Modeling and Optimization of Wire EDM Process

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Abstract: *The present work is aimed to optimize the parameters of (WEDM) process by considering the effect of input parameters viz. Time On, Time Off, Wire Speed & Wire Feed. Experiments have been conducted with these parameters in three different levels data related to process responses viz. Metal removal rate, surface roughness (Ra) have been measured for each of the experimental run. These data have been utilized to fit a quadratic mathematical model (RSM) for each of the responses, which can be represented as a function of the process parameters. Predicted data have been utilized for identification of the parametric influence in the form of graphical representation for showing influence of the parameters on selected responses. Predicted data given by the models (as per Taguchi's L_{27} OA) design have been used in search of an optimal parametric combination to achieve desired yield of the process. Taguchi techniques have been used for optimization of minimizing the surface roughness. The optimal value has been verified to the predicted value.*

Key words*: Wire EDM, Surface roughness, RSM, DOE, Al-SIC (20%)*

I. INTRODUCTION

WEDM process involves the complex erosion effect by rapid repetitive and discrete spark discharges between the wire tool electrode and work piece immersed in a liquid dielectric medium. WEDM is used in the area of production of aerospace parts micro gas turbine blades and electronic components. As research work even in WEDM much standard references are not available for the selection of the parameters and the level for optimizing the performance characteristics. Hence it is necessary to conduct an extensive experimental investigation to study the effect of different process parameters for the accuracy and surface finish of WEDM machined components an attempt is also made to obtain machinery performance with the RSM. The electrical discharge energy affected by the spark plasma intensity and the discharging time will determine the crater size, which in turn will influence the machining efficiency and surface quality [1]. For determining the optimal parametric settings, lot of work has been done in the engineering design. But mostly all of them concentrated on a single response problem. However, the WEDM processes are having several important performance characteristics like MRR, SR, etc. The optimal parametric settings with to different performance characteristics are different. Scott et al [2] have presented a formulation and solution of a multi objective optimization problem for the selection of the best parameter settings on a WEDM machine. The measures of performance for the model were MRR and surface quality. In that study, a factorial design model has been used to predict the measures of performance as a function of a variety of machining parameters. Lin [3] presented the use of grey relational grade to the machining parameter optimization of the EDM process. Optimal machining parameters setting for WEDM still has some difficulty. It may be noted that most of the prevailing approaches have used complex mathematical or statistical methods such as ANN, dual response approach, genetic algorithm, simulated annealing, linear or non linear or dynamic programming. These approaches are difficult to implement by individuals with little background in mathematics/statistics and so are of little practical use. Ramakrishnan et al [4] also lacks the way to convert multiple objectives into a single objective format though the method is relatively simple. Tanimura et al [5] projected new EDM process using water mist, which requires no tank for the working fluid. They also pointed out that the mist-EDM/WEDM enables non-electrolytic machining even, when electrically conductive water is used as the working liquid. Fu-chen Chen et al [6] Research is based on fuzzy logic analysis coupled with taguchi methods to optimize the precision and accuracy of the high-speed electrical discharge machining (EDM) process, pulse time, duty cycle, peak value of discharge current as the most important parameters, powder concentration, powder size are found to have relatively weaker impacts on the process design of the high speed EDM. H.Singh et al [7] analyze the effects of various input process parameters like pulse on time, pulse off time, gap voltage, peak current , wire feed and wire tension have been investigated and impact on MRR is obtained. Finally they reported MRR increase with increase in pulse on time and peak current. MRR decrease with increase in pulse off time and servo voltage. Wire feed and wire tension has no effect on MRR. A.K.M. Nurul Amin et al [8] Conducting experiments on cutting of tungsten carbide ceramic using electro-discharge machining (EDM) with a graphite electrode by using taguchi methodology. The taguchi method is used to formulate the experimental layout, to analyze the effect of each parameter on the machining characteristics, and to predict the optimal choice for each EDM parameter such as peak current, voltage, pulse duration and interval time. It is found that these parameters have a significant influence on machining characteristic, such as metal removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR). Kuo-Wei Lin et al [9] conduct test Wire Electrical Discharge Machining (WEDM) of magnesium alloyparts via the taguchi method-based gray analysis was conducted; they considered multiple quality characteristics required include material removal rate and surface roughness following WEDM. Kamal Jangra et al [10] Investigated on Influence of taper angle, peak current, pulse-on time, pulse-off time, wire tension and dielectric flow rate are investigated for material removal rate (MRR) and surface roughness (SR) during intricate machining of a carbide block. In order to optimize MRR and SR simultaneously, grey relational analysis (GRA) is employed along with taguchi method. WC-Co composite is studied, grey relational analysis

(GRA) is employed along with taguchi method, the percentage error between experimental values and predicted results are less than 4% for both machining characteristics.

The highlights of this paper is to significance the process parameters and different machining condition on MRR and surface roughness of the Al-sic(20%) mathematical models are developed to correlate the process parameters and performance measures. The objective of the study is to minimize the surface roughness.

II. EXPERIMENTAL WORK

Experiments are conducted in series with three level three full factorial experimentation is developed using DOE with input parameters shown in table 1. Holes of 5mm diameter are drilled on 10mm thick Al-sic(20%) plate WEDM using molybdenum wire of diameter 0.18mm. The influence of process parameters on the machining of drilled hole is also analyzed. The average surface roughness (Ra) value of drilled hole is determined using surface roughness tester.

Table1. L27 orthogonal array with Wire EDM process parameters

Exp No	Speed	Feed	Time ON	Time OFF
1	500	0.5	100	40
2	500	0.5	100	40
3	500	0.5	100	40
4	500	0.7	102	42
5	500	0.7	102	42
6	500	0.7	102	42
7	500	0.9	104	44
8	500	0.9	104	44
9	500	0.9	104	44
10	1000	0.5	102	44
11	1000	0.5	102	44
12	1000	0.5	102	44
13	1000	0.7	104	40

Exp No	Speed	Feed	Time ON	Time OFF
14	1000	0.7	104	40
15	1000	0.7	104	40
16	1000	0.9	100	42
17	1000	0.9	100	42
18	1000	0.9	100	42
19	1500	0.5	104	42
20	1500	0.5	104	42
21	1500	0.5	104	42
22	1500	0.7	100	44
23	1500	0.7	100	44
24	1500	0.7	100	44
25	1500	0.9	102	40
26	1500	0.9	102	40
27	1500	0.9	102	40

The experiments were performed on SPRINT CUT 734 DI WATER CUT WEDM and the experimental setup is shown in figure 1.

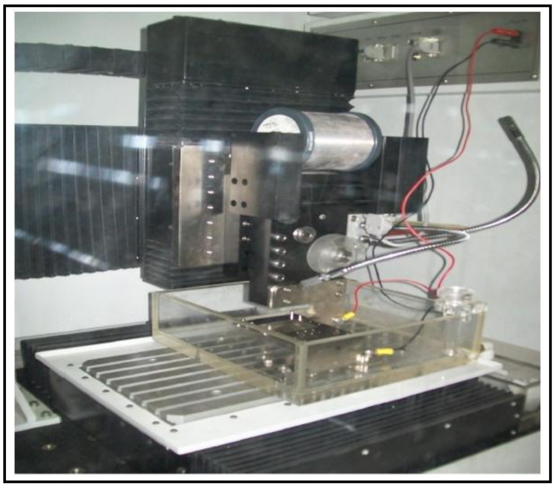

Figure1. WEDM experimental set up

The molybdenum wire as tool electrode with flushed type dielectric fluid pressure 0.2 kgf/cm^2 (distilled water) bath between work piece and electrode. Electrical power and controlling system is controlled with servo controlled resistance capacitance (Rc) circuit which ensures low discharge current with high frequency to control input process parameters.

The analysis is done to study the main effects and their interactions to explore the effect of the influence of parameters on the performances.

In this study, Taguchi method, a powerful tool for parameter design of the performance characteristics has been used to determine optimal machining parameters for maximization of MRR and minimization of SF in wire EDM.

Experiments have been carried out using Taguchi's L27 Orthogonal Array (OA) experimental design which consists of 27 combinations of four process parameters. According to the design prepared by Taguchi, L27 Orthogonal Array design of experiment has been found suitable in the present work. It considers four process parameters (without interaction) to be varied in three discrete levels. Based on Taguchi's L27 Orthogonal Array design (Table 3), the predicted data provided by the mathematical models can be transformed into a signal-to-noise (S/N) ratio; based on three criteria. The characteristic that higher value represents better machining performance, such as MRR, 'higher-the-better, HB; and inversely, the characteristic that lower value represents better machining performance, such as surface roughness is called 'lower-the-better', LB. Therefore, HB for the MRR, LB for the SF has been selected for obtaining optimum machining performance characteristics.

Table 2. Surface roughness predicted for 27 experiments

Exp No	Ra	Exp No	Ra	Exp No	Ra
1	2.35	10	1.45	19	1.257
2	2.402	11	1.526	20	1.283
3	2.37	12	1.582	21	1.265
4	2.645	13	1.752	22	1.468
5	2.721	14	1.79	23	1.457
6	2.82	15	1.808	24	1.365
7	3.094	16	3.203	25	2.308
8	3.265	17	3.012	26	2.45
9	3.354	18	3.208	27	2.22

From the predicted surface roughness values, the S/N ratios and their corresponding mean of means plots are shown in figure 2 and 3 respectively. Analysis of the result leads to the conclusion that factors at level A3, B3, C1, D3 gives maximum surface roughness. Although factors A factor is not show significant effect on surface roughness, it is recommended to use the factors at level A2, B3, C2, D3 for minimization of Ra as shown in Fig. 2 and 3. Factors A have least contribution for maximization of surface roughness. Figure 4 represents the closeness between the predicted and the observed reading of surface roughness (Ra).

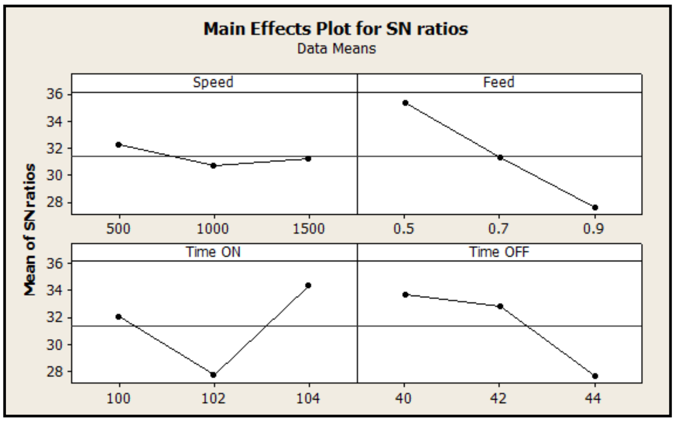

Figure 2. Main effect plot for S/N ratio

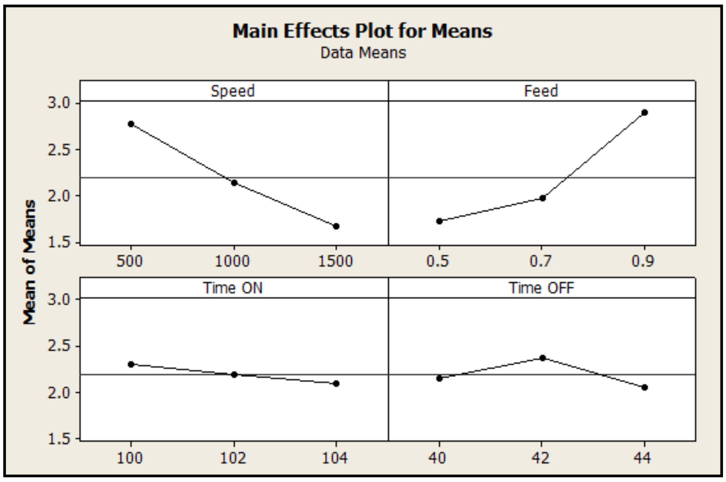

Figure 3. Main effect plot for Means

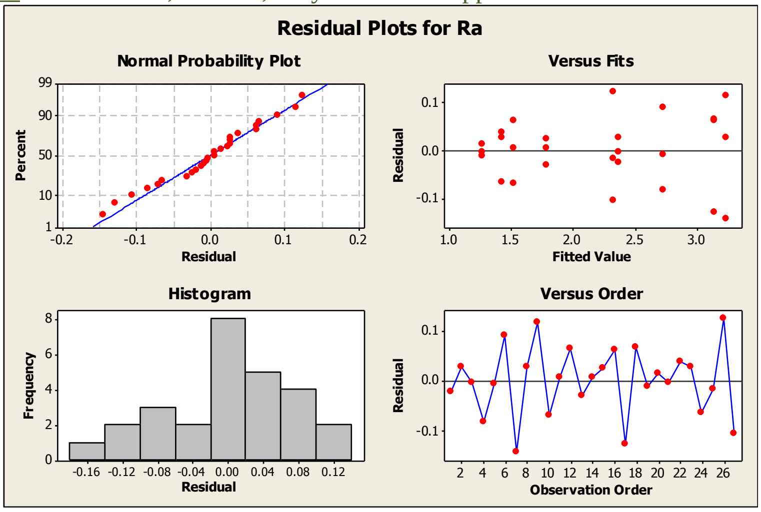

Figure 4. Residual plot for WEDM process parameters

III. CONCLUSION

In this article, an attempt was made to determine the significant machining parameters for performance measures surface roughness in the WEDM process. Factors like speed, feed, Time on and Time off have been found to play a significant role for MRR and surface roughness. Taguchi's method is used to obtain optimum parameters combination for maximization of surface roughness. The conformation experiments were conducted to evaluate the result predicted from Taguchi Optimization.

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