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INTELLIGENT HYBRID ANFIS-GRG METHOD FOR MACHINABILITY ANALYSIS OF METAL MATRIX COMPOSITES IN WIRE ELECTRICAL DISCHARGE MACHINING

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Abstract

The present investigation entails the integrated optimization and modelling of the Wire Electro-Discharge Machining (WEDM) process for the stir-cast AA7050 alloy reinforced with graphite particles, forming metal matrix composites. Because of the composite's high strength and heterogeneous nature with a very fine microstructure, machining parameters must be carefully controlled for an improved process capability. A Taguchi-based design is practically followed so that important process variables-pulse-on time, pulse-off time, and peak current are effectively evaluated for their effects on important performance measures such as material removal rate (MRR), surface roughness (SR), and Dimensional Deviation (DD), and form/orientation tolerances. Grey Relational Analysis (GRA) techniques optimize the multi-objectives to analyse the best possible settings that will maximize overall performance. For modelling and prediction of the process behaviour, an Adaptive Neuro-Fuzzy Inference System (ANFIS) was developed with the Grey Relational Grade (GRG) as the output response. The ANFIS model is developed to capture the nonlinear interactions between the input variables and has a very high prediction accuracy, proving its usefulness for modelling the WEDM process. The synergistic application of Taguchi, Grey, and ANFIS modelling is a robust structure for improving the machinability of AA7050-graphite composites and aiding intelligent decision-making in advanced manufacturing applications.

Keywords : WEDM; MMC; Taguchi Design; Analysis; MCDM; Grey Theory; ANFIS

I. Introduction:

In the present day, technological advancement is accelerating to such an extent that the need for new materials to enter the market with improved mechanical, thermal, and functional property sets in. The interest of the applications in composite materials is increasing on account of the planes, automobiles, defence, and structural engineering for efficient performance characteristics. Composite materials have been applied over centuries in several engineering applications, including the making of traditional weapons [I-V]. Modern development and application continue to diversify rapidly, especially in demanding high-performance and precision sectors. Metal matrix composites (MMCs) are among the many composite materials that have drawn, to an extent enormous interest. They are lighter with great strength, wear resistance, and thermal stability, all aspects making them superior to the traditional monolithic materials [VI]. The balance they offer between mechanical performance and durability makes them essentially desirable in applications subject to punitive situations. Because of developments emerging concerning MMCs, there is also an emergence in hybrid MMCs (HMMCs) with different reinforcements, further improving the functional characteristics of the composite. One of the most widely adopted fabrication methods for -based MMCs is stir casting, a cheap and simple process that ensures reliable dispersion of reinforcement particles within the metal matrix [VII]. Several factors such as stirring speed, stirring time, position of the impeller, holding temperature, and melting point influence the quality and uniformity of the composite [VIII, IX]. Stir casting remains one of the most viable methods for large-scale production of MMCs, ensuring homogeneity in microstructure and desirable mechanical behaviour [X].

Aluminium-based Metal Matrix Composites (MMCs) are increasingly used in aerospace, civil, and transportation sectors due to their superior mechanical properties. Among various alloys, AA7050—a heat-treatable aluminium-zinc alloy—is widely preferred in aerospace applications for its high strength, toughness, and resistance to stress corrosion cracking. To further enhance its performance, graphite particles (3% by weight) are added as reinforcement, forming a novel composite (AA7050 + 3% Graphite) that combines the robustness of AA7050 with the advantageous characteristics of graphite. Graphite offers low density, excellent thermal and electrical conductivity, dimensional stability, and solid lubrication, thereby improving wear resistance, machinability, and thermal dissipation under operational stresses [XXII – XXIV].

While typical aluminium-based MMCs utilize reinforcements like Al_2O_3, SiC, or B_4C to enhance mechanical and thermal properties, this study focuses solely on graphite to examine its specific effect on machinability. Applications of such MMCs span across nuclear power plants, automotive parts, electronics, and medical devices [XIII–XIX]. Graphite-reinforced MMCs are particularly useful in automotive components like brake rotors and connecting rods, where weight reduction and wear resistance are crucial [XX, XXI].

Despite improved properties, graphite reinforcement complicates machining. Conventional methods like milling or turning face issues such as tool wear and poor surface finish. Therefore, non-traditional processes like Wire Electrical Discharge Machining (WEDM) are explored. WEDM, illustrated in Figure 1, uses electrical discharges to machine conductive materials precisely, offering an efficient solution for difficult-to-machine composites [XXIV, XXV].

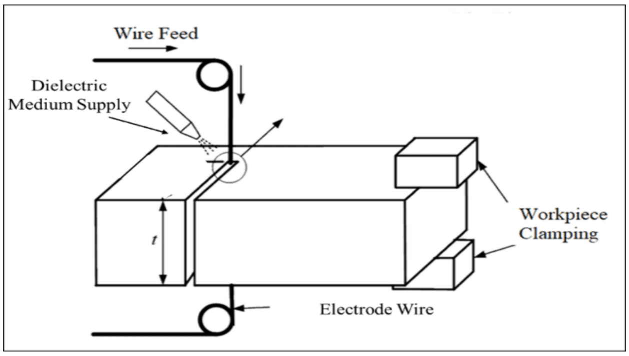

Fig. 1. Schematic of WEDM

Wire Electrical Discharge Machining (WEDM) is highly effective for machining intricate profiles and achieving tight tolerances in MMCs, making it suitable for evaluating the machinability of AA7050 + 3% Graphite composites. To optimize machining performance, a statistical design approach using the Taguchi method is adopted. This technique reduces the number of experiments while identifying optimal parameter combinations. Key WEDM parameters—pulse-on time, pulse-off time, and peak current—are varied to study their effects on material removal rate, surface roughness, dimensional deviation, and form/orientation tolerance. The complexity of evaluating multiple performance outputs is addressed using Grey Relational Analysis (GRA), which consolidates them into a single metric called Grey Relational Grade (GRG). Though GRA is effective for multi-objective optimization, it is limited by the uncertainty in weight assignment. To overcome this, intelligent modelling tools are integrated.

An Adaptive Neuro-Fuzzy Inference System (ANFIS) is developed to model and predict machining behaviour. ANFIS combines the learning capabilities of neural networks with the reasoning power of fuzzy logic [XXIX – XXXI], enabling it to capture non-linear relationships between WEDM parameters and performance metrics. The model is trained using experimental data derived from Taguchi-GRA analysis, with WEDM parameters as inputs and GRG as output. This allows for accurate prediction and real-time control of machining processes. Dimensional and geometric precision is essential in manufacturing. This study investigates perpendicularity error, a critical form tolerance, and its control through WEDM parameters to enhance component functionality and assembly precision [XXXII, XXXIII].

From the available literature, it is noticed that the development of AA7050 + 3% Graphite metal matrix composites needs great attention in contemporary engineering applications. The machining of this material with WEDM offers a viable solution for accomplishing intricate shapes and precision. To optimize and forecast machining performance, a hybrid framework that entails the Taguchi method, Grey Relational Analysis, and ANFIS modelling has been fruitfully adopted. The study offers a pathway for enhancing machining accuracy, productivity, and dimensional control in advanced composite materials.

II. Materials and Methods

This study examines a casting material produced via the stir casting process, that is, a metal matrix composite (MMC), AA7050 reinforced with graphite (3 percent weight). The composite is prepared with a 97% AA7050 alloy matrix and a reinforcement of 3 percent graphite particles. Its use can improve a variety of mechanical and thermal properties, which also make this MMC a good candidate where there is a need to have a high strength-to-weight ratio, technical applications including aerospace industries like aircraft wings. It is also dimensionally stable and wear-resistant, which makes it useful in different precision engineering products.

For the machining of the fabricated MMC, a Wire Electrical Discharge Machining (WEDM) setup was utilized. The machine employed is a Concord-make DK 7732 model, using a molybdenum wire as the electrode. The schematic representation of the WEDM setup is provided in Figure 2. The output responses chosen for evaluation in this study include Material Removal Rate (MRR), Surface Roughness (SR), Dimensional Deviation (DD), and orientation tolerance. The composite specimen is machined into a square hole geometry during the trials.

Fig. 2. Experimental Setup (a. Stir Casting for fabrication b. WEDM for Machining)

The MRR is calculated based on the weight loss method using a precision Contech weighing machine with an accuracy of 0.0001 g. To evaluate the surface finish, a contact-type surface roughness tester (Make: Mitutoyo, Model: Surftest SJ-310) is employed. The orientation error, which reflects geometric accuracy, is measured using a Coordinate Measuring Machine (CMM) of Helmel make. Each experimental condition is repeated three times to ensure consistency and repeatability, and the mean values are considered for further analysis. The focus of the current study is on three independent process parameters in WEDM, namely pulse duration (on/off) and Peak current (A).

Table 1. Factors and their levels

Symbols	Factors	Levels		
		1	2	3
A	Pulse On - 'T_{on}' (μs)	10	20	30
B	Pulse Off – 'T_{off}' (μs)	5	10	15
C	Peak Current - (A)	1	2	3

The selected parameter levels for each of these variables are listed in Table 1. For a better understanding of how these variables influence the chosen output characteristics, experimentation with different combinations of input factors is necessary. The Taguchi method is best suited for this as it is a truly reliable tool for robust design and analysis. The experimental layout for the specific design used a Taguchi L27 Orthogonal Array (OA), which allows different combinations of inputs to be systematically experimented with, with the minimum number of runs, while at the same time, the significance of each factor can be tested for different levels. This would provide a pathway to understanding the optimal machining conditions as well as to provide insight into the individual and interactive effects of the process parameters on machining performance.

III. Results and Discussion:

The influence of process parameters in WEDM of AA7050-Graphite (3%) metal matrix composite was analysed using an L27 Orthogonal Array. The aim of this study is to determine the significant factors affecting the machining performance. Output responses were evaluated as Material Removal Rate (MRR), Surface Roughness (SR), Dimensional Deviation (DD), and orientation error. The goal was to maximize MRR, while minimizing both SR and DD and orientation error. This systematic scheme will help develop a robust WEDM process for this composite to perform high-quality and accurate machining appropriate for aerospace and engineering applications that require very high strength-to-weight ratios and extremely tight dimensional tolerances.

III.i. Ascendency of Variables on MRR:

As shown in Figure 3, the MRR in WEDM of AA7050-Graphite (3%) composite increases with the increase of pulse-on/pulse-off durations and peak current. This means that a longer pulse-on time would cause greater energy to be input per discharge, creating further localized melting and vaporization thermal erosion, whereas an extended pulse-off time would give enhanced flushing of debris in terms of a more stable discharge condition.

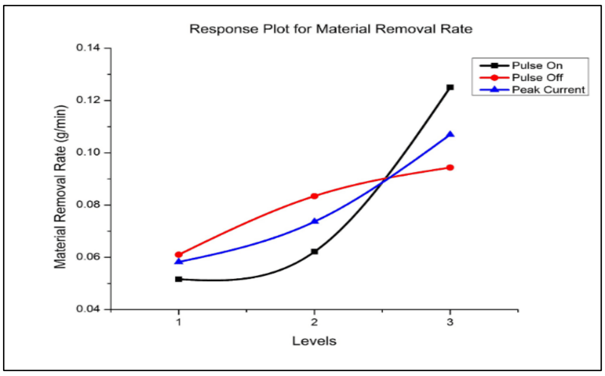

Fig. 3. Response plot for MRR

An increase in peak current further raises discharge energy, resulting in higher localized temperatures and accelerated material removal. Among the parameters, pulse-on time ('Ton') is identified as the most influential factor affecting MRR. The optimal parameter combination for maximizing MRR is A3B3C3—i.e., high 'Ton' (30 µs), high 'Toff' (15 µs), and high peak current (3 A).

III.ii. Ascendency of Factors on SR:

In the WEDM of AA7050–Graphite (3%) composite, surface roughness is significantly influenced by key machining parameters such as pulse-on time, pulse-off time, and peak current, as shown in Figure 4.

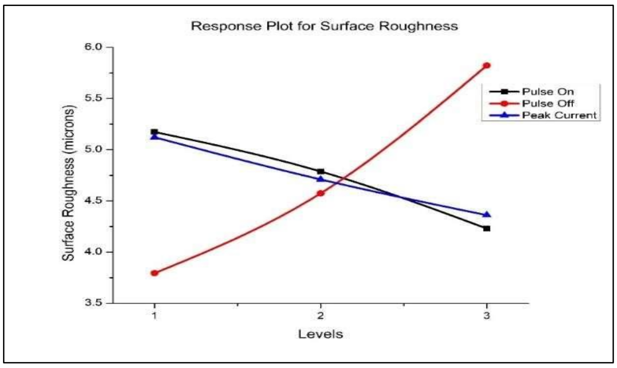

Fig. 4. Response plot for SR

An increased pulse-on time ('Ton') enhances energy discharge, promoting uniform melting and vaporization, which leads to a smoother surface. Higher peak current supplies greater thermal energy, reducing irregularities caused by partial melting or debris adhesion. Conversely, a longer pulse-off time ('Toff') can worsen roughness by allowing debris to solidify, creating micro-defects. The analysis confirms that 'Toff' is the most influential factor on surface finish. The optimal parameter combination for minimizing surface roughness is A3B1C3—i.e., high 'Ton' (30 µs), low 'Toff' (5 µs), and high peak current (3 A).

III.iii. Ascendency of Factors on Dimensional Deviation:

In the WEDM of AA7050–Graphite (3%) composite, dimensional deviation is notably affected by key machining parameters such as pulse-on time, pulse-off time, and peak current, as illustrated in Figure 5. An increase in pulse-on time ('Ton') helps reduce dimensional deviation by enabling uniform energy delivery and consistent material removal, thereby minimizing overcut and enhancing dimensional accuracy. On the other hand, a longer pulse-off time ('Toff') may lead to greater deviation due to debris formation and inconsistent discharges, affecting machining stability. Similarly, higher peak current introduces excessive discharge energy, which can cause localized thermal distortion and overcut, resulting in dimensional inaccuracies.

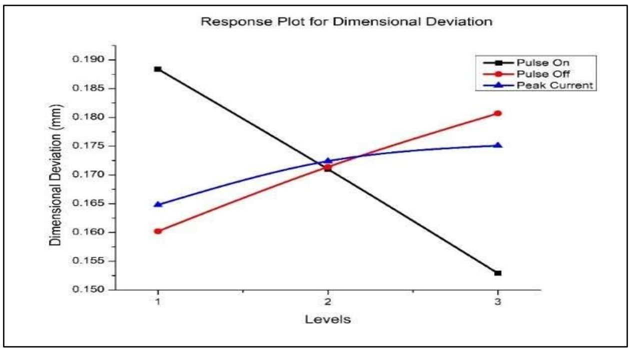

Fig. 5. Response graph for dimensional deviation

The findings highlight the importance of optimizing WEDM parameters to achieve precise dimensional control in machining AA7050–Graphite composites. The study confirms that 'Ton' is the most influential factor affecting dimensional accuracy. The optimal parameter setting identified is A3B1C1—i.e., high pulse-on time (30 µs), low pulse-off time (5 µs), and low peak current (1 A)—which yields improved dimensional precision.

iii.iv. Ascendency of Factors on GD&T error:

In the WEDM of AA7050–Graphite (3%) metal matrix composite, GD&T (Geometric Dimensioning and Tolerancing) errors, as shown in Figures (6&7), encompassing perpendicularity and squareness deviations, are critically influenced by machining parameters such as pulse-on time ('Ton'), pulse-off time ('Toff'), and peak current. An increase in 'Ton' duration significantly improves form and orientation accuracy by delivering consistent energy discharge, ensuring uniform material removal and minimizing deviations in geometry. Conversely, a higher 'Toff' duration adversely affects machining consistency, leading to debris accumulation and fluctuations in the cutting path, thereby increasing both perpendicularity and squareness errors. Similarly, elevated peak current enhances material removal but introduces excessive thermal stress and localized overcut, resulting in dimensional and form distortions. The study highlights that among all variables, 'Ton' is the most influential factor in controlling GD&T errors. The optimal parameter setting identified—A3B1C1 (Ton at 30 µs, Toff at 5 µs, and peak current at 1 A)—offers enhanced geometric accuracy, minimizing form and orientation deviations and ensuring precision machining of AA7050–Graphite composites.

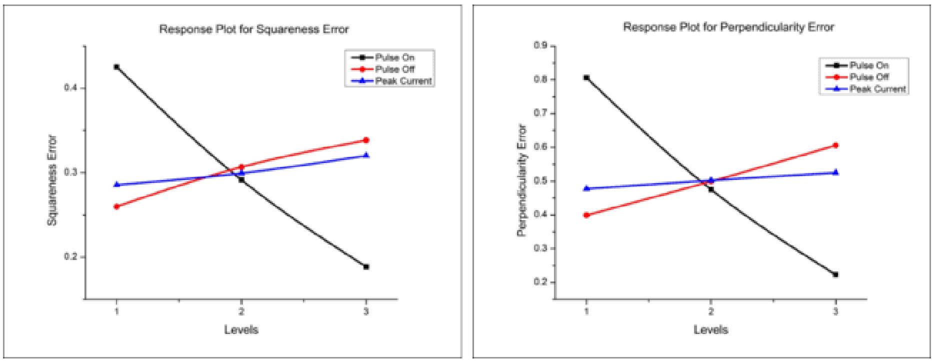

Fig. 6. & 7. Response graph for orientation error

IV. Analysis on WEDM-Processed Composites:

The SEM image of the fabricated AA7050–Graphite (3%) metal matrix composite, as shown in Figure 8, confirms a uniform dispersion of graphite particles throughout the matrix. This homogeneous distribution plays a vital role in enhancing the mechanical and thermal characteristics of the composite. The microstructural evaluation of the WEDM-machined surface reveals notable changes resulting from the intense thermal and electrical energy input inherent to the process. The localized heat generated during electrical discharges causes rapid melting and vaporization of the material at the interface, leading to the formation of a recast layer—a thin layer of re-solidified material formed during the rapid cooling phase following each discharge.

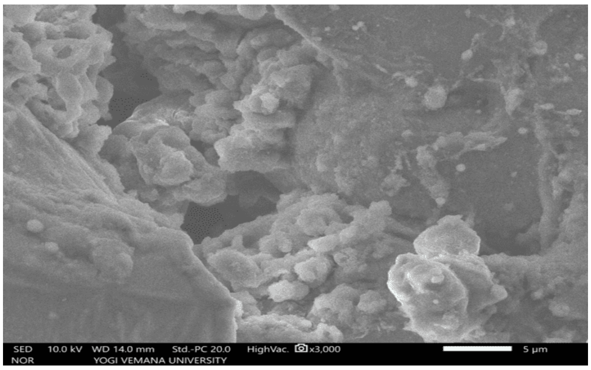

Fig. 8. SEM Micrograph of WEDM Machined Sample

This is an imprint of the repetitive thermal cycles within WEDM that, in terms of micro-structure changes, serves as a place where there may possibly exist a micro-crack or porosity resulting from the residual stresses caused by extreme thermal gradients. These microstructural defects, most of the time, would be found in the recast layer itself or around it, and may contribute to surface integrity and reliability of a machined part. Again, redeposited solidified debris on the surface gives texture to the machined surface, and those may change functional performance or fatigue life in some way. "Overall, SEM could demonstrate complex interactions of machining parameters, thermal effects, and materials behaviour, providing insight into surface morphology and structural integrity of AA7050–Graphite composites processed by WEDM."

V. Development of ANFIS structure for WEDM - MMC (AA7050+Graphite)

To build a predictive model of the Grey Relational Grade (GRG), the MATLAB ANFIS toolbox was utilised. The model was created and programmed to have three working input parameters and one output GRG. Table 2 explains the training process carried out using experimental data to effectively plot the relationship between the variables of the process and the performance results. The static model of the membership function was changed to triangular (trimf), and 27 rules of fuzzy inference were generated automatically using the input dataset.

Table 2. ANFIS Training variables for WEDM of HMMC

No. of membership functions	3 3 3
Input 'mf' opted	trimf
Output 'mf' opted	constant
Optimizing Approach	Backpropagation
Tolerance of Error level	0
Epochs numbers opted	500

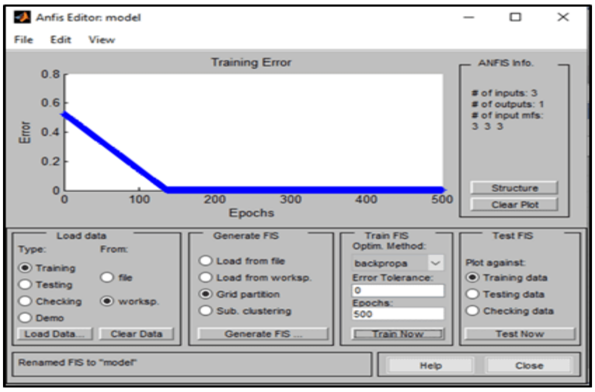

Fig. 9. ANFIS Editor

The GRG values obtained due to model training were derived with the help of the Grey Relational Analysis (GRA), which is a regular method of the Multi-Criteria Decision Making (MCDM). Figure 9 demonstrates the architecture of the developed model with the help of the ANFIS editor. After training the ANFIS model, the ANFIS-GRG prediction model successfully predicted multiple performance indices, and this shows that the ANFIS model can capture the nonlinear relationship between the process parameters in the WEDM process.

V.i. Interpretation of Outcomes of ANFIS analysis for GRG:

Figures 10–12 present the surface plots illustrating the influence of key WEDM parameters on the Grey Relational Grade (GRG) during machining of the AA7050 + 3% Graphite composite. The input data for the ANFIS model development are provided in Table 3.

Figure 10 depicts the surface plot of GRG as a function of pulse on-time ('Pon') and pulse off-time ('Poff'). The plot indicates that maximum GRG is attained when 'Pon' is at its highest level and ‘Poff’ is at its lowest. This combination facilitates sustained energy discharge, resulting in more efficient material removal and enhanced performance across multiple machining objectives.

Table 3: GRG values attained for WEDM of HMMC

S.NO	Input			GRG Output	
	Pulse on (µs)	Pulse off (µs)	Peak current (A)	GRG	ANFIS GRG
1	10	5	1	0.4668	0.4665
2	10	5	2	0.4706	0.4703
3	10	5	3	0.5007	0.5000
4	10	10	1	0.4095	0.4093
5	10	10	2	0.4120	0.4118
6	10	10	3	0.4146	0.4142
7	10	15	1	0.3799	0.3798
8	10	15	2	0.3707	0.3706
9	10	15	3	0.3737	0.3735
10	20	5	1	0.5109	0.5100
11	20	5	2	0.5463	0.5456
12	20	5	3	0.5552	0.5534
13	20	10	1	0.5041	0.5036
14	20	10	2	0.5064	0.5060
15	20	10	3	0.5105	0.5096
16	20	15	1	0.4480	0.4478
17	20	15	2	0.4544	0.4542
18	20	15	3	0.4524	0.4520
19	30	5	1	0.8216	0.8197
20	30	5	2	0.7241	0.7225
21	30	5	3	0.7208	0.7168
22	30	10	1	0.6010	0.6000
23	30	10	2	0.6141	0.6134
24	30	10	3	0.6525	0.6506
25	30	15	1	0.5347	0.5343
26	30	15	2	0.5452	0.5449
27	30	15	3	0.6520	0.6512

Figure 11 displays the GRG surface plot against ‘Pon’ and peak current. The GRG improves significantly under conditions of high ‘Pon’ and elevated peak current, suggesting that the synergistic effect of longer discharge duration and intensified energy input leads to better performance metrics, including improved MRR and surface quality.

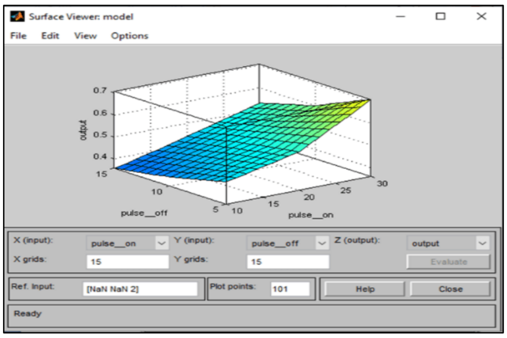

Fig. 10. Surface plot for ANFIS-GRG vs Pulse duration (on/off)

Figure 12 illustrates the GRG as a function of 'Poff' and peak current. Here, the GRG peaks when 'Poff' is minimized and peak current is maximized. Reducing the idle time while increasing the discharge energy promotes consistent material erosion and minimizes irregularities, contributing to optimal machining outcomes. These surface plots clearly highlight the critical role of parameter interaction in optimizing the WEDM process for AA7050-Graphite composites.

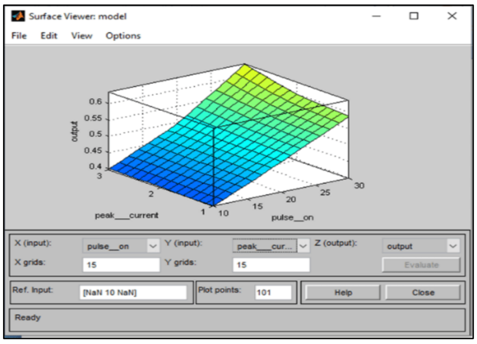

Fig. 11. Surface graph for ANFIS-GRG vs Pulse on and Peak Current

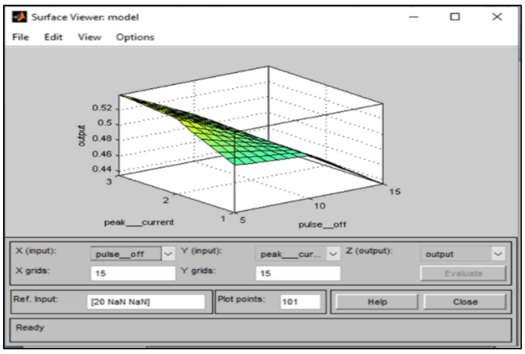

Fig. 12. Surface graph for ANFIS-GRG vs Pulse off and Current

The trained ANFIS model was used to identify the candidate optimum condition from the GRG response surfaces. The response surfaces indicate that higher GRG is associated with a high pulse-on time and low pulse-off time. Based on the ANFIS-GRG analysis, the candidate optimum condition was identified as Ton = 30 µs, Toff = 5 µs, and peak current = 1 A (A3B1C1). This condition corresponds to Run 19 of the L27 experimental design. The experimental GRG obtained at this condition was 0.8216, while the corresponding ANFIS-predicted GRG was 0.8197, giving an absolute difference of 0.0019. Thus, the ANFIS-identified candidate optimum shows close agreement with the experimentally obtained GRG. Since Run 19 was already experimentally machined at the identified condition, its measured result was used for experimental verification rather than performing another trial at the same parameter combination. The individual machining responses, namely MRR, SR, DD, and GD&T/orientation error, were experimentally measured and incorporated into the GRA procedure to obtain the GRG. Since the developed ANFIS model uses these machining parameters as inputs and GRG as the single output, the model validation is therefore presented in terms of the experimental and predicted GRG at the identified optimum.

V.ii. Analysing Performance of evolved ANFIS model:

The deviation between the experimental data and the predicted values generated by the developed model is referred to as the **prediction error**. To assess the performance and accuracy of the developed model, various statistical evaluation metrics are computed, including **Mean Absolute Percentage Error (MAPE)**, **Root Mean Square Error (RMSE)**, and the **Coefficient of Correlation (R)**. These metrics are calculated using the standard equations.

The results generated by the ANFIS structure for the WEDM of the AA7050 + Graphite (3%) metal matrix composite were thoroughly analyzed and compared against the corresponding experimental findings. A strong correlation was observed between the actual and predicted results, indicating high accuracy of the developed model.

Table 4. Performance Metrics of ANFIS Model

Model - ANFIS	
Errors/Metrics	**Error Values**
MAPE	0.13600
RMSE	0.00113
MAE	0.00136
Correlation Coefficient	0.9999

The model's performance evaluation was carried out using Equations (1)–(3), with detailed results presented in **Table 4**. **Figure 13** illustrates the computed values for Root Mean Square Error (RMSE) and Mean Absolute Error (MAE), while **Figure 14** shows the Mean Absolute Percentage Error (MAPE) and the correlation coefficient (R).

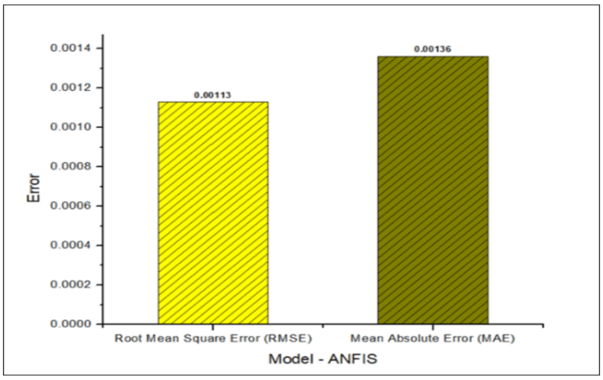

Fig. 13. Errors obtained from the developed ANFIS model

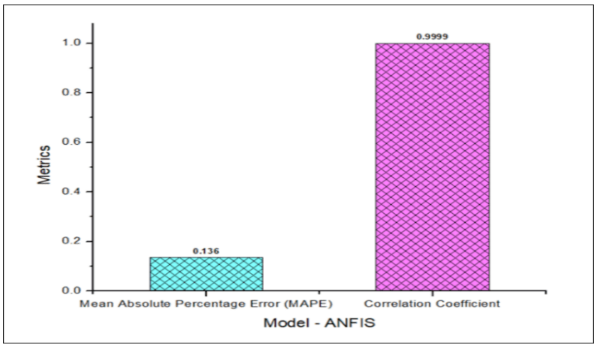

Fig. 14. Outcomes of Analysis of ANFIS model

The comparison between experimental and predicted values confirms a close agreement, demonstrating the predictive reliability and efficiency of the ANFIS model for machining AA7050 + Graphite (3%) composites using the WEDM process.

V.iii. ANOVA analysis on performance measures:

The statistical significance and percentage contribution of Ton, Toff, and peak current on MRR, SR, DD, orientation error, and GRG were studied by analysis of variance (ANOVA) as shown in Table 4. The dominant parameter for MRR, DD, orientation error, and GRG at 95% confidence level was Ton (42.53%), DD (56.82%), orientation error (86.01%), and GRG (71.64%) with $P < 0.001$ in each case. Peak current was likewise significant for MRR (P=0.016) although 'Toff' was insignificant (P=0.119). For SR, all three parameters were significant ($P < 0.001$) with 'Toff' contributing the highest (68.57%) followed by 'Ton' (14.72%) and peak current (9.50%).

Table 4. ANOVA on performance measures for WEDM of HMMC

Source	DF	Seq SS	Adj SS	Adj MS	F	P
MRR						
Pon	2	0.028394	0.028394	0.014197	12.91	0
Poff	2	0.005209	0.005209	0.002605	2.37	0.119
Current	2	0.011163	0.011163	0.005581	5.08	0.016
Error	20	0.021993	0.021993	0.0011		

Total	26	0.066759				
SR						
Pon	2	4.0466	4.0466	2.0233	20.41	0
Poff	2	18.849	18.849	9.4245	95.05	0
Current	2	2.6107	2.6107	1.3054	13.17	0
Error	20	1.9831	1.9831	0.0992		
Total	26	27.4894				
DD						
Pon	2	0.00569	0.00569	0.002845	29.66	0
Poff	2	0.001887	0.001887	0.000943	9.84	0.001
Current	2	0.000518	0.000518	0.000259	2.7	0.092
Error	20	0.001918	0.001918	9.59E-05		
Total	26	0.010013				
CIR						
Pon	2	0.253413	0.253413	0.126707	378.36	0
Poff	2	0.028043	0.028043	0.014021	41.87	0
Current	2	0.005421	0.005421	0.002711	8.09	0.003
Error	20	0.006698	0.006698	0.000335		
Total	26	0.293575				
PERP						
Pon	2	1.5418	1.5418	0.7709	320.22	0
Poff	2	0.19234	0.19234	0.09617	39.95	0
Current	2	0.01031	0.01031	0.00515	2.14	0.144
Error	20	0.04815	0.04815	0.00241		
Total	26	1.7926				
GRG						
Pon	2	0.243882	0.243882	0.121941	92.85	0
Poff	2	0.068184	0.068184	0.034092	25.96	0
Current	2	0.0021	0.0021	0.00105	0.8	0.463
Error	20	0.026266	0.026266	0.001313		
Total	26	0.340431				

'Ton' and 'Toff' were significant for DD while peak current was not (P = 0.092). Similarly, 'Ton' and 'Toff' were significant for orientation error but peak current was not significant (P = 0.144). For GRG, Ton and Toff were statistically significant with a contribution of 71.64% and 20.03%, respectively. Peak current had a statistically insignificant (P = 0.463) minimal impact of 0.62%. Therefore, the main parameters controlling the total machining performance are 'Ton' and 'Toff'. Among these, Ton has the most influence on the combined GRG response.

VI. Conclusions

This exploratory analysis emphasizes the experimental investigation of WEDM on AA7050 + Graphite (3%) metal matrix composite. A hybrid ANFIS-based intelligent decision-making model was developed to predict the required multi-performance index effectively. The outcomes of this study reveal the following significant findings:

1. Stir casting was employed to fabricate the AA7050 + Graphite (3%) metal matrix composite, ensuring uniform dispersion of graphite reinforcement within the aluminium matrix.
2. Key process parameters in WEDM were observed to significantly influence performance outcomes such as Material Removal Rate (MRR), Surface Roughness (SR), Dimensional Deviation (DD), and GD&T-related errors.
3. In a single-objective optimization study on the WEDM of the AA7050 + Graphite (3%) composite, it was found that pulse-on duration is the dominant parameter under consideration for performance indicators.
4. The ANFIS prediction model was constructed by employing the Grey Relational Grade (GRG) derived from Grey Relational Analysis (GRA). The greatest experimental GRG of 0.8216 was recorded at Run 19 with Ton = 30 µs, Toff = 5 µs, and peak current = 1 A (A3B1C1), whereas the comparable ANFIS-predicted GRG was 0.8197. The good agreement between the experimental and predicted GRG values indicates the predictive power of the constructed ANFIS model.
5. The ANFIS model performed remarkably in terms of predictive metrics, including a Mean Absolute Percentage Error (MAPE) of 0.136, Root Mean Square Error (RMSE) of .00113, Mean Absolute Error (MAE) of .00136, and a correlation coefficient of 0.9999.
6. Combining GRA and ANFIS modelling for predictions seems to be a robust, reliable, and highly precise method of prediction. The model shows an outstanding correlation coefficient of 0.9999 and can find application in precision machining in aerospace and automotive sectors.

Conflict of Interest:

There is no conflict of interest regarding this article.

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