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Multi Objective Optimization of Machining Parameters for AA7075 Metal Matrix Composite Using Grey - Fuzzy Technique

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Abstract

Wire cut discharge Machining is an advanced machining method controlled by a variety of interrelated complex parameters like discharge current, pulse on time, pulse off time and servo speed rate. Any slight variations in one will have an effect on the machining quality measures like surface roughness and material removal rate. In the present work Aluminium 7075 is used as matrix and activated charcoal with different percentage as reinforcement to fabricate metal matrix composites. The specimens are tested for Density, Hardness, Impact Strength and Ultimate tensile Strength. Best chosen samples are used to perform machining process in wire cut electrical discharge machine. 27 trials of experiments based on Response surface methodology are done and the observations are made. The quality of the machined samples is evaluated by the measurement of material removal rate and surface roughness. Results are utilized to develop the grey-fuzzy model. From this technique, the optimum combinations of process parameters are obtained and corresponding values of maximum material removal rate and minimum surface roughness are found out. From ANOVA analysis it is found that servo speed is the significant factor in determining the machining quality. Confirmatory experiments are performed to determine the effectiveness of the approach.

Keywords: AA7075, Material removal rate, Surface Roughness, Grey relational analysis, ANOVA

INTRODUCTION

Wire electrical discharge machining (WEDM) is an electro thermal machining process for conductive resources. WEDM is able to machine complex and exactness parts for hard conductive materials [1].WEDM are used to machine variety of materials for modern tooling applications. Besides that, WEDM is used to desktop modern-day composite materials. WEDM is an intricate machining process controlled by means of an enormous quantity of approach parameters [2]. Any slight variants in some of the approach parameters can affect the machining performance. The most amazing machining strategy is determined by classifying the different causes affecting the WEDM method, and searching for the different ways of obtaining the premiere machining condition and efficiency [3]. Ibrahem [4] have investigated the efforts of optimal machining conditions for improving the output and realizing high quality through increase removal rate and improve surface quality. Ravindranadh et al [5] have performed theoretical and empirical results used in modelling of WEDM process of Al alloy. Chiang [6] have examined Taguchi system and response surface methodology are probably the most used statistical approaches for identifying the relationship between various input parameters and yield responses. Durairaj [7] have analysed the method Parameters in Wire EDM with stainless-steel utilizing Single purpose Taguchi approach and multipurpose grey Relational Grade. Natarajan [8] have optimized the EDM machining inputs with more than one routine characteristic by means of Taguchi method and grey relational evaluation. Rajneesh [9] applied parametric optimization of wire reduce machining utilizing fuzzy good judgment. It provides associated fuzzy inference process to monitor the given enter-output information. Gopalakrishnan et al, [10] evaluated Statistical parameters of EDM parameters on machining of aluminum metal matrix composites through making use of Taguchi through grey evaluation. Shailesh [11] researchers have done Multi-response optimization of surface integrity characteristics of EDM approach making use of grey-fuzzy good judgment-established hybrid procedure. Biswajit et al [12] have studied the applying of grey fuzzy good judgment for the optimization of CNC milling parameters for Al–TiC MMCs with multi-performance features. Arsalan et al [13] have optimized the procedure parameters for machining of metal fabric making use of Taguchi design and evaluation of variance.

Whereas a very few research works have been conceded out to study the have an impact on of wire EDM machining parameters on special aspects, it is vitally essential to set up top-quality parametric mixture with the intention of acquiring improves machined area. AA7075 is reinforced with various weight compositions of powdered activated carbon (PAC) of 3 to 10wt % using down pouring stir casting method.

Mechanical and metallurgical tests have been done the manufactured composites. It is found that AA7075 reinforced with 9wt % of PAC exhibits desirable characteristics [14]. This paper highlights the multi objective optimization of AA7075 with 9wt % PAC metal matrix composites using wire cut EDM process using grey-fuzzy technique. Experimentation is planned using Box Behnken design matrix. Crucial four machining parameters including discharge current, pulse on time, pulse off time and servo speed are to develop hybrid grey - fuzzy model for improve the two responses namely Material Removal Rate (MRR) and surface roughness (SR).

METHODOLOGY USED

A. Response surface methodology

The proposed work is done by Response surface methodology (RSM) design. RSM design is a collection of mathematical and statistical techniques for empirical model constructing [15]. By using cautious design of experiments, the target is to optimize a response which is influenced via several enter variables. Experiment is conducted using RSM on WEDM machining. The relation is explained with the aid of the 2nd order polynomial model shown below.

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i + \sum i \sum j \beta_{ij} X_i X_j + \varepsilon \quad (1)$$

In the relation y is the estimated response; βzero is the steady; and βi and βii and βij characterize the coefficients of linear, quadratic and move product phrases respectively. X is the coded variables; ε is the random fault tenure. The proposed work methodology is shown in fig 1.

B. Grey relational analysis

Within the grey relative evaluation, experimental outcome of MRR and SR had been initial normalized and so the grey relative regular was calculated from the normalized experimental data to special the connection between the desired and genuine experimental knowledge. Then, the grey relative grade used to be computed through averaging the grey relative regular harking back to every process response [16]. The overall evaluation of the more than one approach responses relies on the grey relative grade. Therefore, optimization of the subtle multiple system responses may be regenerate into optimization of grey relative grade. In different phrases, the grey relative grade is also treated seeing that the total analysis of experimental competencies for the multi response approach. Optimization of an element is that the extent with the very best grey relative grade.

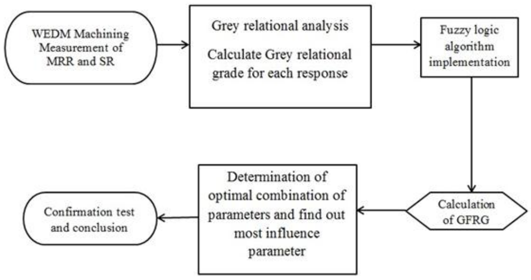

Figure 1: Proposed grey-fuzzy method

a. Grey relationl relation

GRA is categorized into three types namely Lower the better, Higher the better criterion [17]. To obtain the normalized better-the-higher MRR values [6] the following equation is used:

$$X_i^*(\mathrm{k}) = \frac{\mathrm{y}_i(\mathrm{k}) - \min y_i(\mathrm{k})}{\max y_i(\mathrm{k}) - \min y_i(\mathrm{k})} \quad (2)$$

In a similar way the normalized information processing for SR is minimize the simpler is expressed as:

$$Y_i(k) = \frac{max\, y_i(k) - y_i(k)}{max\, y_i(k) - \min y_i(k)} \quad (3)$$

Where i= 1,2,….m; k= 1,2,….n; m= no of experimental data; n= no of factors; y_i(k)= original sequence; yi(k) value after grey relational generation; min y_i(k) and max y_i(k) are the minimum and maximum value of y_i(k) respectively. The normalized values are shown in table 3.

b. *Grey relational coefficient*

Grey relational coefficient was calculated by the following equation (4)

$$\in_i(k) = \frac{\Delta min + \omega \Delta max}{\Delta_{oi}(k) + \omega \Delta max} \quad (4)$$

Where ε_i (k) is the grey relation coefficient. Δ_{oi} is deviation among y_o (k) and y_i (k); y_0 (k) is the ideal sequence; Δ_{max} is highest value of Δ_{oi} (k); Δmin is least value of Δ_{oi} (k).

c. *Grey relation grade*

The grey relation grades determined by taking average of the grey relation constant associated with each observation as bestowed in equation (5).

$$\Gamma_i = \frac{1}{M} \sum_{=1}^{Q} i(k) \quad (5)$$

Where Q is total quantity of responses and n denotes the quantity of output responses. The grey relative grades represent degree of relationship between among the reference and therefore the comparative sequence. If better grey relative grade is bought for the identical set of procedure parameters compared to different sets, it is considered as essentially the most favorable greatest values [18].

C. Fuzzy Analysis

The fundamental premise in the back of Fuzzy logic is that there are inaccuracies in attribute and within the geometry of spatial information. Fuzzy common sense presents procedures to address both types of inaccuracies, however fuzzy good judgment, as it pertains to overlay evaluation, makes a specialty of inaccuracies in attribute data [19]. The two principal areas the place inaccuracies come up in attribute data arise in the definition of the courses and in the size of the phenomenon. The Mamdani implication methods with fuzzy controller operations are shown in fig 2.Fuzzy controllers and fuzzy reasoning [20] have observed exact functions in very elaborate industrial methods that cannot be modeled precisely even under various assumptions and approximations.

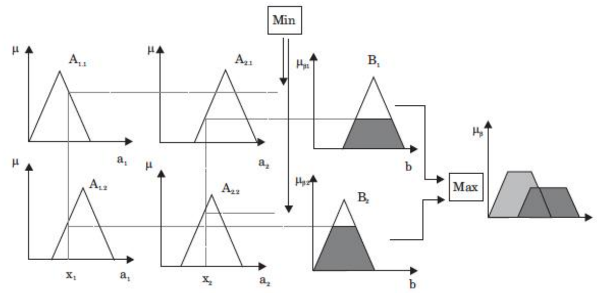

Figure 2: Mamdani implication methods with fuzzy controller operations

The grey relational coefficients x_1, x_2...x_n and a multi-objective output y are of the form if the following rules are adhered to:

Rule 1: if x_1 is A_1 and x_2 is B_1 then y is C_1 else
Rule 2: if x_1 is A_2 and x_2 is B_2 then y is C_2 else
. . . .
Rule n: if x_1 is A_n and x_2 is B_n then y is C_n.

A_n, and B_n, is fuzzy subsets outlined by the corresponding membership features, i.e.,μA_1 and μB_1. The fuzzy multi-function output y is furnished from those above ideas through employing the max-min interfaced operation. Inference outcome in a fuzzy set with MF for y can be expressed as Eqn. (6).

$$\mu(y) = (\mu A_1(x_1) \wedge \mu B_1(x_2) \wedge \mu C_1(y) \ldots (\mu A_n(x_1) \wedge \mu B_n(x_2) \wedge \mu C_1(y)) \quad (6)$$

The place ∧ and ∨ are the minimal and maximum operation respectively. Ultimately a centroid defuzzification process is adopted to transform the fuzzy multi response output $\mu_{C0}(y)$ right into a non-fuzzy y_0 as equation in (6).

EXPERIMENTAL PROCEDURE

The experiments are conducted in WEDM machine based on the box Behnken design. Four input machining parameters with three stages were chosen in line with machining ideas as shown in table 1.The fabrication of material used for the experiment is AA7075-9wt%PAC metal matrix composite prepared through the Stir casting process. The wire cut machining parameters including Discharge current (I_A), pulse on time (T_{on}), Pulse off time (T_{off}) and Servo speed rate (rpm) have chosen in this optimization work to investigate the effect on machining quality including Material Removal Rate and surface roughness. The material removal rate was calculated with the help of a formulae has been used from the final weight and the initial weight of the specimens. Surface roughness output was measured using a profilometer. The photograph of the experimental setup used for machining is shown in Fig. 3. A right RSM box Behnken design for the experiments requires a measure of freedom larger than or at least equal to these of the approach parameters.

Table I. Input Process Parameters and Their Levels

Parameters	Symbols	Level 1	Level 2	Level 3	Units
Current	I_A	1500	1750	2000	mA
Pulse on Time	T_{on}	5	10	15	µs
pulse off time	T_{off}	25	50	75	µs
Servo speed	SS	50	100	150	RPM

Figure 3: Photograph of the WEDM experimental setup

RESULT AND DISCUSSION

A. Computing the grey relational coefficient

The experimental outcome are pre-processed the grey relational coefficient and the total grey relational grade for each of the combination of parameters is given in table2. Alternatively to obtain an accelerated first-rate in the performances and to minimize the imprecision in the information, grey-fuzzy logic system is additionally used for computing the Grey fuzzy reasoning grade (GFRG).

B. Execution of Grey-Fuzzy Based Method

***Step 1*:** Normalize the value of given responses using Eq. (2) which results in values same as given in table 2.

***Step 2*:** participate in the grey relation evaluation. Calculate grey relational coefficient utilizing Eqn. (4). When consider that equal significance was once given to each target, the value for used to be taken as 0.5 as in Eqn. (4) [Table 2].

***Step 3*:** Work out the grey relational grade utilizing fuzzy good judgment analysis. The grey relational coefficients of MRR and SR have been used as input to the fuzzy model and the output used the grey-fuzzy reasoning grade. In this finding the most widespread defuzzification approach used for the centroid calculation, which returns the centre of the discipline beneath the curve. The defuzzifier is convert the fuzzy worth right into a non-fuzzy value which is outlined because the grey-fuzzy reasoning grade. Figure 4 and 5 shows the membership function fuzzy sets of input and output parameters. The max values of GFRG give the best performance characteristics. Analysis of the mean in performed for GFRG. These main effect values are plotted in fig.7 for the machining parameters.

Table II. Standards of Normalised, Grey Relational Coefficient and Fuzzy Reasoning Grade

Exp No	Experimental values		Normalized values		Grey relational coefficient		Fuzzy reasoning Grade
	MRR	SR	MRR	SR	MRR	SR	
1	9.54	3.67	0.5648	0.8888	0.4695	0.36	0.4604
2	6.84	4.03	0	0.2222	1	0.6923	0.7903
3	8.2	3.99	0.2845	0.2962	0.6373	0.6279	0.6181
4	7.44	3.93	0.1255	0.4074	0.7993	0.5510	0.4640
5	8.82	3.89	0.4142	0.4814	0.5469	0.5094	0.5588
6	8.82	3.89	0.4142	0.4814	0.5469	0.5094	0.5588
7	10.8	3.74	0.8284	0.7592	0.3763	0.3970	0.3928
8	10.26	3.85	0.7154	0.5555	0.4113	0.4736	0.5182
9	8.02	3.83	0.2468	0.5925	0.6694	0.4576	0.5587
10	7.56	3.82	0.1506	0.6111	0.7684	0.45	0.5602
11	9.66	3.95	0.5899	0.3703	0.4587	0.5744	0.5353
12	9.6	3.61	0.5774	1	0.4640	0.3333	0.4655
13	8.14	4.01	0.2719	0.2592	0.6476	0.6585	0.7617
14	9.36	3.85	0.5271	0.5555	0.4867	0.4736	0.4619
15	7.62	4.15	0.1631	0	0.7539	1	0.7617
16	11.1	3.91	0.8912	0.4444	0.3593	0.5294	0.4611
17	8.34	3.93	0.3138	0.4074	0.6143	0.5510	0.5896
18	8.04	3.88	0.2510	0.5	0.6657	0.5	0.6369
19	8.04	3.77	0.2510	0.7037	0.6657	0.4153	0.5294
20	8.58	3.73	0.3640	0.7777	0.5786	0.3913	0.4325
21	11.62	3.86	1	0.5370	0.3333	0.4821	0.4333
22	8.94	3.83	0.4393	0.5925	0.5322	0.4576	0.5331
23	9.57	4.06	0.5711	0.1666	0.4667	0.75	0.5587
24	9.31	3.9	0.5167	0.4629	0.4917	0.5192	0.4904
25	7.33	4.05	0.1025	0.1851	0.8298	0.7297	0.7880
26	8.82	3.89	0.4142	0.4814	0.5469	0.5094	0.5588
27	8.64	3.87	0.3765	0.5185	0.5704	0.4909	0.5639

C. Grey-fuzzy reasoning analysis

Here two inputs (MRR and SR) and one output (GFRG) fuzzy-logic system is used. Fuzzy inference method achieves fuzzy reasoning with fuzzy ideas for producing a fuzzy price. The grey relational coefficient for MRR and SR are inputs to the fuzzy logic system. The linguistic membership operate Lowest, Low, Medium, excessive and maximum are used to signify the grey relational coefficient (GRC) of enter variables. Likewise the yield grey relational

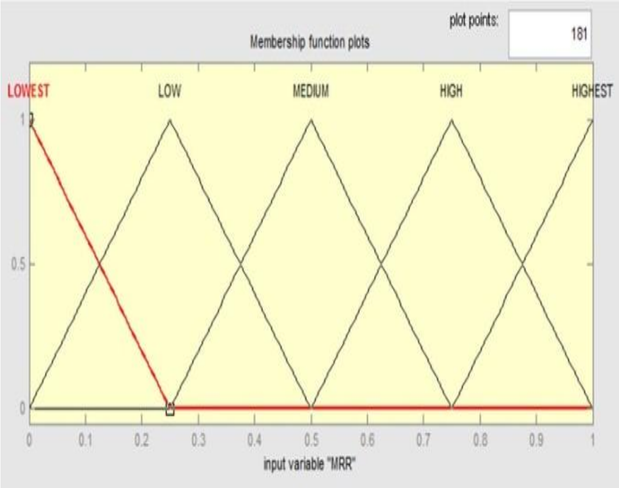

Figure 4. Membership functions for material removal rate and surface roughness

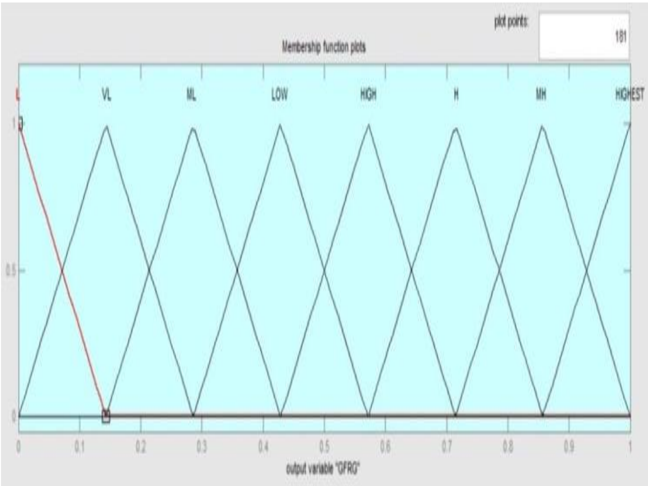

Figure 5. Membership function for multi response output

Grade is being represented through the membership functions similar to Lowest, Very Low, Medium Low, Low, Medium, and high, better, Medium larger and perfect. The triangular shaped membership performs which is possessed on this work. A total of 26 numbers of fuzzy ideas are used for this purpose. The rule of fuzzy grade reasoning is shown in Fig. 6. Difference in compositional operation by tracking the fuzzy reasoning yields a fuzzy output. Fuzzy techniques increasingly applied to the research area and no work has been summarized this techniques in 7075 metal matrix composites. From the response analysis given in the table concluded that, that parameter combination A1B3C3D1 had the best performance for all the quality features. The fuzzy predicted values addicted to GRFG using MATLAB function. The generated GFRG values are tabulated in Table 2.

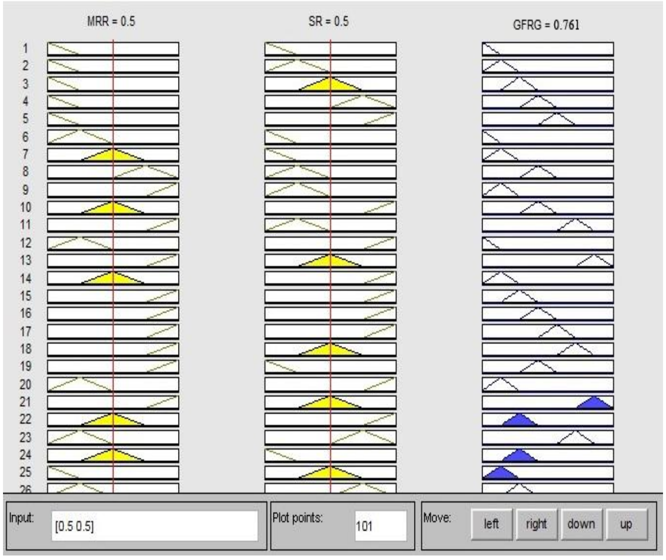

Figure 6. Fuzzy logic rules viewer

Table III. Response Table For Grey-Fuzzy Reasoning Grade

Symbol	Parameter	level 1	level 2	level 3	Main effect	Rank
A	I_A	0.58873	0.55414	0.35332	0.235415	2
B	T_{on}	0.48966	0.5683	0.58154	0.091883	4
C	T_{off}	0.47468	0.54572	0.62742	0.152745	3
D	SS	0.74778	0.53389	0.46038	0.287398	1

D. ANOVA analysis

ANOVA analysis is achieved to categories the approach parameters of wire reduce EDM that enormously impact the more than one efficiency traits. An ANOVA table includes sums of squares, corresponding degrees of freedom, the F-ratios comparable to the ratios of two mean squares, and the contribution proportions from each of the control causes. These contribution portions can be used to determine the importance of every aspect for the interested more than one performance characteristics. The results in table 4 exhibit that servo speed cost used to be probably the most colossal manipulate factor, adopted by way of pulse on time. The every manipulate component diversified in its contribution to the total variance: servo speed (68.45%), pulse on time (13.09%), pulse off time (9.97%) and discharge current (3.52%). Servo speed attains maximum speed of the wire tension and can run the voltage at maximum level. From the results, discharge current was established to be an insignificant factor in manipulating the overall fuzzy reasoning grade. Because in WEDM conduction is minimum when cutting speed is increases through the speed of servo voltage. When the servo speed is decreases then automatically the discharge current parameter will be most influencing parameter in this process. Fig 8 shows the SEM image of optimal parameter experiment at 1500 amperes, pulse on time of 15μs, pulse off time 75μs and servo speed 50rpm.

Table IV: Analysis of Variance Results

Source	DF[a]	SeqSS[b]	AdjSS[d]	Adj MS[c]	F	P	% contribution
IA	2	0.014672	0.007724	0.003862	0.67	0.523	3.5243
Ton	2	0.054051	0.00507	0.002535	5.44	0.65	13.0936
Toff	2	0.041542	0.057846	0.028923	2.04	0.018	9.9788
SS	2	0.284986	0.172981	0.08649	15.07	0	68.4558
Error	18	0.021201	0.010332	0.00574	-	-	
Total	26	0.416308	-	-	-	-	

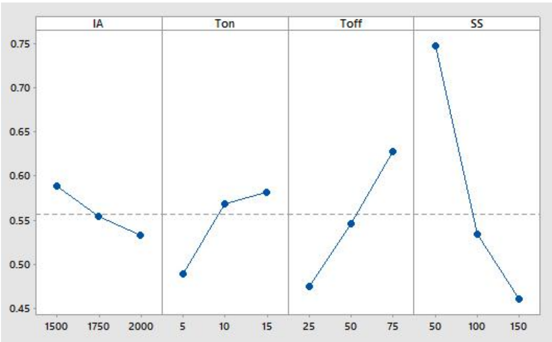

Figure 7. Main effect plot for grey-fuzzy reasoning grade

E. Confirmation Test

The ultimate step used to verify the development of the performance traits making use of the most fulfilling stage of machine parameters. Table 6 shows the comparison of the more than one performance traits for preliminary and highest quality machining parameters. The preliminary designed stages of machining parameters are A2B3C3D1. The estimated fuzzy reasoning grade γ using surest level of the wire cut machining parameters is calculated.

Table V: Results of Machining Performance Using the Initial and Optimal Factors

	Initial process parameters	Optimal process parameters	
		Prediction	Experiment
Level	A2B3C3D1	A1B3C3D1	A1B3C3D1
Material Removal Rate(mm^3/min)	8.62	-	8.78
Surface Roughness (μm)	3.11	-	3.05
GFRG	0.761	0.7972	0.806
Improvement of GFRG	-	0.0352	0.045

Where γ is the whole mean of the fuzzy reasoning grade, γ_m is fuzzy reasoning grade at premier stage and q is the number of the machining parameters that impacts the couple of response traits. From table 5 the MRR is increased from 8.62 (mm3/min) to 8.78 (mm3/min) and the SR is lowered from 3.11μm to 3.05 μm. The estimated fuzzy reasoning grade is multiplied from 0.761 to 0.7972. Additionally it's determined that most effective design bought from the fuzzy common sense evaluation has the largest experimental and estimated fuzzy reasoning grade. It is clearly proven that the multiple objectives of the machining approach are collectively improved remarkably.

CONCLUSIONS

In summarizing the present work, experiments are done using RSM design on fabricated AA7075-PAC composites using wire EDM process. Grey fuzzy technique is applied on the multi responses obtained and the following conclusions are drawn.

- The machining parameters such as MRR and SR have been optimized to achieve good quality for low SR and high in MRR using grey fuzzy analysis.
- It is identified that at a discharge present of 1500 amperes, pulse on time of 15μs, pulse off time 75μs and servo speed 50rpm the optimal combination of machining parameters to provide a max value of grey fuzzy reasoning grade (0.761) is obtained.
- ANOVA facts published that servo speed is the most influencing parameter achieve excellent results, adopted by means of pulse on time, discharge current and pulse off time.
- Consequently it's decided that the grey-fuzzy optimization suggested in this work enormously improves the quality fabrication of WEDM machining parameters of AA7075-9wt% PAC Metal matrix composites. Hence it is recommended to use in strengthen aerospace wing structures.

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