) effectively [12].

II. EXPERIMENTAL PROCEDURE

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 I

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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

A. 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

A. *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.

B. *Machining Characteristic Calculation*

The Material Removal Rate (MRR) is being calculated using the formula, MRR = WRW/T. It is expressed as the workpiece removal weight (WRW) under a period of machining time in minute unit. The measurement is taken by using a weighing machine and a stopwatch.

C. *Optimum Condition and Verification*

The optimum condition for the respective machining characteristic is determined by using response graph where the quality characteristics should be known to select which point exhibit the relation with the quality characteristics. In this case, for MRR the quality characteristic is higher-the-better where the maximum points is chosen from the response graph. Verification of the optimum condition is done where the confirmation result for machining characteristics (after determine the optimum condition) is not less than 90% difference with the predicted values to proof that the optimum condition obtained is acceptable. Significant Factor Analysis using ANOVA The significant factors that contributed to the optimized machining characteristic (MRR) is determined to discussed in detail its' relation with overall process performance.

III. RESULTS AND DISCUSSIONS

Figure 1 shows the response graph for MRR machining characteristic.

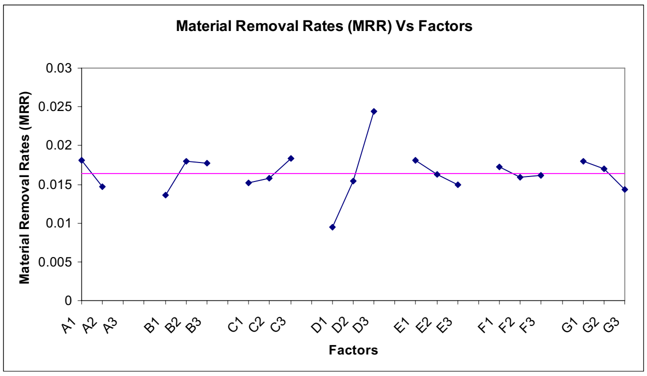

Fig. 1: Response Graph for MRR

According to the higher-the-better quality characteristic for MRR, based from the maximum point on the graph, the optimum condition for each factor indicated is A1 (positive polarity), B2 (6μs), C3 (75A), D3 (120V), E1 (1.0 mm), F1 (9.5 mm), G1 (1.0 bar). The confirmation experiment indicated that it has 3.69% 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 III.

TABLE III
ANOVA FOR MRR

Factor	Description	F-ratio	% contribution ratio, ρ
A	Polarity, P	7.180	5.164
B	Pulse-on-duration, τ_{on}	8.336*	6.776
C	Discharge Current, I_d	3.812	2.597
D	Discharge Voltage, V_d	78.607**	71.680
E	Machining Depth, l_i	3.577	2.380
F	Machining Diameter, d	0.805	0.002
G	Dielectric Liquid Pressure, P_l	5.041	3.732

The highest F-ratio contributes to be the most significant factor which is discharge voltage, V_d followed with 2nd highest F-ratio to be the significant factor which is pulse-on-duration, τ_{on}. MRR Most Significant Factor - Discharge Voltage In this research, discharge voltage is the most significant factor that affects MRR. Wang C.C. (2000) and Huang H. (2003) research papers reported that MRR increases with the increase in voltage. In H Huang research paper, he had proved that for a machining of a through hole of 2.54 mm deep, the machining time for 200 V applied is over two times shorted than that for the 80V. Hence, discharge voltage is agreed as the most significance factor that affects the machining rate (MRR). In the fundamentals of EDM, the sufficient potential difference between the electrode and the workpiece will emits cold electron from cathode to anode where electrons will attract to anode. This cold emission of electron will ionize dielectric fluid and negative ion from dielectric fluid combining with electron will cause avalanche of electron that we could view as spark in the machining gap. Through this spark phenomenon, heat will be generated to the localized location of the workpiece where it will melts and evaporates. Hence, more voltage will generate more potential difference where more sparks will occur during machining and finally the machining rate will increase. MRR Significant Factor - Pulse-On-Time In this research, pulse-on-time is a significant factor for MRR. This is because pulse-on-time is related with peak currents as reported by Wang C.C. (1999). Pulse-on-time is current discharge duration on the voltage gap. Short peak current duration or short pulse duration may cause less surface vaporization of the workpiece during machining, whereas long pulse duration may cause the plasma channel to expand in the machining gap. Finally, for this research the pulse-on-time setting of 6 microseconds is the best optimal setting between 4 and 8 microseconds in the control factors table.

IV. Conclusions

This research has investigated the optimization of control parameters in injection flushing type of electrical discharge machining on stainless workpiece with copper tools. 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 MRR machining characteristic.
2. Discharge voltage and pulse-on-duration are most significant and significant factors that affect MRR.
3. Optimum condition for MRR are being set at positive polarity (workpiece positive and tool negative), 6 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 1.0 bar of dielectric liquid pressure.
4. For future research work, other single objective performance characteristic namely electrode wear ratio (EWR) and surface roughness (SR) could be made using the same method.

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