EXPERIMENTAL ANALYSIS OF MRR OF AL COMPOSITE USING RESPONSE SURFACE METHODOLOGY RSM

Vikrant Sharma
Green Hills Engineering College, Kumarhatti, Solan (HP)

Abstract

The usage of composite materials has been increasing globally in all manufacturing industries. Nontraditional machining methods like electric discharge machining, ultrasonic machining, etc are used to accomplish better results in the machining of composite materials. In the present work, an attempt is made to study the study the effect of Wire Electric Discharge Machining (WEDM) parameters like pulse-on time, pulse-off time and peak current on Material Removal Rate(MRR) in AluminumComposites. Experimentation was conducted in a series of tests using response surface methodology, in which changes are made in the input variables in order to identify the reasons for changes in the output response.
Keywords: Wire electrical discharge machine; optimization; MRR; Response surface methodology, ANOVA

Electrical Discharge Machining

EDM is a thermal process that uses spark discharges to machine electrically conductive materials. A shaped electrode or wire acts as a tool which makes cavities or holes in the workpiece. Electrically conducting workpiece is connected to one pole of a pulsed power supply. The electrode (tool) is connected to another pole of power supply. A small gap is maintained between electrode and workpiece to provide controlled electrical resistance in gap.
The mechanism of metal removal in wire electrical discharge machining mainly involves the removal of material due to melting and vaporization caused by the electric spark discharge generated by a pulsating direct current power supply between the electrodes. In WEDM, negative electrode is a continuously moving wire and the positive electrode is the work piece. The sparks will generate between two closely spaced electrodes under the influence of dielectric liquid.
There are many input parameters affecting the performance of wire electrical discharge machining. So consideration of the performance of WEDM in combination with different parameter are required.. Proper selection of process parameters is essential to obtain maximum material removal rate. In Wire-EDM operations, material removal rate determine the economics of machining and rate of production, surface roughness is the measure of quality. Proper selection of process parameters is essential to obtain higher MRR.
Consideration of the performance of WEDM in combination with different parameter are required. An experimental work is proposed to study the effect of various process parameters of WEDM using aluminium alloy as a workpiece on its performance characteristics. The concept of response surface methodology has emerged as key element to obtain optimal parameters and parametric optimization for achieving best performance. In the present work, data have been collected from experimentation using response surface methodology. A quadratic model has been fitted for identification of the process to establish approximate interrelation among various process parameters as well as response variables

Literature survey

Some literature has been reviewed to find some gaps in WEDM process and to find out the effect of different input parameters on surface finish and material removal rate in WEDM process. Some papers are discussed below to get idea:-
1. Huang.T et al. (2003) used SKD 11 alloy steel to conduct experiments. In this study Grey relational analyses are applied to determine the optimal selection of machining parameters for the Wire Electrical Discharge Machining (Wire-EDM) process. The relation between machining parameters and performances can be found by using the Grey relational Analysis. An L18 mixed orthogonal array table was chosen for the experiments using Taguchi quality design concept.
2. MahadaviNejad R (2011) used SiC in experiments.Work is aimed to optimize the surface roughness and material removal rate of

electro discharge machining of SiC parameters simultaneously. Artificial neural network (ANN) with back propagation algorithm is used to model the process. A multi-objective optimization method, non-dominating sorting genetic algorithm-II is used to optimize the process.

3. Yang R.T et.al (2011)conducted the testing on pure tungsten.A hybrid method including response surface methodology (RSM)and back-propagation neural network (BPNN) integrated simulated annealing algorithm (SAA) were proposed to determine an optimal parameter setting. The results of 18 experimental runs via a Taguchi orthogonal table were utilized to train the BPNN to predict the MRR, Ra, and CD properties. Comparisons of the results of the algorithms and confirmation experiments show that both RSM and BPNN/SAA methods are effective tools for the optimization of parameters in WEDM process.

4. Malik M et al (2012) used tungsten carbide. Three factors have been taken for optimization i.e. Metal removal rate, Electrode wear rate, and Surface roughness using Zinc-coated brass wire. To solve the multiple performance characteristics problems, the Taguchi method is coupled with grey relational analysis. The analysis of the Taguchi method reveals that, in general the peak current significantly affects the EWR and SR, while, the pulse duration mainly affects the MRR.

5. Boopathi S et al. (2012) conducted the experiments by using High speed steel (HSS-M2) as a work piece.Experiments have been performed using air-mist as the dielectric medium to study the impact of gap voltage, pulse-on time, pulse-off time, air mist pressure and discharge current on the MRR and Ra using the mixed orthogonal (L18) array-Taguchi method. Taguchi based analysis of variance test was performed to identify the significant parameters. This shows that pulse on time, discharge current and gap voltage are responsible for MRR and to improve the surface finish in near- dry WEDM.

6. Majumder A (2013):-AISI 316LN STAINLESS STEEL was used as a work material.A Taguchi L9 orthogonal array was produced to plan the experimentation and the regression method was applied to model the relationship between the input factors and responses. A fuzzy model was employed to provide a fitness function to PSO by unifying the multiple responses. Finally, PSO (particle swarm optimization) was used to predict the optimal process parametric settings for the multi-performance optimization of the EDM operation.

7. Phipon R et al. (2012):-The material was Titanium Super alloy (Ti-6Al-4V).This present research study deals with the single and multi-objective optimization of micro EDM process using Genetic Algorithm. Mathematical models using Response Surface Methodology (RSM) is used to correlate the response and the parameters. The desired responses are minimum tool wear rate and minimum overcut while the independent control parameters considered are pulse on time, peak current and flushing pressure.

8. 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.

9. 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.

10. 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.

11. 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.

Research Methodology

In present study, Response Surface Methodology (RSM) was used to design the experiment. Minitab 16.1 Software was used to implement RSM to construct an experimental design. Experimentation has been carried out according to design of experiment using wirecut EDM and aluminium composite as a work piece. Peak Current (Ip), Pulse on Time (Ton) and Pulse off Time (Toff) are used at five different levels to fabricate micro-channels. Two response variables in this experimental work are taken into consideration. Material removal rate (MRR) is the output variable (desired responses) which will judge the performance of Wire-EDM when the values of input parameters will be varied in different levels. Table 1 shows the values of different parameters and their level.

Table1- Input parameter 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

Experiments have been performed according to prepared design of experiment using wire cut EDM experimental setup using aluminium composite. The material remonal rate is calculated as:

$$MRR = m_i - m_f / \rho \times t \ (mm^3/\text{min}) \quad (1)$$

Where,

$m_i(gm)$=Mass of specimen before Wire-EDM operation.

$m_f(gm)$=Mass of specimen after Wire-EDM operation.

ρ = density of composite specimen which is taken in .

t is time taken in fabrication of one slot. Time is taken in minutes.

Results and Discussions

Analysis of variance (ANOVA):

ANOVA analysis was carried out by MINITAB software in response surface methodology.ANOVA table signifies about the effect of input parameters on responses. It indicates that which parameter is significant in a particular process. As in this work, ANOVA tables are also generated to get the information of significance of input parameters on response parameters. The interactions also shown in the tableTable 1 represents the ANOVA analysis of the model. The results of the ANOVA are represented in the table,it is clear that pulse on time is the major influencing factor followed by pulse off time, the interaction also shows significant effect of material removal rate.

Table 1 Analysis of variance

Source	DF	Seq SS	Adj SS	Adj MS	F-ratio	P-value
Regression	9	13.5396	13.5396	1.50440	21.30	0.000
Linear	3	7.7348	3.6173	1.20577	17.07	0.000
Ip	1	0.5332	0.1556	0.15562	2.20	0.169
Ton	1	7.0187	2.4399	2.43987	34.54	0.000
Toff	1	0.1830	0.6266	0.62657	8.87	0.014
Square	3	3.4891	3.5219	1.17397	16.62	0.000
Ip*Ip	1	0.0084	0.0088	0.00879	0.12	0.732
Ton*Ton	1	2.5419	2.8915	2.89152	40.93	0.000
Toff*Toff	1	0.9388	0.9311	0.93114	13.18	0.005
Interaction	3	2.3157	2.3157	0.77190	10.93	0.002
Ip*Ton	1	0.0028	0.0031	0.00310	0.04	0.838
Ip*Toff	1	1.0399	1.9574	1.95737	27.71	0.000
Ton*Toff	1	1.2729	1.2729	1.27294	18.02	0.002
Residual Error	10	0.7064	0.7064	0.07064	----------	-----------
Lack-of Fit	3	0.3011	0.3011	0.10036	1.73	0.247
Pure Error	7	0.4053	0.4053	0.05790		
Total	19	14.2460				

(A) Regression analysis:

Regression based mathematical modelling was also developed using Response surface Methodology.Based upon the proposed second-order polynomial model, the effects of the process parameter taking into consideration the material removal Rate has been calculated by computing the values of the different constants. Equation (1) shows the mathematical model developed.

$$MRR = -193.679 + (Ip\times 0.069) + (Ton\times 3.657) - (Toff\times 0.783) - (Ton\times Ton\times 0.018) - (Toff\times Toff\times 0.003) - (Ip\times Toff\times 0.001) + (Ton\times Toff\times 0.010)$$

Conclusion

In this work Material Removal Rate is investigated by varying the three Process parameters on work-piece with wire electric discharge machine. The performance parameters included pulse on time (Ton), Pulse off time (Toff), Peak current. Experiments were conducted according response surface methodology.it is found that for material removal rate Pulse on time and Pulse off time are two main significant factors. Interaction between variable also shows a significant effect on MRR. Regression based mathematical model has been developed.

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