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Drilling of Aluminum Reinforced with HNT Hybrid Matrix Composites: Effect of Control Parameters

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Abstract

The goal of the current paper is to identify the best control parameters for drilling aluminium hybrid metal matrix composites, including drilling speed, feed rate, HNT and boron nitride weight percentages, respectively. HNT (3%, 5%, and 7%) and BN (2%, 3%, and 4%) in varying weight percentages are used to reinforce the aluminium matrix material. The sir casting technique is used to create the hybrid matrix. Using grey relation analysis with assistance from Taguchi, process parameter predictions are optimised. Moreover, an ANN model is created to forecast the output parameter. The effects of each control parameter are optimised using the Taguchi S/N ratio approach. The findings indicate that the feed rate and weight percentage of HNT are the two factors that have the greatest influence on the drilling of.

1. Introduction

Composites made of aluminium and metal are becoming more and more significant in today's industrial technological trends. They had grown significantly in popularity and significance as a result of their distinctive mechanical and physical characteristics. Composite materials have largely replaced conventional ferrous materials in the automotive sector due to their excellent strength and wear resistance. To increase the mechanical strength, wear resistance, and corrosion resistance of aluminium alloys, ceramic particles are frequently utilised [1]. Aluminum composites have much better properties than alloys or other metals, including high tensile strength, toughness, stiffness, low density, and exceptional wear resistance. Composite materials with low densities and prices have drawn a lot of interest [2]. Processes including milling, turning, and drilling as well as temperature changes are quite difficult because of the materials' tough reinforcements. Ultimately, there is more vibration, poor surface quality, and greater tool wear.

the drilling process's end outcome [3]. The created matrix must go through sufficient control parameter optimization in order to achieve proper drilling quality and find proper surface quality [4]. Input parameters can be applied to any optimization technique to provide results like an increase in material removal rate, a decrease in surface roughness, and a minimization of the building process [5]. The right input parameters can be chosen by choosing from a variety of optimization processes. Increasing the spindle speed and optimising the feed rate will result in a higher material removal rate, but doing so will also result in higher machining temperatures and poorer surface finishes. In order to achieve optimum MRR and lowest surface finish with a reduced cutting force, these response parameters must be tuned [6]. Most of the mechanical properties of MMC are determined by the amount of reinforcement and the abridgment procedure. Poor wettability is caused by an increase in porosity as the reinforcing percentage rises. The density is to blame for this.

here is a difference between the base alloy and the reinforcing, thus the casting technique must be properly chosen [7]. To investigate the machinability characteristics of hybrid composites made of SiC and graphite-reinforced aluminium matrix, Pal- anikumar and Muniaraj employed carbide drills of various diameters. They claimed that the most crucial machinability parameters for metal-matrix hybrid composites were cutting force and feed [8]. In this research, Al2219/15SiCp and Al2219/15SiCp-3Gris hybrid metal matrix composites (MMCs) were tested to see how cutting settings affected drilling characteristics. These composites' drilling properties are investigated using Taguchi experiment design and variance analysis (ANOVA). The findings showed that the ceramic reinforcement SiC + Gr has superior characteristics in comparison to SiC alone [9]. According to Karabulut et al. [10], milling Al-6061/B4C MMC with 5, 10, 15, and 20% B4C was explored. As B4C is increased, the hardness of the MMC has been seen to grow, reaching its maximum hardness at 20% B4C. Yet, the impact resistance decreases as the percentage of B4C rises. The optimal surface polish seems to be 15% B4C at high speed, low feed rate, and dry cutting conditions [10]. Kavimani et al. [11] employed Taguchi-based GRA coupled PCA to analyse the machining reactions on WEDM performed on Mg-based materials.

The trials' findings indicate that MRR and Ra are the variables that have the most influence. Principal component analysis coupled with hybrid GRA was used to evaluate the replies for many objectives in order to determine the weighting values. The optimal value was chosen based on each performance, and the results obtained using the best combination were discovered to have a maximum MRR of 14.9 ml/min and a Ra of at least 2.04 m [11].

2. Experimental Details

Materials and Methods

Specimen Preparation. Aluminum alloy 5052 is chosen as a matrix material due to its high fatigue strength and corrosion resistance. The chemical composition of Al5052 isshown in Table 1. HNT was chosen as a primary re- inforcement with weight percentage of 3, 6, and 9. The chemical compound or the molecular chemical formula of HNT is ($H_4AL_2O_9$ $Si_2.2H_2O$). HNT is a low-cost materialand it is widely used in many medical fields, especially for anticancer medical aid. The material mainly contains alu- minum and silica, which shows high strength-to-weight ratio, better corrosion properties, and high wear re-sistance. The HNT has high bonding between the surfaces ofthe matrix material due to its anisotropic arrangement of carbonyl groups. Al203 is the outer part of HNT, whereas the inner core material is silicon dioxide (Sio2). Mainly HNT isused as a culpableness for plastic filler agent and also for bone implants. In this current research work the compo- sition of HNT is, Al_2O_3-35.4, Fe_2O_3-0.39, TiO_2-0.15, MgO- 0.16, Na_2O-0.20, and SiO_2-48.8. The secondary re- inforcement was chosen as Boron Nitride with a weight percentage of (2, 3, and 4) due to its wettability and self- lubricant nature.

Table 1: Chemical composition of Al 5052.

Mn	Fe	Cu	Mg	Si	Zn	Cr	Ti	Zr	Bal
0.10	0.35	0.8	2.60	0.20	0.25	0.30	0.05	0.10	Al

Fabrication Technique. The matrix material Al 5052 was fabricated by using a combo-casting process. Initially Al5052 was heated upto 720 °C, in muffie furnace the both the re- inforcement

HNT and Boron Nitride (BN) are preheated. Meanwhile, the molten material was cooled down to 575 °C during that process, the preheated reinforcement material was added to the slurry and stirred at 500 rpm continuously for 10 minutes [12]. After that, the molten material is poured into a required die and cooled down. The several combinations of Aluminum hybrid matrix are shown in Table 2.

Table 2 shows the hardness value of newly developed composites. The hardness of the composites was measured using Vickers hardness test. The hardness value of 39.7 HV exhibits at 7%, and 4% of boron nitride shows high hardness value. On increase in weight, percentage of reinforcement shows higher hardness value.

Drilling Experimental Setup. The hybrid composites are shaped into 70 mm 40 mm 10 mm for the purpose ma- chining process. In this process, optimization of ×drilling× process parameters is chosen as the machining process. The high speed steel (HSS) is used as a drilling tool with a diameter of 8 mm. For each of the three experiments, the drill bit is changed in order to reduce the error. The tests were performed on a three-pivot CNC machining focus which has an axle speed scope of 60–6000 rpm with an 802D BMV 40 320D control framework. The surface roughness (Ra) of the processed ex- ample was estimated by the MITUTOYO SJ 210M convenient surface unpleasantness gadget [13]. The cutting power was estimated by a Kistler 9257B 3-part dynamometer, and a Kistler 5070A enhancer was utilized to intensify the signals.

Process Parameters. The control parameters chosen in this experiments are four factor and three levels as shown in Table 3. The weight percentage of HNT and weight per- centage of BN along with feed rate and drilling speed are the process parameters. Based on the literature and expert analysis, the experiment parameters are chosen.

L_{27} Orthogonal Array. In this current experimental plan, it is intended to distinguish the impact of parameters like weight % of HNT, weight level of boron nitride, cutting rate and cutting feed over cutting speed, temperature, MRR, and surface roughness. To break down the cycle boundaries, the test configuration was finished utilizing Taguchi or- thogonal array to limit the number of experiments [14]. In light of the Taguchi plan, L_{27} symmetrical exhibit was chosen depending on the total degrees of freedom.

Taguchi S/N Ratio Analysis. The deviation between

TaBlE 2: Composition of aAluminum MMC with hardness.

HNT	3	3	3	5	5	5	7	7	7
BN (%)	2	3	4	2	3	4	2	3	4
HV	31.4	32.9	33.8	34.2	35.7	36.9	37.2	38.5	39.7

TaBlE 3: Control parameters and corresponding levels.

S. no	Factors	Unit	Values

			I	II	III
1	Weight percentage of HNT	%	3	5	7
2	Weight percentage of BN	%	2	3	4
3	Spindle speed	rpm	500	1000	1500
4	Feed rate	mm/min	20	40	60

strategy, the output factors are investigated as far as signal-to- noise (S/N) proportion, it is used for measuring the noise factor[15]. The legitimate S/N proportion computation standards should be picked among three measures to be specific "Larger is better," "Medium is better," and "Smaller is better." As the goal is to limit the surface roughness, temperature, and cutting force, "MRR larger is better" rules are chosen.

Stage 3. Ascertain real yields utilizing the sigmoidal nonlinearity given in condition 3.

$$f\left(net_i\right) = \frac{1}{1-e^{-net}} \cdot \quad (3)$$

Stage 4. Adjust loads utilizing condition 4

$$w_{ij}(t+1) = w_{ij}(t) + \eta\delta_j o_i, \quad (4)$$

where is the yield of the hub I and η is the learning rate steady and is the afectability of the hub j. Assuming hub j is a yield hub,

$$\delta_j = f'\left(net_j\right)\left(d_j - y_j\right), \quad (5)$$

where d_j is the ideal yield of the hub j and y_j is the genuine yield and is the induction of the initiation work determined at net j. Assuming the hub j is an interior hub, the afectability is characterized as follows:

$$\delta_j = f'\left(net_j\right)\sum_k \delta_k w_{jk}, \quad (6)$$

$$\frac{S}{N}\text{ratio} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \quad (1)$$

where k aggregates over all hubs in the layer over the hub j. Refreshed conditions are determined utilizing the chain induction rule applied to the LMS preparing

For finding the S/N ratio for MRR which has to be increased during machining process, the "larger is better" criteria is selected and the equation is as follows:

basis work.

Stage 5. Repeat by going to stage 2

The least difficult halting basis is to end when the ad-

$$\frac{S}{N} \quad \frac{1}{n} \quad \frac{1}{}$$

justment of the preparation test work is more modest than

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$$N \text{ ratio} = -10 \log \left(\frac{1}{n} \sum_{i=1}^{n} y_i^2 \right), \quad (2)$$

some preset worth θ. A superior methodology is a cross-
approval procedure to quit preparing when the mistake on

where "i" is the number of experiments and "y_i" is the observational results of i^{th} experiments.

Artificial Neural Network Model. ANN is the in- formation process that mind measures data. It comprises of countless interconnected components called neuron work- ing in corresponding to take care of a specific issue [16]. Figure 1 shows the design of a three-layer artificial neural network (ANN). The information neurons are weight per- centage of HNT, weight percentage of Boron nitride, speed, and feed rate, similarly, the yield neurons are surface roughness, temperature during machining, MRR rate, and cutting force. The information and yield estimates are prepared utilizing back propagation algorithm, and 27 ex- ploratory variables are validated and trained.

Preparing the organization with back proliferation cal- culation brings about a nonstraight planning between the information and yield factors. In this manner, given the information/yield matches, the organization can have its loads changed by the back-engineering calculation to catch the nonstraight relationship [17]. It comprises the accom-
a diferent approval set arrives at least. Subsequent to pre-
paring, the organizations with fixed loads can give the yield to the given input.

Grey Relational Analysis. Taguchi S/N proportional examination is restricted to minimize number of experi- ments. To improve the information boundaries for multi- goals such as surface roughness, temperature, material removal rate and cutting force, a multiobjective algorithm along with Taguchi configuration is a better option [18]. Furthermore, the Taguchi plan with GRA is the strongest technique to take care of the multiobjective problems.

Three significant advances are associated with tackling multiobjective response parameters through GRA. The initial step is to standardize the deliberate yield work in- dependently and it is basically the same as the S/N pro- portion estimation in Taguchi technique where various models are followed. The "smaller is better" standardization condition is chosen for minimizing surface roughness, temperature, and cutting force which the formula can be written as follows:
panying advances:

$$Y_{ij} = \frac{z_{ij} - \min z_{ij}}{\max z_{ij} - \min z_{ij}}. \quad (7)$$

Stage 1. Instate loads and balances
Stage 2. Present Input and Desired Output variable

In the event of material removal rate, the used for in- creasing MRR is "larger is better" and the condition is as follows:

inference, it can be relatively said that the hardness value is

Efect of Process Parameters on MRR. Figure 3(a) shows the efect of MRR along with HNT and boron nitride. It shows that minimum percentage of HNT and maximum 4%

$$Y_{ij} � \frac{Z_{ij} - \min z_{ij}}{\max z_{ij} - \min z_{ij}}, \quad (8)$$

of boron nitride increases in material removal rate. From the

the main factor for MRR. The lower hardness is easily to be machined [20]. Figure 3(b) shows the efect of speed and feed

where Z_{ij} is the worth obtained from the trial information, min (Z_{ij}) is the base worth from the ex- amination. Additionally, max (Z_{ij}) is the most extreme deserving is acquired from the test for that specific parameter.

The second step is to calculate grey relational coefficient for the normalized data using the following equation:

where i � 1, 2, 3, . . ., n j � 1, 2, 3, . . ., m

where i � 1, 2, 3, . . . n j � 1, 2, 3, . . . m

GRC_{ij} is grey relational coefficients for the i^{th} try/ preliminary and j^{th} subordinate variable/reaction value. δ outright unique among y_{oj} and y_{ij}, which is a distinction from the objective esteem and can be treated as a quality misfortune. It is the distinctive coefficient, which is gen- erally fixed at 0.5.

The final step is to create grey rational grade for all experimental data. This is to find the optimum combination for the multiresponse parameters of these aluminum composites. The GRG is determined using the following equation:

over the developed composites. At 1500 rpm and 60 mm/ min MRR increases.

Efect of Process Parameters on Temperature. Figure 4(a) shows the influence of process parameters on temperature. The mean efect plot shows the relation be- tween HNTand boron nitride. Addition of HNTover 6% the hardness is increased, drilling the harder composites are challenging for machining, subsequently the increase in temperature happens at maximum percentage of HNT re- inforcement and boron nitride. The feed rate is the second afecting component for increase in temperature during drilling process. Increase in feed rate above 40 mm/min results in higher volume of material is eliminated from the workpeice that requires enormous amount of force is needed to eliminate the chip which results in higher amount of material is removed results in rise in temperature [21]. The vibration of the instrument at the most extreme at the maximum depth of cut and point of contact is high at this point which increases the temperature .

$$n \frac{1}{n}$$

3.5. Efect of Process Parameters on Cutting Force.

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GRG_{ij} � GRC_{ij}. (9)
i�0

3. Results and Discussion

Analysis of the signal-to-noise ratio. Table 4 lists the experimental findings for the corresponding input control parameters for the L27 orthogonal array. The ideal decision is suggested by the S/N ratio value for each level of response parameters, and the most important parameters can be chosen by the S/N ratio rank order.

Surface Roughness and Process Parameters The effect of process parameters on surface roughness between boron nitride and HNT is depicted in Figure 2(a). We have the minimum surface roughness value at 3% of HNT and 2% with the minimum feed rate. The most important variables that affect the surface finish are the feed rate and HNT %. The effect of the control parameter on the relationship between speeds and feed rate is depicted in Figure 2(b). The surface smoothness is better when drilling at a lower feed rate and a medium speed in the speed-feed rate relationship. Increased composite hardness typically results in unsatisfactory surfaces since developed composites have higher levels of hardness. Machine work is challenging for the harder component. The composite has a 39.7 HV hardness at 7% HNT and 4% BN. Drilling and chip removal are quite challenging in this scenario [19]. 5(a) shows the efect of process parameters on cutting force on HNT and boron nitride. The increase in weight percentage of reinforcement increases the hardness of the developed composites. While machining the harder com- posites, it is very difficult to drill which results in increased cutting force [22]. Figure 5(b) shows the efect of process parameters on cutting force BN and feed rate. Increased feedrate increases the cutting force due to continual chip re- moval from the cutting zone, which becomes tougher with time, enhancing the build-up edge and making machining more difficult [23]. In addition to increasing the cutting forces due to the hard ceramic particles present in HNT included in the aluminum alloy, the amount of re- inforcement also increases the drilling process difficulty.

Grey Relational Analysis. The Taguchi S/N ratio and ANN model is used to predict only single objective function. In order to find the optimum combination of multiresponse function GRA is pursued.

Table 5 shows the normalized value for response pa- rameters for GRA.

Figure 6 shows the overall combination of control pa- rameter in drilling of developed aluminum composites using grey relational analysis. 3% of HNT, and 4% of boron nitride and 500 rpm of spindle speed and at 20 mm/min exhibits lower surface roughness, reducing in cutting force, lowering in the drilling temperature, and an increase in material removal rate. Table 6 shows the ANOVA results for overall

BN% MRR

Speed Temp

H
2

Fe Cutti

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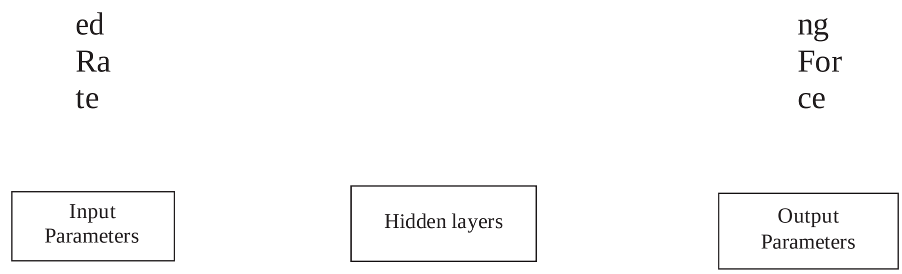
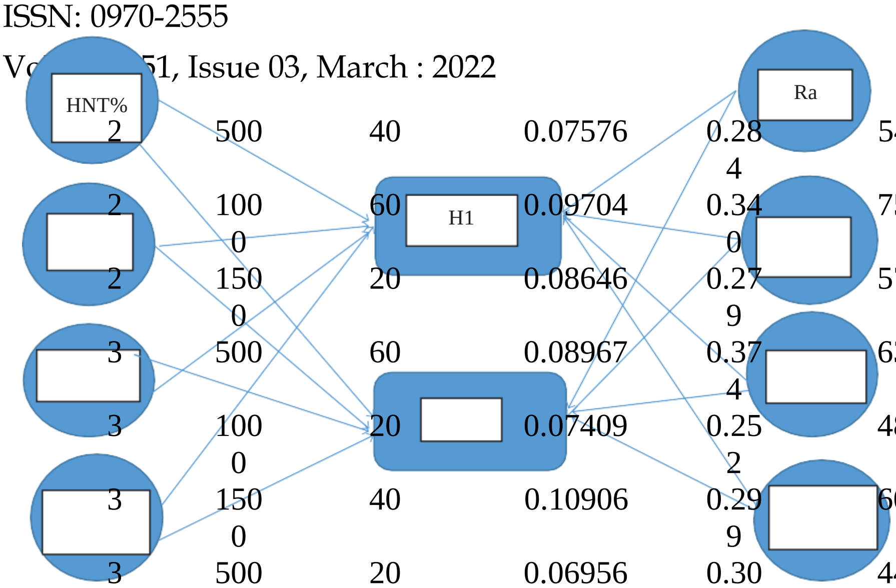


Figure 1: Artificial neural network model.

Table 4: L_{27} orthogonal array and results.

	Input parameters				Output parameters			
Sl. no	HNT %	BN %	Spindle speed (rpm)	Feedrate (mm/min)	MRR (g/min)	Surface roughness	Temperature	Cutting force
1	3	2	500	20	0.08721	0.229	41.23	109.98
2	3	2	1000	40	0.09126	0.249	54.34	219.16
3	3	2	1500	60	0.11987	0.307	63.31	290.54
4	3	3	500	40	0.10436	0.210	47.35	131.90
5	3	3	1000	60	0.11745	0.321	62.88	290.27
6	3	3	1500	20	0.11874	0.201	53.69	161.76
7	3	4	500	60	0.10098	0.304	54.87	181.85
8	3	4	1000	20	0.08634	0.168	40.17	129.76
9	3	4	1500	40	0.11975	0.263	53.77	229.17
10	5	4	500	20	0.07289	0.246	41.54	116.87
11	5	4	1000	40	0.12365	0.251	57.76	202.38
12	5	4	1500	60	0.14002	0.327	65.75	320.94



13	5	2	500	40	0.07576	0.284	54.12	201.76
14	5	2	1000	60	0.09704	0.340	75.59	290.58
15	5	2	1500	20	0.08646	0.279	57.98	239.77
16	5	3	500	60	0.08967	0.374	63.93	280.03
17	5	3	1000	20	0.07409	0.252	48.65	179.98
18	5	3	1500	40	0.10906	0.299	60.96	245.34
19	7	3	500	20	0.06956	0.301	44.62	120.98
20	7	3	1000	40	0.07006	0.337	60.67	259.89
21	7	3	1500	60	0.10702	0.412	75.90	372.18
22	7	4	500	40	0.07897	0.319	58.98	200.90
23	7	4	1000	60	0.09364	0.399	71.89	319.72
24	7	4	1500	20	0.08978	0.311	55.98	198.56
25	7	2	500	60	0.06857	0.402	74.57	288.89
26	7	2	1000	20	0.05786	0.293	63.78	190.21
27	7	2	1500	40	0.06956	0.343	72.85	289.09

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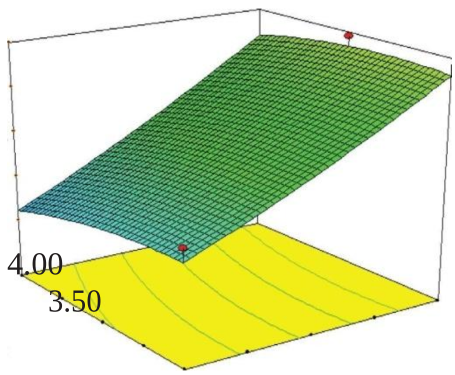
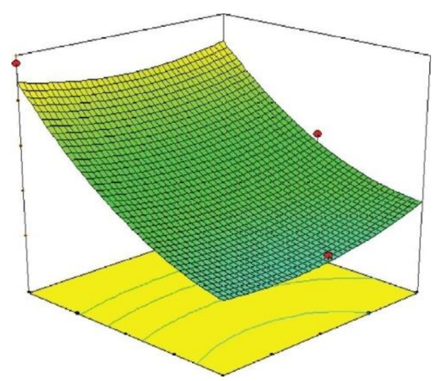
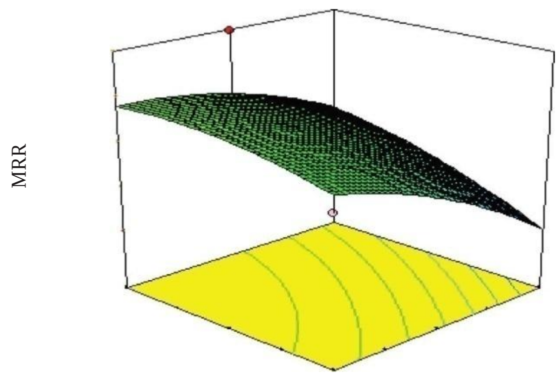


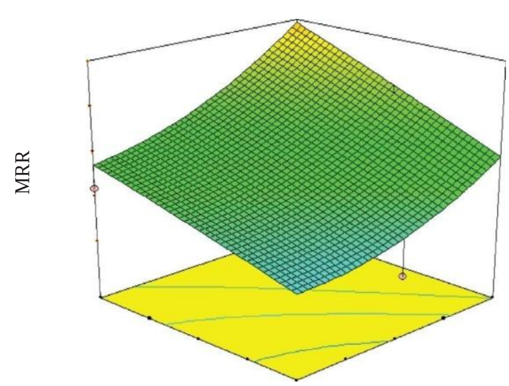


(a)

(b)

Figure 2: (a) Efect on Ra on BN vs. HNT. (b) Efect on Ra on feed vs. speed.


MRR
0.124
0.10825
0.0925
0.07675
0.061
4.00
3.50
3.00
.00
5.00
7.00


MRR
0.126
0.113
0.1
0.087
0.074
60.00

50.00
40.00

1500.00
1250.00
1000.00

B: BN

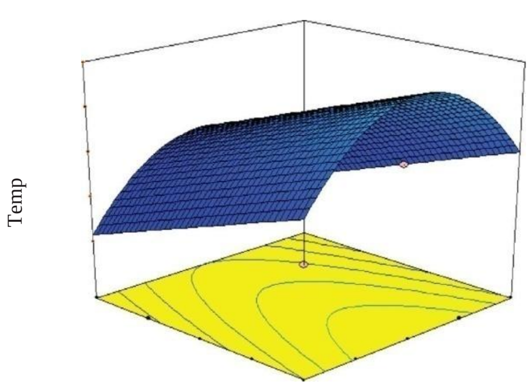
.50 2.00 3.00 4.00
A: HNT
D: Feed

.00 750.00
20.00 500.00

C: Speed

(a) (b)

FIgurE 3: (a) Efect of MRR on HNT vs. BN. (b) Efect of MRR on HNT vs. BN.



1000
675
350
25
-300

4.00

3.50

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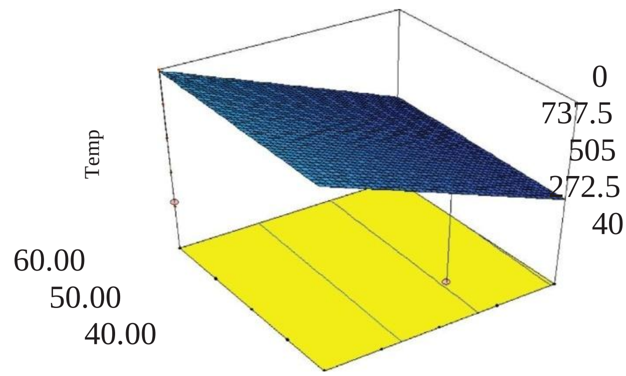
.00



3.50

4.00

B: BN

3.00
2.50

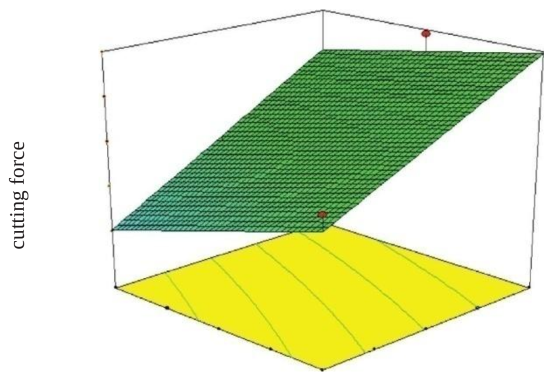
2.00 3.00
(a)

5.00

4.00 A: HNT
D: Feed
30.00
20.00 2.00

(b)

2.50
3.00
B: BN



262
241.75
221.5
201.25
181

4.00

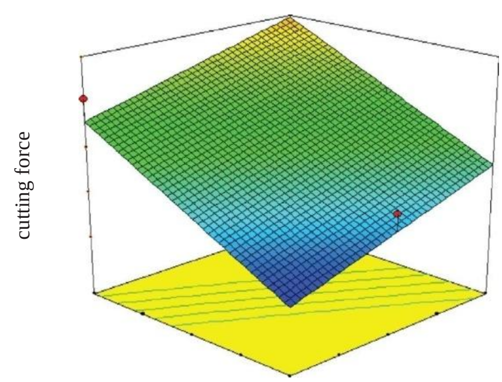
3.50

3.00

6.00

7.00
330
275
220
165
110

60.00
0.00



1500.00
1250.00
1000.0

B: BN

2.50 4.00
2.00 3.00
(a)
0.00 750.00
20.00 500.00

(b)

C: Speed

Figure 5: (a) Efect of cutting force on HNT vs. BN. (b) Efect of temperature on speed vs. feed.

Table 5: Normalized value for response parameters.

Coef of MRR	Coef of Ra temp	Coef of temp	Coef cutt force	Avg	Rank
0.43753	0.33333	0.94399	1.00000	0.679	22
0.45726	0.90372	0.55767	0.54561	0.616	16
0.67091	0.84543	0.43568	0.42065	0.593	12
0.53531	0.94765	0.71332	0.85675	0.763	25
0.64540	0.83247	0.44030	0.42102	0.585	11
0.65876	0.95840	0.56922	0.71686	0.726	23
0.51273	0.84826	0.54860	0.64591	0.639	17
0.43352	1.00000	1.00000	0.86890	0.826	27
0.66960	0.88892	0.56777	0.52379	0.663	20
0.37963	0.90695	0.92878	0.95007	0.791	26
0.71506	0.90157	0.50388	0.58658	0.677	21
1.00000	0.82704	0.41121	0.38327	0.655	19
0.38998	0.86762	0.56153	0.58821	0.602	14
0.48870	0.81550	0.33527	0.42060	0.515	5
0.43407	0.87260	0.50077	0.50251	0.577	9
0.44931	0.78681	0.42919	0.43533	0.525	6
0.38389	0.90050	0.67812	0.65191	0.654	18
0.57024	0.85302	0.462	0.492	0.594	13

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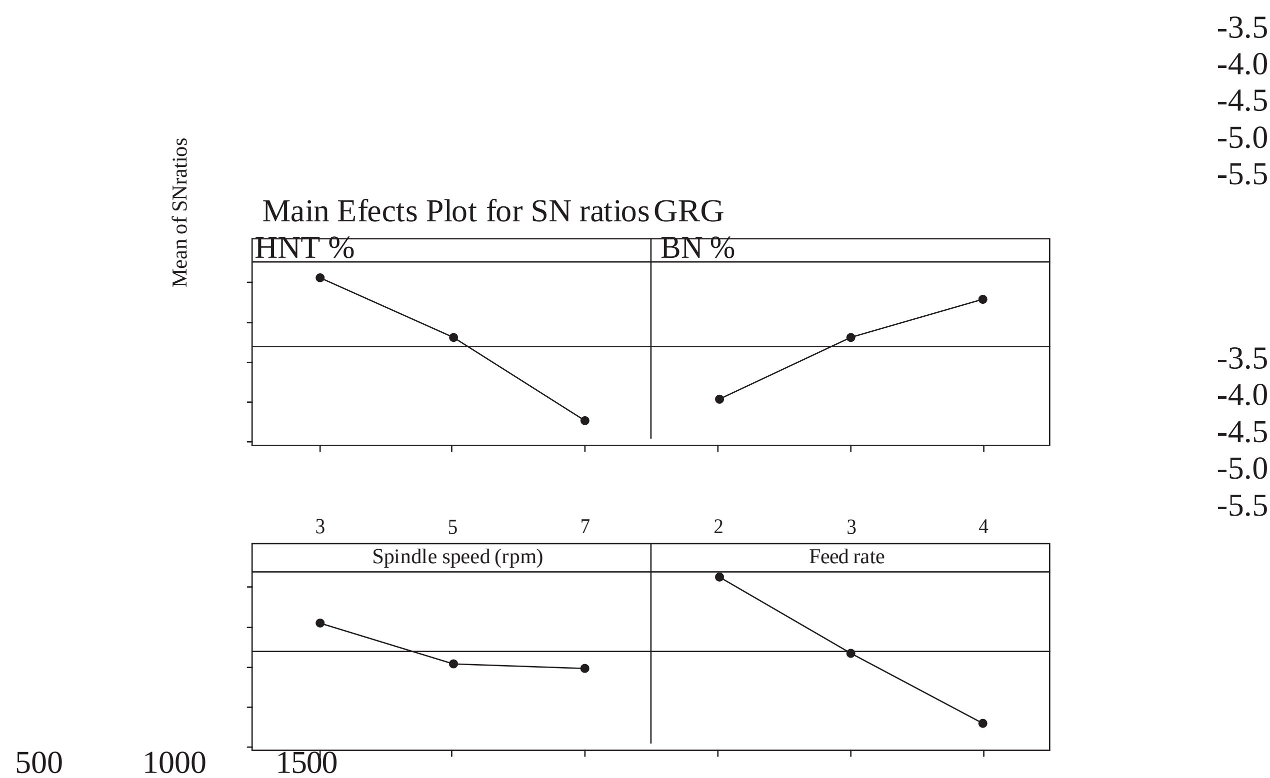
		17	01		
0.36830	0.85111	0.800 58	0.922 59	0.736	24
0.36996	0.81814	0.465 66	0.466 53	0.530	7
0.55454	0.75704	0.333 33	0.333 33	0.495	3
0.40223	0.83430	0.487 12	0.590 49	0.579	10
0.46970	0.76696	0.360 29	0.384 64	0.495	4
0.44985	0.84169	0.530 51	0.596 78	0.605	15
0.36506	0.76465	0.341 82	0.422 89	0.474	1
0.33333	0.85880	0.430 74	0.620 36	0.561	8
0.36830	0.81289	0.353 45	0.422 62	0.489	2



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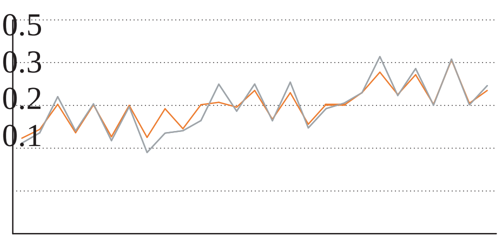
Signal-to-noise: Larger is better
20 40 60

Figure 6: GRG.

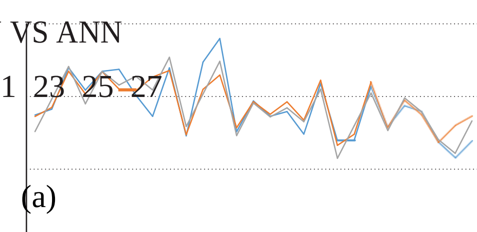
Table 6: The ANOVA results of the analysis.

Source	DF	Seq SS	Adj SS	Adj MS	*F*	*P*	%
Regression	4	0.193603	0.193603	0.0484006	25.2976	0.000001	
HNT %	1	0.070460	0.070460	0.0704595	36.8272	0.0000042	29.89
BN %	1	0.037642	0.037642	0.0376418	19.6743	0.0002082	15.97
Spindle speed (rpm)	1	0.008436	0.008436	0.0084359	4.4092	0.0474359	3.57
Feed rate	1	0.077065	0.077065	0.0770653	40.2798	0.0000022	32.89
Error	22	0.042091	0.042091	0.0019132			17.85
Total	26	0.235694					

Ra
ACTUAL VS REGRESSION VS ANN



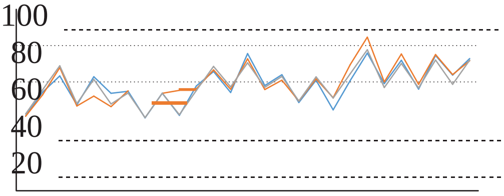
MRR
ACTUAL VS REGRESSION VS ANN



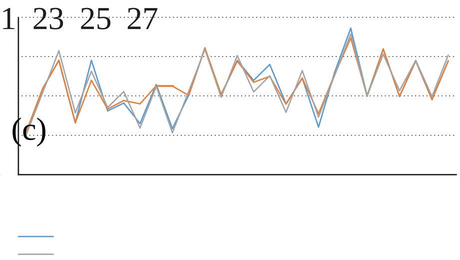
(a)

(b)

gurE 7: Continued.



(c)



(d)

FigurE 7: (a) Actual vs. regression vs. ANN on Ra. (b) Actual vs. regression vs. ANN on MRR. (c) Actual vs. regression vs. ANN ontemperature. (d) Actual vs. regression vs. ANN on cutting force.

combinations of input parameters. The feed rate and HNT %are most influencing parameters identified through GRG.

Regression Equation

MRR � 0.0565315 − 0.00669278 HNT % + 0.00846833 BN% + 2.35878*e* − 005 Spindle speed(rpm) + 0.000531472 Feed, Ra � 0.0911574 + 0.0240278 HNT % − 0.00766667 BN % + 8.11111*e* − 006 Spindle speed(rpm) + 0.00251667 Feed,

Temp � 26.3036 + 2.98972 HNT % − 3.17 BN% + 0.00877556 Spindle speed(rpm) + 0.447361 Feed,

(10)

Cutting Force � −18.9769 + 13.7786 HNT % − 12.2128 BN % + 0.0793544 Spindle speed(rpm) +

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3.29758 Feed.

Figure 7(a) shows the graph of actual experimental and predicted ANN and regression values on surface roughness. The prediction of ANN is 96.3% whereas the regression value shows 93.1%. In case of MRR Figure 7(b) shows the re- gression value is 92.7%, meanwhile the ANN predicted value is 95.2%.

Figure 7(c) shows the graph of actual experimental and predicted ANN and regression values on temperature measured during drilling process. The prediction of ANN is 98.1%, whereas the regression value shows 94.3%. Figure 7(d) shows the regression value of cutting force during machining is 91.9%, whereas the ANN predicted value is 95.2%. It is understood that the developed ANN model exhibits good results for estimating the surface roughness, material removal rate, temperature, and cutting force.

4. Conclusion

In the current study, the best input process parameter combinations to lower surface roughness, cutting force, and temperature while raising the rate of metal removal from aluminium hybrid metal matrix composites during drilling of aluminium composites were found using Taguchi design-based grey relational analysis.

The findings demonstrate that feed rate and weight percentage of HNT are the key variables that affect drilling of produced aluminium composites, which are indicated by the percentage contribution hrough GRA. GRA results, the ideal parameters are 3% HNT, 4% BN, 500 rpm drilling speed, and 20 mm/min in combination. These parameters have the lowest surface roughness, lowest temperature, lowest cutting force, and highest rate of material removal.

For each of the response parameters in AMMC drilling, the suggested ANN model performs better than the regression model and strongly indicates the projected value of observational data.

Data Availability

All the data used in this study are provided in themanuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] V. K. Sharma, R. C. Singh, and R. Chaudhary, "Efect of fly ash and graphite addition on the tribological behavior of alu- minum composites," *Surface Topography: Metrology and Properties*, vol. 9, no. 2, Article ID 025027, 2021.

[2] C. S. Rubi, J. U. Prakash, and C. Rajkumar, "Optimization ofprocess parameters using Taguchi technique for drilling aAluminum matrix composites (LM6/B4C) IOP conference series: materials science and engineering," *IOP Publishing*, vol. 912, no. 3, Article ID 032016, 2020, August.

[3] S. Ajith Arul Daniel, A. Parthiban, S. Sivaganesan, and S. Vijay Ananth, "Investigation on surface roughness in drilling of al/ SiC/MoS 2 metal matrix composites," in *Advances in In- dustrial Automation and Smart Manufacturing*, pp. 717–724, Springer, Singapore, 2021.

[4] T. Rajmohan, K. Palanikumar, and S. Ranganathan, "Evalu- ation of mechanical and wear properties of hybrid aluminum matrix composites," *Transactions of Nonferrous Metals Society of China*, vol. 23, no. 9, pp. 2509–2517, 2013.

[5] M. Ramasamy, A. A. Daniel, and M. Nithya, "Investigation on surface roughness of aluminum (Al7050/TiC/BN) hybrid metal matrix," *Materials Today Proceedings*, vol. 46, pp. 852–856, 2021.
[6] S. Deshmukh, G. Joshi, A. Ingle, and D. Thakur, "An overview of Aluminum Matrix Composites: particulate reinforcements, manufacturing, modelling and machining," *Materials Today Proceedings*, vol. 46, pp. 8410–8416, 2021.
[7] C. K. Saurabh, A. Mustapha, M. M. Masri et al., "Isolation and characterization of cellulose nanofibers from Gigantochloa scortechinii as a reinforcement material," *Journal of Nano-materials*, vol. 2016, Article ID 4024527, 8 pages, 2016.
[8] K. Palanikumar and A. Muniaraj, "Experimental investigation and analysis of thrust force in drilling cast hybrid metal matrix (Al–15% SiC–4% graphite) composites," *Measurement*, vol. 53, pp. 240–250, 2014.
[9] S. Basavarajappa, G. Chandramohan, and J. P. Davim, "Some studies on drilling of hybrid metal matrix composites based on Taguchi techniques," *Journal of Materials Processing Technology*, vol. 196, no. 1-3, pp. 332–338, 2008.
[10] S. Karabulut, H. Karakoc, and R. Cıtak, "Influence of B4C particle reinforcement on mechanical and machining prop- erties of Al6061/B4C composites," *Composites Part B: Engi- neering*, vol. 101, pp. 87–98, 2016.
[11] V. Kavimani, K. S. Prakash, T. Thankachan, S. Nagaraja, A. K. Jeevanantham, and J. P. Jhon, "WEDM parameter optimization for silicon@r-GO/magneisum composite using Taguchi based GRA coupled PCA," *Silicon*, vol. 12, no. 5, pp. 1161–1175, 2019.
[12] S. A. A. Daniel and G. Pm, "Study on tribological behaviour of Al/SiC/MoS2 hybrid metal matrix composites in high tem- perature environmental condition," *Silicon*, vol. 10, no. 5, pp. 2129–2139, 2018.
[13] M. Balaji, K. Venkata Rao, N. Mohan Rao, and B. S. N. Murthy, "Optimization of drilling parameters for drilling of TI-6Al-4V based on surface roughness, flank wear and drill vibration," *Measurement*, vol. 114, pp. 332–339, 2018.
[14] M. Ramasamy, A. Arul Daniel, and M. Nithya, "Aluminum (Al7050) metal matrix composites: a review of reinforcement and mechanical characteristics AIP Conference Proceedings," *AIP Publishing LLC*, vol. 2358, no. 1, Article ID 020003, 2021.
[15] M. Kurt, E. Bagci, and Y. Kaynak, "Application of Taguchi methods in the optimization of cutting parameters for surface finish and hole diameter accuracy in dry drilling processes," *International Journal of Advanced Manufacturing Technology*, vol. 40, no. 5-6, pp. 458–469, 2009.
[16] K. Hemadri, S. Ajith Arul Daniel, V. Kukanur, S. Vijayananth, and R. Kumar, "Investigation on mechanical characterization of Al/Mos2/WC hybrid composite," *Materials Today Pro- ceedings*, vol. 69, pp. 995–999, 2022.
[17] A. David Stephenson and S. John Agapiou, *Metal Cutting Theory and Practice*, Routledge, Singapore, 2006.
[18] B. Rajeswari and K. S. Amirthagadeswaran, "Experimental investigation of machinability characteristics and multi-response optimization of end milling in aluminum com- posites using RSM based grey relational analysis," *Measure- ment*, vol. 105, pp. 78–86, 2017.

[19] M. Ramasamy, A. Arul Daniel, and M. Nithya, "Investigation on surface roughness of aAluminum (Al7050/TiC/BN) composite through wire electric discharge machining," in *Recent Advances in Materials and Modern Manufacturing*, pp. 933–941, Springer, Singapore, 2022.

[20] J. P. Kumar and P. Packiaraj, "Efect of drilling parameters on surface roughness, tool wear, material removal rate and hole diameter error in drilling of OHNS," *International Journal of Advanced Engineering Research and Studies*, vol. 1, no. 3, pp. 150–154, 2012.

[21] E. Bagci and B. Ozcelik, "Analysis of temperature changes on the twist drill under diferent drilling conditions based on Taguchi method during dry drilling of Al 7075-T651," *International Journal of Advanced Manufacturing Technology*, vol. 29, no. 7, pp. 629–636, 2005.

[22] A. Pramanik, "Problems and solutions in machining of ti- tanium alloys," *International Journal of Advanced Manufacturing Technology*, vol. 70, no. 5-8, pp. 919–928, 2014.

[23] S. Bhattacharya, P. P. Das, P. Chatterjee, and S. Chakraborty, "Prediction of responses in a sustainable dry turning oper- ation: a comparative analysis," *Mathematical Problems in Engineering*, vol. 2021, Article ID 9967970, 15 pages, 2021.