STATISTICAL ANALYSIS OF SURFACE ROUGHNESS BY RESPONSE SURFACE METHODOLOGY IN WEDM USING AL COMPOSITE

Vikrant Sharma[1], Onkar Singh Bhatia[2]

[1,2]*Mechanical Engineering Department, Green Hills Engineering College, Kumarhatti, Solan*

ABSTRACT

Non-conventional machining technology is effectively used in modern manufacturing industries. This paper investigatesthe influence of three different input parameters such Peak current, Pulse on time and Pulse off Time ofwire electrical discharge machining (WEDM) performances of surface roughness (SR) using response surface methodology with central compositedesign (CCD). The Machining analyses were performed at WEDM machine utilizing 0.25 mm wire as electrode material on aluminium based alloy . The machining characteristicsare significantly influenced by the electrical and non-electrical parameters in WEDMprocess. The impacts of the methodology parameters on surface roughness were assessed by the examination of change (ANOVA). Analysis of variance (ANOVA) was performed to find out the significant influence of each factor.

Keywords:wire electrical discharge machine; optimization; Surface roughness; Response surface methodology,ANOVA

I. INTRODUCTION

WEDM is recognized as an effective machining techniqueused in a wide range of applications namely automotive, aerospace,defense, electronics, telecommunications, healthcare, environmental,industrial and consumer products of micro-feature withmicro- and nano-level surface finish. WEDM process transforms electrical energy into thermalenergy for eroding the material. The electrodes are immersed indielectric liquid or flowing pressurized dielectric medium. A verysmall amount of work materials melt and vaporize by a series ofdischarge energy between tool and work piece. Debris materials areflushed out from the sparking area by the dielectric fluid. Due to thecontactless process between tool and work piece, any conductivematerial can be machined by WEDM regardless of its hardness andtoughness.Non traditional machining methods are dynamically used to fabricate great mechanical segments. In non traditional machining methodology wire electrical discharge machine (WEDM) is a thermo electrical machining process in which the material is expelled from work piece by series of electrical sparks between wire electrode and work piece. The vitality substance of a single spark discharge is communicated as a result of pulse on time and peak current. Vitality contained in a minor sparkle release evacuates as part of work piece material. Extensive number of such time separated minor releases between work piece and wire electrode causes the electro disintegration of the work piece material. Al, brass, zinc covered metal or copper wires are generally used as electrode material. The distance across of the wire electrode is of 0.25mm to 0.50mm measurement .Wire electrical discharge machine will be machine instrument to create parts of perplexing and multifaceted segments in the field of tool and die, aviation,

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automobile, atomic, machine industry. In the present exploration study WEDM on aluminum alloy has been conducted . This material is considered for exploration work because of its both high wear resistant and ductility. Response surface methodology (RSM) is a collection of statistical and mathematical techniques useful for design of experiments and optimizing process parameters . RSM was used to predict the machining performance of WEDM process in terms of surface roughness with input process parameters. The optimal values were obtained from the RSM based on careful planning and execution. Many researchers have evaluated the machining characteristic of WEDM using response surface methodology. The central composite design (CCD) is an efficient technique that could be applied to modeling of micro-WEDM in RSM. The polynomial equation formed from RSM was used to express the machining performance of the WEDM process. In this experiment, machining performance of SR was modeled in terms of pulse on time, pulse off time and peak current.

II. LITERATURE REVIEW

1. Rajyalakshmi G et al. (2013) used Inconel 825.Taguchi orthogonal array design of experiment and grey relational analysis were combined. The main objective of this study is to obtain improved material removal rate, surface roughness, and spark gap. Grey relational theory is adopted to determine the best process parameters that optimize the response measures. The experiment has been done by using Taguchi's orthogonal array L36. The experimental results confirm that the proposed method in this study effectively improves the machining performance of WEDM process.
2. Kumar K et al. (2013):- Material used was Al-SiC plate. Experiments have been conducted with parameters (Time On, Time Off, Wire Speed & Wire Feed)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. Taguchi techniques have been used for optimization of minimizing the surface roughness.
3. Tosun N et al. (2003):- In this study SAE 4140 STEEL was used. The variation of workpiece surface roughness with varying pulse duration, open circuit voltage, wire speed and dielectric fluid pressure was experimentally investigated in WEDM. Brass wire with 0.25 mm was used. It is found experimentally that the increasing pulse duration, OCV and wire speed, increase the surface roughness whereas increasing dielectric pressure decreases the surface roughness. Regression analysis method is usually used to obtain relation between input-output parameters.
4. Caydas U et al. (2009) conducted the experiments on AISI D5 TOOL STEEL. In this paper an adaptive neuro-fuzzy inference system (ANFIS) model has been developed for the prediction of the white layer thickness (WLT) and the average surface roughness achieved as a function of the process parameters. Pulse duration, OCV, flushing pressure and wire feed rate were input parameters. Both artificial neural network (ANN) and fuzzy logic (FL) are used in ANFIS architecture taken as model's input features. this approach can greatly improved the process responses such as surface roughness and WLT in WEDM.
5. Kumar A et al (2010).:-Material used was EN-24 TOOL STEEL. A technique for optimization of abrasive mixed electrical discharge machining (AEDM) process with multiple performance characteristics based on the orthogonal array with grey relational analysis has been studied. AEDM is a hybrid process in which

dielectric is mixed with powder form abrasive. As a result, the process becomes more stable, thereby improving machining rate and surface finish. It was found that abrasive powder addition has stronger effect on multi performance characteristics than peak current, pulse on time, and duty factor.

6. Vundavilli P.R et al. (2012) used Ti6Al4V TITANIUM ALLOY as a work piece. In present paper, NSGA II (non –dominated sorted genetic algorithm-II) and PSO (practical swarm optimization)are utilized to optimize the performance of WEDM process. Both the approaches are found to show similar trend on the pereto-optimal fronts. Moreover, GA has slightly outperformed PSO in terms of the optimal solution obtained. It is also important to note that PSO has produced the optimal front in less time when compared with the GA.
7. Dave .K.V et al. (2012) used AISI H13 STEEL in experiment. This study present the analysis based on Taguchi design and ANOVA. Experiments were conducted and found the contribution of Tool Geometry on the Surface Roughness and Material Removal Rate (MRR) with other processing parameters. There are four different electrode geometry is taken into consideration. They are Round, Square, Rectangle, Triangle .Tool geometry is not the most significant factor but it is a significant factor that affects the performance measures.
8. Lal H et al. (2012):- Standard aluminium test piece was used in study. This paper provides a summary of the three types of manufacturing processes currently being used in the fabrication of micro channels. The three micromachining techniques compared in this research are wire-cut EDM, micro-slotting and micro-milling. Surface finish of fabricated micro-channel in case of wire-cut EDM was observed to be superior than using micro end mill cutter, followed by those from slotting saw. The time taken to finish the job using wire-cut EDM was highest.
9. Bobbili R.et al.(2013);-Study was done on Armor STEEL. Pulse on-time, spark voltage, wire tension, wire feed, pulse off-time, and flushing pressure are the main process variables of the WEDM. In the current investigation, Taguchi orthogonal array (L27) was chosen for designing the experiments. ANOVA and regression model were employed as mathematical tools in understanding the effects of process parameters. CuZn37 suncut brass wire with 0.25mm diameter was employed in the present trials. The SR decreases with the raise in Ton. Conversely, it increases with raise in Toff and SV. The influence of wire tension is not very significant.
10. Liao Y.S et al.(2004):- With the assistance of Taguchi quality design, ANOVA and F-test, machining voltage, current-limiting resistance, type of pulse-generating circuit and capacitance are identified as the significant parameters affecting the surface roughness in finishing process. To obtain good SR, the traditional circuit using low power for ignition is modified for machining as well. A dc pulse-generating circuit of positive polarity (wire electrode is set as anode) can achieve a better surface roughness in finishing operation. A fine surface of roughness Ra = 0.22m is achieved.
11. AravindS.Ret al (2012):-The work-piece material used in this study was Brass. In this work, an attempt was made to determine the important machining the parameters of brass material for the performance measures like MRR and SR separately in WEDM process. Factors like the pulse duration and the feed rate have been found to play as significant role in rough cutting operations for the maximization of metal removal rate and minimization of surface roughness Taguchi's experimental design (Ll8orthogonal array) is used to obtain

the optimum machining parameters for the maximization of metal removal rate and minimization of surface roughness.

12. Reddy P.V et.al (2010):-Material used in the study was Cr-Mo-V alloyed special steel. In this paper the Artificial Neural Network (ANN) model is developed to predict the surface roughness in WEDM. The neural network Models strained with experimental results conducted using L16 orthogonal array by considering the input parameters such as pulse duration, open voltage, wire speed and dielectric flushing pressure at four different levels. The mathematical relation between the work piece surface roughness and WEDM cutting parameters is also established by multiple regression analysis method.
13. Yeakub Ali M et al. (2008):-Copper was used as a work material. The effect of discharge current, pulse-on time, and gap voltage on surface finish were studied. Conventional WEDM could be used to manufacture a miniaturized component with low cost compared to other methods such as EDM, FIB, LIGA, etc. The size of the micro components to be produced by WEDM depended on wire electrode diameter. Use of smallest diameter and optimum machining parameters resulted in high geometrical integrity and surface finish.
14. Lin Y.C et al(2006).:-SKH 57 HIGH SPEED STEEL was used in the study as work material.Parts of the experiment were conducted with the L18 orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios associated with the observed values in the experiments were determined by ANOVA and F-test. In this investigation six machining parameters were considered. Three observed values of MRR, EWR, and SR were examined.

III. EXPERIMENTATION AND RESULTS:

Work piece area (200mm×70mm) with height 5mm is prepared by cutting operation. The material from substrate is removed by machining and the specimen is ready for wire-EDM process with the help of which Square pieces are made. Figure of machined pieces is shown below.

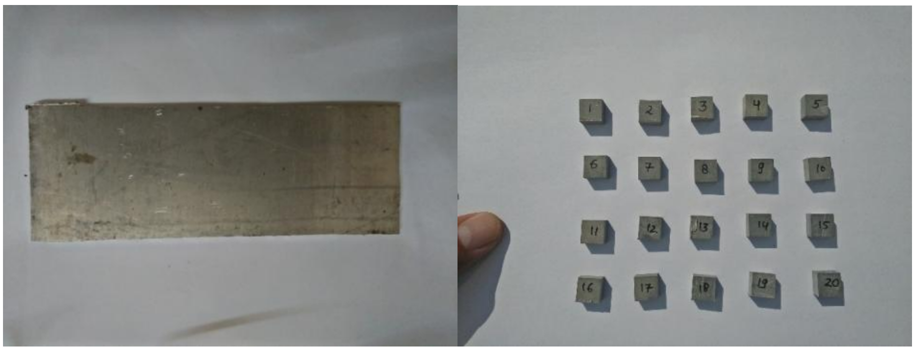

Fig.4.1 Work piece before and after machining

Response surface methodology provide an efficient and systematic way to optimize designs for performance,. The objective is to study a large number of variables with a small number of experiments usingRSM significantly reduces the number of experimental configurations to be studied. Furthermore, the conclusions drawn from small-scale experiments are valid over the entire experimental region spanned by the control factors and their settings. Table1 shows the parameters and their levels.

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Table 1 Parameters and their levels

Levels						
Input Parameters	-α	-1	0	+1	+α	Units
Peak Current	65.91	100	150	200	230	Amp
Pulse on Time	101.5	105	110	115	118.4	µsec
Pulse off Time	18.4	25	35	45	51.81	µsec

Analysis of variance (ANOVA):

Experimentation according to design of experiment has been done using wire cut EDM. The experimental results drawn from experimentation has been analyzedTable2 show the analysis of variance done for regression model.

Table2 analysis of variance for regression

Source	DF	Seq SS	Adj. SS	Adj MS	F-ratio	P-value
Regression	9	10.0670	10.0670	1.11856	11.38	0.000
Linear	3	2.7182	3.7765	1.25884	12.81	0.001
Ip	1	0.0136	0.3648	0.36475	3.71	0.083
Ton	1	2.3174	2.9824	2.98242	30.35	0.000
Toff	1	0.3872	0.0375	0.03751	0.38	0.550
Square	3	6.5199	6.6784	2.22612	22.66	0.000
Ip*Ip	1	1.8877	2.1726	2.17260	22.11	0.001
Ton*Ton	1	3.5647	3.2558	3.25585	33.14	0.000
Toff*Toff	1	1.0675	0.9751	0.97510	9.92	0.010
Interaction	3	0.8290	0.8290	0.27632	2.81	0.094
Ip*Ton	1	0.8282	0.8282	0.82818	8.43	0.016
Ip*Toff	1	0.0006	0.0007	0.00072	0.01	0.933
Ton*Toff	1	0.0001	0.0001	0.00014	0.00	0.971
Residual Error	10	0.9825	0.9825	0.09825	----------	-----------
Lack-of Fit	3	0.4318	0.4318	0.14392	1.83	0.230
Pure Error	7	0.5507	0.5507	0.07868		
Total	19	11.0496				

From ANOVA tables, it was noticed that at 95% level of confidence ($p<0.05$), Ip, Ton, Toff have significant effect on Surface roughness. It can be seen that Toffis most significant in case of surface roughness.

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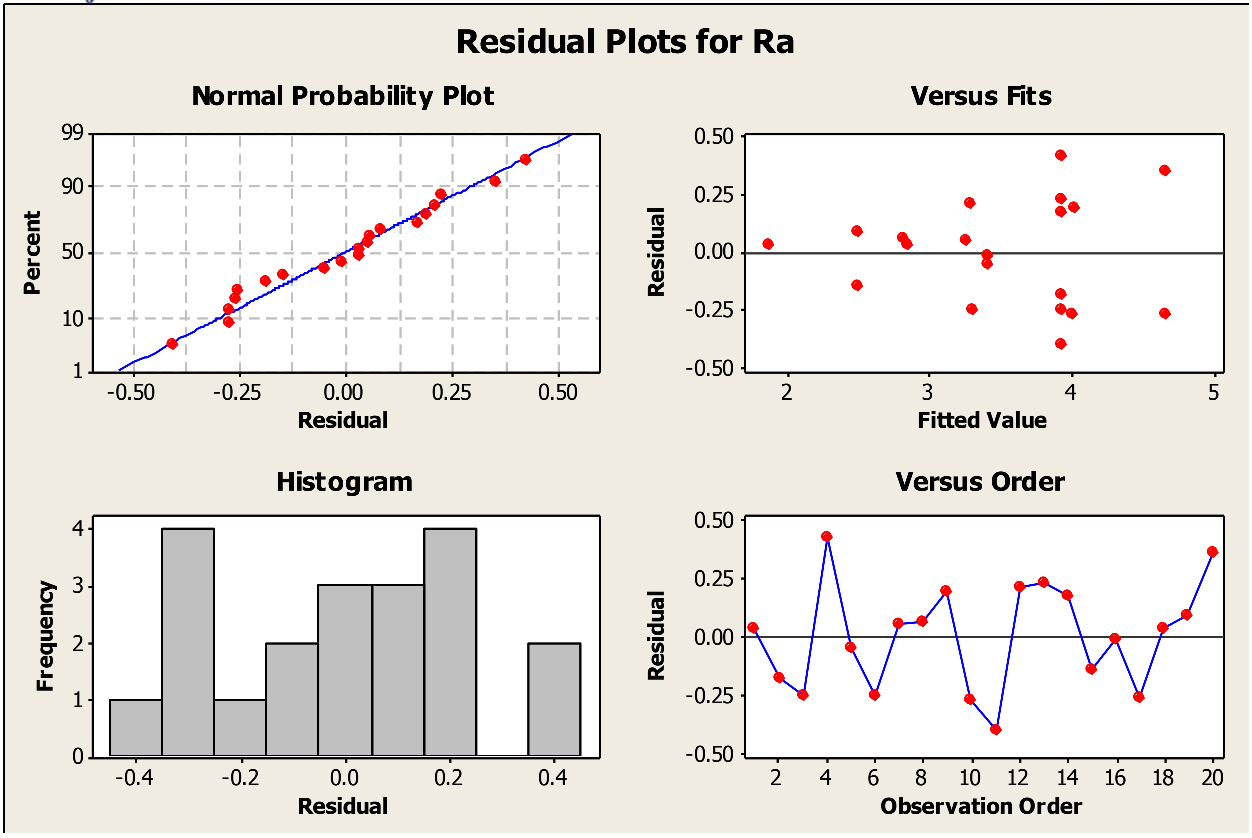

Fig 6.10 Residual Plot for Roughness (Ra)

By generating these plots, the authenticity of regression equation is checked. It can be seen from residual plots that the residuals follow an approximately straight line in normal probability plot and approximate symmetric nature of histogram indicates that the residuals are normally distributed. Since residuals exhibit no clear pattern, there is no error due to time or data collection order. It is indicated in residual vs. fits plot that variances are not equal.

IV. REGRESSION ANALYSIS

Regression coefficients of the second order equation are obtained by using experimental data. The regressionequation for the surface roughness as a function of three input process parameters was developed and is given below.

$$Ra=-211.488-(Ip\times0.106)+(Ton\times4.043) - (Toff\times0.192) -(Ton\times Ton\times0.019)+(Toff\times Toff\times0.003)+ (Ip\times Ton\times0.001) \quad (1)$$

V. CONCLUSIONS

Experimental investigation on wiirecutelectrical discharge machiningof Al composite has been done using response surface methodology. The following conclusions are made.

1. From ANOVA analysisit was noticed that Toff is most significant in case of surface roughness.
2. The statistical graph has been plotted and from histogramit is observed that the residuals are normally distributed.and residuals exhibiting no clear pattern.

3. Regression coefficients of the second order equation has been obtained by using experimental data. Mathematical model for surface roughness as a function of three input process parameters was developed.

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