Optimization of WEDM Process Parameters on Machining of AA6082/SiC Metal Matrix Composites

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Abstract - *In this investigation, optimization of process parameters of WEDM on AA 6082/SiC metal matrix composite was performed to achieve better quality product in minimal time. Preparation of AA6082 + 5 wt. % SiC MMC was done using stir casting furnace and machining using Wire Electrical Discharge Machining. Taguchi based L9 orthogonal array is used for plan of experiments. The objectives chosen are the Maximum Material removal rate and Minimum surface roughness using process parameters viz., pulse on time, pulse off time and Peak Current. Grey relational analysis was employed for the multi-objective optimization. The optimal machining parameters results better quality and removal rate.*

***Key Words*: AA6082, Wire electric discharge machining, Multiobjective optimization, Grey relational analysis.**

1. INTRODUCTION

Composites plays vital role in the replacement of existing metals and alloys due to the superior characteristics i.e., light in weight, high strength, economical and resistance to corrosion and oxidation. Composites are of polymer, metal and ceramic matrix based, among these metal matrix composites are highly suitable in the field of structural and functional applications due to its high strength compared to the other [1-2]. In the family of MMC's. Aluminium metal matrix composites draw huge attention of researchers to develop a new alloy and to investigate the effect of types of reinforcement [3] and its sizes on strength, corrosion and many studies. AA6082 is one of the new aluminium alloy has good formability, weldability, machinability and corrosion resistance, with good strength compared to other grades of aluminium alloys [4].

Wire Electric Discharge Machining (WEDM) is an advanced machining process used to cut very hard and complicated geometries using thermal energy. WEDM yields high precision and best finished product [5].

In the industrial scenario, organizations aims to reach the maximum profits with minimum investment. Manufacturing plays maximum role in achieving the target, i.e., if the products are manufactured with less costs and time with best quality. economical obtain a product with best quality and economical, to achieve this skilled labor/advanced machineries/feasible parameters are required. From the literature survey, it is observed that setting the optimal/feasible parameters gives the desired output [6].

Optimization techniques/tools plays an important role to meet the demands of product with best quality with less price. Taguchi methodology optimizes single objective, but are not suitable for the requirement of industries which has multi objectives for a single product [7]. Multi objective optimization is more difficult compared to single objective optimization. It is studied that, taguchi integrated grey relational analysis was used to convert multi-objective system into single objective to determine the optimal parameters using grey relational grade [8].

2. LITERATURE SURVEY

Liu et al. [9] studied the effect of machining voltage, current, pulse duration, and electrolyte concentration, on material removal rate (MRR) of Al 6061/Al2O3 MMC and observed high current or high concentrations of electrolyte results in high MRR, and also suggest that to achieve the highest MRR, the applied current is the most influential factor. Sanjeev et al. [10] investigated the effect of process parameters such as pulse width, time between pulses, servo control mean reference voltage, short pulse time, wire feed rate and wire mechanical tension on performance measures such as surface roughness and cutting velocity (CV) of newly developed Al/10 % ZrO metal matrix composite (MMC).

Patil et al. [11] investigated the effect of pulse on-time, off-time, pulse current, wire speed, wire tension and flushing pressure on cutting speed and surface finish and found that large pulse on-time, flushing pressure, appropriate wire speed and tension should be used so as to obtain optimum machining performance. Satish Kumar et al. [12] investigated, the effect of parameters such as pulse-on time, pulse-off time, gap voltage and wire feed on material removal rate and surface roughness of Al6063/ SiC MMC by varying 5%, 10% and 15% volume fractions of SiC. The results reveals that For Al6063, Al6063 + 5% SiC, Al6063 + 10% SiC and Al6063 + 15% SiC gap voltage, wire feed, wire feed, Pulse off time is the most significant factor for better MRR and Ra. Udayaprakash et al. [13] investigated, the effect of parameters such as pulse-on time, pulse-off time, gap voltage and wire feed and percentage of reinforcement on material removal rate and surface roughness of A413/Fly/B4C MMC. The results presents that for MRR - Gap voltage is the most significant followed by pulse on, %of reinforcement, pulse off and wire feed and for Ra – Gap voltage is the most significant followed by wire feed, %of reinforcement, pulse off and pulse on.

Gopala Kannan et al. [14] studied the effect of process parameters such as pulse on, pulse off, pulse current and gap voltage on Al7075/B4C MMC using response surface methodology. The study presents that the two most significant factors that affect MRR are pulse current, pulse on time. MRR increases with increase in pulse on and then decreases. SR increases with increase in pulse current and pulse on time. Narender Singh et al. [15] studied the influence of process parameters on material removal rate (MRR), Tool wear rate (TWR), taper (T), radial overcut (ROC) and Surface roughness (SR) machining of Al–10%SiC MMC using Grey relational Analysis. In this study, Pulse-on, pulse current and flushing pressure are taken as process parameters and observed that Pulse on time is the most significant followed by pulse current, where flushing pressure has no impact. Gopala kannan et al. [16] studied the effect of process parameters such as pulse on, pulse off, pulse current and gap voltage on Al7075/Al2O3 MMC using response surface methodology. The study presents that the main significant factors that affect the MRR are pulse current, pulse on time and pulse off time whereas voltage remains insignificant. The value SR increases with increase in pulse current and pulse on time. Manna et al. [17] studied different control parameters for optimization of WEDM using Taguchi design methodology during machining of Al/SiC-MMC. Mathematical models relating to the WEDM performance criteria were established for the machining of Al/SiC MMC by means of the Gauss elimination method. They considered three parameters viz., cutting speed, surface roughness and wire offset as measures of the process performance.

From the literature study, it is observed that none of the work has been carried out using AA6082+ 5% SiC. In the present investigation, an attempt is made to study and determine the optimal machining parameters of WEDM on AA6082/SiC MMC for minimum surface roughness and maximum material removal rate. Pulse on, Pulse off and Peak Current are chosen as the process parameters with a L9 array plan of experiments, to collect the experimental data and to analyse the effect of these parameters on surface roughness and material removal rate. Taguchi integrated Grey relational analysis is chosen for Multi-objective optimization.

3. EXPERIMENTAL DETAILS:

In tis study, AA6082 and SiC was chosen as matrix and reinforcement respectively, for the preparation of metal matrix composite using stir casting furnace as shown in Fig.1.

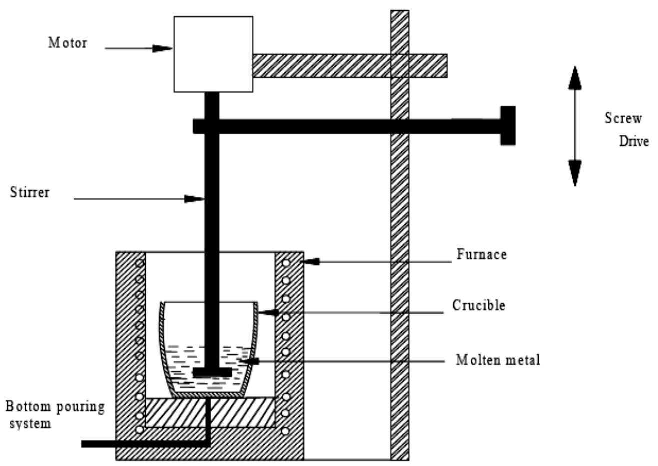

Fig. 1 Stir casting Furnace

Microstructure of the sample depicted in Fig.2, exhibits the homogeneous distribution of SiC reinforcement in the AA6082 matrix.

Fig. 2 Microstructure of A6082/SiC MMC

After the preparation of MMC, Machining was performed using Electronica Maxicut Wire EDM as shown in "Fig.3." A 0.25 mm dia brass wire was used as an electrode to erode the metal under distilled water. A small gap of 0.025 mm to 0.05 mm is maintained in between the wire and work-piece.

Fig. 3 Material in Fixture

In the present investigation, three process parameters i.e., Pulse-on, pulse-off, Peak current, were chosen which have more influence on material removal rate and surface roughness and each parameter is set at three levels as shown in Table 1. Design of Experiments were made using taguchi L9 array as shown in Table 2. L9 (3^{3-1} = 9 runs) was chosen for experimentation, instead of L 27 array (3^3 =27 runs) to reduce the experimentation cost. The time required for material removal of workpiece is determined by using stopwatch and the surface roughness is determined by using talysurf instrument and the results were tabulated in Table 2.

Table 1. Process parameters and levels

Process parameters	Levels		
	Level-1	Level-2	Level-3
Pulse-on (μs)	6	7	8
Pulse-off (μs)	1	2	3
Pulse Current (A)	3	4	5

Table 2. Design of experiments and Responses

S.No	Pulse On A (µs)	Pulse off B (µs)	Pulse Current C (A)	MRR (mm^3/sec)	Ra (µ)
1	6	1	3	14.399	5.5622
2	6	2	4	13.712	5.6298
3	6	3	5	13.025	5.6974
4	7	1	4	13.693	5.6428
5	7	2	5	13.006	5.7104
6	7	3	3	14.248	5.5755
7	8	1	5	12.987	5.7234
8	8	2	3	14.229	5.5885
9	8	3	4	13.542	5.6561

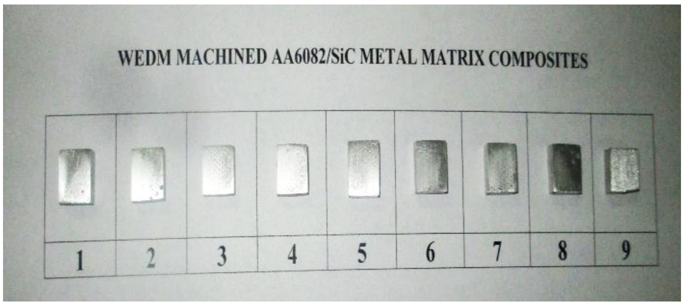

Fig. 4 Specimens after machining.

4. Taguchi integrated Grey Relational Analysis

4.1 Grey relational analysis:

Grey relational analysis (GRA) methodology is used to optimize the process parameters having multi-objectives through grey relational grade. The GRA methodology is as follows:

1. Conduct the experiments as per plan.
2. Normalize the responses.
3. Calculate the grey relational coefficients.
4. Calculate the grey relational grade by averaging the grey relational coefficient.

4.1.1 Normalization:

Convert the original sequences to a set of comparable sequences by normalizing the data. Depending upon the response characteristic, three main categories for normalizing the data is as follows:

'*Larger the better*' $$a_i^{(*)}(k) = \frac{b_i^{(*)}(k) - \min b_i^{(*)}(k)}{\max b_i^{(*)}(k) - \min b_i^{(*)}(k)} \quad (1)$$

'*Smaller the better*' $$a_i^{(*)}(k) = \frac{\max b_i^{(*)}(k) - b_i^{(*)}(k)}{\max b_i^{(*)}(k) - \min b_i^{(*)}(k)} \quad (2)$$

'*Nominal the better*' $$a_i^{(*)}(k) = 1 - \frac{b_i^{(*)}(k) - OV}{\max\{\max b_i^{(*)}(k) - OV, OV - \min b_i^{(*)}(k)\}} \quad (3)$$

4.1.2 Grey relational coefficient and grey relational grade

Grey relation coefficient (α_{ij}) is calculated for each of the performance characteristics, which expresses the relationship between ideal and actual normalized experimental results, as shown in "Eq.(4)."

$$\alpha_{ij} = \frac{\Delta\min + \xi\Delta\max}{\Delta oi(k) + \xi\Delta\max} \quad (4)$$

Grey relational grade can be calculated by taking the average of is the weighted grey relational coefficient and defined as follows

$$\Sigma\beta_k\gamma(x_0^{(*)}(k), x_i^{(*)}(k)) = 1 \quad (5)$$

Table -3: Grey Relational Grades

Expt. No	MRR	Ra	Normalized values		Grey Relational Coefficients		Grey Relational Grades
			MRR	Ra	MRR	Ra	
1	14.399	5.5622	1.0000	1.0000	1.000	1.000	**1.000**
2	13.712	5.6298	0.5135	0.5806	0.507	0.544	0.525
3	13.025	5.6974	0.0269	0.1613	0.339	0.373	0.356
4	13.693	5.6428	0.5000	0.5000	0.500	0.500	0.500
5	13.006	5.7104	0.0135	0.0806	0.336	0.352	0.344
6	14.248	5.5755	0.8931	0.9175	0.824	0.858	0.841
7	12.987	5.7234	0.0000	0.0000	0.333	0.333	0.333
8	14.229	5.5885	0.8796	0.8368	0.806	0.754	0.780
9	13.542	5.6561	0.3931	0.4175	0.452	0.462	0.457

From the table 3, it shows that Experiment 1 has the highest grey relational grade (GRG) of 1.000 indicates experiment no.1 parameters are the optimal combination to achieve the desired objectives. Optimal parameter combination is $A_1B_1C_1$

5. ANALYSIS OF VARIANCE

ANOVA was performed to identify the process parameters that significantly affect the time and quality. This is accomplished by separating the total variability of the grey relational grades, which is measured by the sum of the squared deviations from the total mean of the grey relational grade, into contributions by each machining process parameters and the error. An ANOVA table consists of sums of squares, corresponding degrees of freedom, the F-ratios, and the contribution percentages of the machining factors. These contribution percentages can be used to assess the importance of each factor for the interested grades.

Table - 4: Analysis of Variance

Source	DF	Seq SS	Adj SS	F - Value	P- Value	%Contribution
Pulse on	2	0.016485	0.008242	3.57	0.219	3.47
Pulse off	2	0.007325	0.003662	1.58	0.387	1.54
Pulse Current	2	0.446741	0.22337	96.66	0.01	**94.01**
Error	2	0.004622	0.002311			0.98
Total	26	0.475172				100

The relative effect among the control factors for the Grey relational grades can be verified by using the ANOVA so that the optimal combinations of the machining factors can be accurately determined. From Table 4, it is also evident that the control factors Pulse current has the most influence on the output i.e., 94.01 % of contribution followed by Pulse on and Pulse off of 3.47 and 1.5 4%. Error has the 0.98% indicates the optimal parameters for the best quality product without any discrepancy.

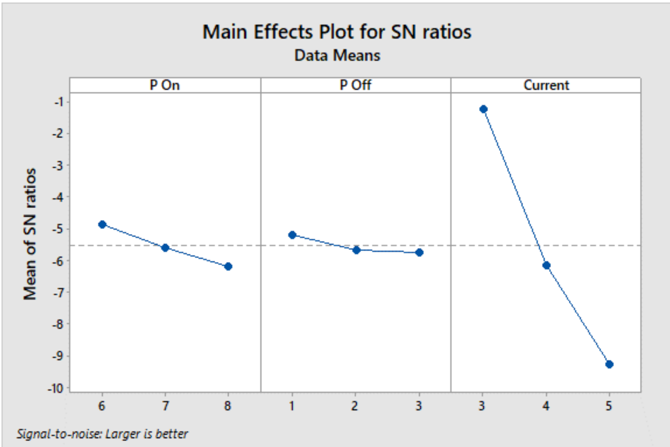

Fig. 5: S/N ratio – Grey relational grades.

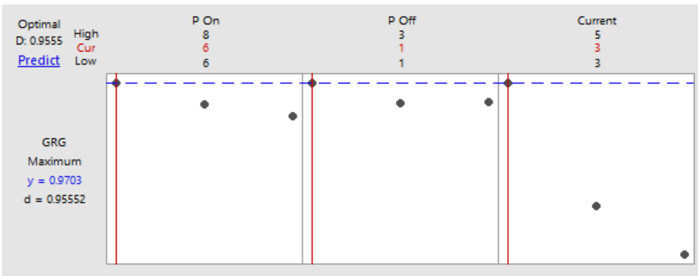

Fig. 6 Optimal Parameters $A_1B_1C_1$

6. CONFIRMATION RUN:

After determining the optimal combination of parameters, the last phase is to verify the MRR, surface roughness by conducting the confirmation experiment. The $\mathbf{A_1B_1C_1}$ is an optimal parameter combination of the machining process by Grey relational analysis. The confirmation test is carried out with the optimal parameter combination $\mathbf{A_1B_1C_1}$, and the results are tabulated in Table.5 and matches.

Table 5. Confirmation test results

Type	Initial	Optimal/Predicted	Experimental
Level combination	$A_1B_1C_1$	$A_1B_1C_1$	$A_1B_1C_1$
MRR (mm^3/sec)	**14.399**	**14.399**	**14.393**
SR (μm)	**5.5622**	**5.5622**	**5.58**

Conclusions:

- The effect of process parameters i.e. pulse on-time, pulse off-time, Pulse current on response variables such as material removal rate, surface roughness has been thoroughly studied. The levels of significance of process parameters for each response variable has been investigated using ANOVA.
- Pulse Current found to be the most significant factors influencing all responses investigated for both the experiment sets.
- The $A_1B_1C_1$ is an optimal parameter combination of the machining process by Taguchi based Grey relational analysis.
- It is clear that the MRR and SR increased greatly with the optimal parameters.

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