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Optimization of Process Parameters of Stir casting Process Using Gray Relation Analysis and ANOVA and studying the Mechanical Properties of Al-75075 by Alloy Reinforced the TiO2+Bn/Bn+Wc/Wc+TiO2 Nanoparticles

*Kishorekumar.Nandyala[a], Dr Sanjeevreddy K Hudgikar[b],

a.Research scholar Department of Mechanical Engineering, VTU, Belagavi, India;

b Department of Mechanical Engineering, Sharnbasva University Kalaburagi, India;

Abstract The present trend of the world is to develop the high strength and stiffness metal matrix composite (MMC's) concerning the weight ratio for industrial applications. Due to lightweight and stiffness, the nano-hybrid composites are used in several industrial applications, likely aerospace, Armey forces, automobile, and other commercial applications.

The present work is developing an Aluminum-based hybrid metal matrix composite (MMC) by the stir casting method and applying the optimization technique for unique hybrid composition to find better mechanical properties. Titanium dioxide (Tio2), Boron nitride (Bn), and Tungsten carbide (WC) were used as reinforcements, and Al7075 alloy was taken as a base metal matrix. For developing of hybrid composite. Considering different process parameters for stir casting, namely stirring speed (600, 800, 1000 rpm), stirring time (10, 20, 30 min), temperature (750ºC, 800ºC, and 850ºC), percentage of nanoparticles add (3%, 5%, 6%) and hybrid composition of nanoparticles (TiO2+BN, Bn+Wc, and Wc+TiO2) and the size of nanoparticles add in reinforcement (80, 50, 90 nm). The Taguchi-based grey relational analysis was applied. The composition was developed by the stir casting method, and the specimens were fabricated as per ASTM standards. For conducting mechanical tests, the samples are prepared Taguchi's L27 orthogonal array, and the optimum mechanical properties were analyzed using Gray relation analysis and ANOVA (Analysis of variance). The obtained results were tested and validated, the samples were scanned using SEM (scanning electron microscope) and studied the distribution of the reinforcements.

Keywords: Stir casting, Hybrid Composites, ANOVA, Nanoparticles, and Scanning Electron Microscope.

1. Introduction

The present world needs high strength materials to satisfy engineering applications, automotive, aircraft applications, defence applications, etc., but high strength materials have more weight ratio. To overcome these, aluminium alloys are the best replacement of more weight ratio materials. Aluminium can easily be mixed with other materials and forms into alloys, composite material, and hybrid composite material. These hybrid composite materials show superior results in all applications. Using the Stir casting method, Al7075 is reinforced with 5% of Baggage-ash and observed a slight increase in tensile strength, compressive strength, and impact strength. And also developed hybrid composite by adding Baggase-ash and Graphite to Al7075 recorded the superior mechanical and microstructural properties compared to al7075 [1]. Hybrid Nanocomposites were developed by ultrasonic stir casting by reinforcing the Sci and B_4C to Al6061 alloy. Observed that the 1.5% SiC and 0.5% B_4C reinforcement shows an increase in tensile strength [2]. To improve the mechanical properties of the compressive strength and tensile of Al7075 alloy, reinforced 5%TiC+5%SiC MMCs after reinforcing the TiC and SiC, the tensile strength and compressive strength and compressive strength was increased to 32% and 10.5%, respectively [2]. To improve the tensile strength and compressive strength of Al7075 alloy, reinforced with 5%TiC+5%SiC, the tensile strength and compressive strength were increased to 32% and 10.5%, respectively [3]. Al6063 was reinforced with a different weight percentage of TiB_2 and Gr and fabricated aluminium metal matrix composition using the stir casting process. Attained the required Hardness, Tensile Strength, Impact strength and wear resistance. This 4% TiB2 showed superior properties among the composites [4]. The hybrid Al7075/Tio2/Bn has shown improvement of tensile strength up to 27%, and Al7075/5% Tio2/2%Bn has increased hardness up to the value 83.34 Vickers hardness [5]. The researchers have introduced the ultrasonic stir casting method for developing nano-reinforcement metal matrix composition, which can regulate the temperature and stirring speed of molten metal and reinforcements distributed uniformly. The A356-SiC-Al2O3 metal matrix improved the tensile strength, yield strength, and elongation gradually increased based on the weight of nanoparticles reinforced into the molten metal [6]. Reinforcing SiC and Al2O3 to Al 7075 by stir casting observed in the tensile strength and yield strength were improved. The hardness is also improved by increasing the weight percentages to the metal matrix. The SEM results show a uniform distribution of Al2O3 and SiC was observed[7]. By reinforcing the boron carbide with Al-7068, the corrosion rate was minimized up to 265.43 mm/year. Observed that 6% of reinforcement and 750 rpm of starring speed are the key influencing factor of the process parameters [8]. By Taguchi method, DOE was designed to optimize the process parameters to fabricate the samples for performing mechanical tests on A356 Composite. And also performed the analysis of the signal to noise (S/N) ratio to know the variations in mechanical properties of A356 composition [9]. The TiC is taken as reinforcement, and AA7075 has the base material. Design of experiments was developed by Taguchi design of experiments L9 orthogonal array and considering the Stirring time, Stirring Speed and Temperature as process parameters for fabrication of samples and the stirring temperature is the most affecting factor observed from ANOVA. And the improved mechanical properties were exhibited at 850^0C temperature, 10 min of stirring time, and 600 rpm stir speed [10]. In this research, Taguchi-GRA was applied to optimize the process parameters and to develop the recycling of alumina alloy by reinforcing Al_2O_3. And performed the various mechanical tests to find out the mechanical properties of the fabricated new alumina alloy matrix, finally observed that hardness 60.9 HRB, Compressive strength 433 MPa, and tensile strength of 153 MPa were improved in fabricated alumina alloy matrix [11]. The design of experiments was developed by Taguchi approach and performed L9 experiments and applied ANOVA to study high impacted process parameters in this work [12].

2. Experimental Procedures

2.1 Material selection and Samples Preparation

The Al7075 was taken as a base material matrix in the present study, and Titanium dioxide (Tio2), Boron nitride (Bn), and Tungsten carbide (WC) as reinforcement. The chemical compounds of the AL7075 with weight percentages are shown in table.1. The sizes of reinforcement are at Nanoscale Tio2-80nm, BN -50nm, and WC-90nm. The weight of the reinforcement is 3%, 6%, and 9%. The stirring temperatures of the Al7075 are 750ºC, 800ºC, and 850ºC. The stirring speed of the stirrer is 600 Rpm, 800 Rpm, and 1000 Rpm for the uniform distribution of reinforced nanoparticles in molten metal. In this excrement, the stirring time is also considered at three levels: 10 min, 15 min, and 20 min. To prepare the hybrid composites above process parameters are considered samples were designed as per ASME standards for knowledge of the mechanical properties of the prepared hybrid composite.

Table 1. Combination of chemical elements of Al7075 (in weight %).

Elements	Zn	Fe	Ti	Si	Mn	Cu	Mg	Cr	other	Balance
Percentage	5.1-6.1	0.50	0.20	0.40	0.30	1.2-2.0	2.1-2.9	0.18-028	0.65	Al

2.2 Design of Experiments

The design of experiments (DOE) was developed by the Taguchi method and its vigorous method for optimizing the process parameters. In this experiment, the size of reinforcement, the weight of reinforcement added, stirring speed of stir, stirring time, nanoparticles add and molten metal temperatures are measured as input process parameters, and the experimentations were developed as per the L27 orthogonal array. The experimental parameters are shown in table 2. 27 samples were prepared and conducted the experiments from these process parameters, namely tensile strength, compression test, and hardness test. These are considering the out parameters for calculating the S/N ratio (signal-to-noise ratio), and it helps to find the significant parameter that influences performed experiments.

The logarithmic function for optimization of the process parameters is the S/N ratio. The S/N ratios are divided into three classes, namely nominal-the-better, lower-the-better, and higher-the-better [11]. They are considering the larger-the-better for the finding mechanical properties and the smaller-the-better for wear rate and the formula shown below.

i.Larger-the-better

$$S/N = -10*\log_{10}\left(\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{y2_{ik}} \quad \text{(i)}$$

where n=number of replications, y_{ij} = observed response value, where i=1,2….n; k=1,2,……j the equitation (i) is used for problems where as in maximization conductions only. And the present problem is consider as the larger-the-better type one [12].

ii.Smaller-the-better

$S/N = -10*\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} y2_{ik}\right)$ this is used for smaller-the-better type problem where minimization of the characteristic is intended.

Table 2. Factors and levels

Parameters	Symbol	Units	Levels 1	2	3
Temperature	(T)	ºC	750	800	850
Stirring Speed	(SS)	Rpm	600	800	1000
Stirring Time	(ST)	Min	10	15	20
Weight	(W)	gm	3	6	9
Size of Nanoparticles	(N)	nm	80,50	50,90	90,80
Nanoparticles	(P)		TiO2+BN	BN+WC	WC+TiO2

Table 3. Design of Experimental by using orthogonal array L27 and responses

Trial No.	T	SS	ST	W	N	P	Response of Mechanical properties. Tensile Strength(MPa)	Compressive Strength (MPa)	Hardness (BHN)
1	1	1	1	1	1	1	230.388	234.8	61
2	1	1	1	1	2	2	232.291	229.88	73
3	1	1	1	1	3	3	229.927	228.04	41
4	1	2	2	2	1	1	234.6	232.92	65
5	1	2	2	2	2	2	236.707	221.42	68
6	1	2	2	2	3	3	240.183	219.64	43
7	1	3	3	3	1	1	225.619	220.35	52
8	1	3	3	3	2	2	228.773	221.63	56
9	1	3	3	3	3	3	228.63	214.48	62
10	2	1	2	3	1	2	233.425	224.65	65.17
11	2	1	2	3	2	3	231.768	228.6	72.1
12	2	1	2	3	3	1	239.752	227.63	77.2
13	2	2	3	1	1	2	242.802	213	68.4
14	2	2	3	1	2	3	238.781	213.56	76.76
15	2	2	3	1	3	1	248.404	216.58	83.2
16	2	3	1	2	1	2	242.852	217.56	70.21
17	2	3	1	2	2	3	236.738	215.63	81.71
18	2	3	1	2	3	1	239.701	213.36	79.9
19	3	1	3	2	1	3	258.221	205.8	60.2
20	3	1	3	2	2	1	250.263	206.8	66.7
21	3	1	3	2	3	2	248.301	200.6	67.5
22	3	2	1	3	1	3	256.43	195.84	64.17
23	3	2	1	3	2	1	249.602	216.92	67.3
24	3	2	1	3	3	2	249.852	207.2	68.4
25	3	3	2	1	1	3	253.93	187.56	62.13
26	3	3	2	1	2	1	240.796	192.64	65.17
27	3	3	2	1	3	2	251.36	193.64	68.18

2.3 Mechanical Behavior

2.3.1 Tensile Strength

The 27 specimens were fabricated as per the design of experiments with E-8M ASTM standards. The tensile test was performed on a universal testing machine (UTM) under room conductions. The tensile strength results are presented in Table 2. It is observed from the above results the maximum value was recorded at sample no 19 is 258.221 Mpa, and the minimum value was recorded at workpiece no 7 is 225.619 Mpa. The hybrid composite of Al7075 tensile strength was improved by 122.58% compared with the base alloy.

2.3.2 Compressive strength

The compressive strength was improve in the hybrid composite compared with Al7075, is increased up to 110.03%. The samples were fabricated as per ASTM E9 standards, and the highest value recorded at sample one is 234.8 Mpa, and the minimum value recorded at sample no 25 is 187.56 Mpa.

2.3.3 Hardness test the hardness of the hybrid composite was increased to 108.4% with respective with Al7075. The Maximum value recorded at sample no 15 is 83.2 Bhn, and the minimum is 41.

3. Grey Relation Analysis (GRA) it is easy to perform a single performance of optimization in the Taguchi method but we cannot perform multi performances. Grey relation analysis is one of the best optimization techniques for multi-performances. In this analysis, factors having multi-performances can easily be controlled. The GRA has various steps for solving the multi-performances are:

Step 1: Normalization

In this step the output parameters tensile strength, compressive strength and hardness was normalized first from range zero to one and it is called Grey relation generation. These three methods for normalization, Larger-the-better, smaller-the-better, and nominal-the-better [12]. In this work, considering the larger, the better, the higher mechanical properties, so consider the larger-the-better. Equation no 3 is used for normalized.

$$X_i^*(j) = \frac{X_i(j) - \min X_i(j)}{\max X_i(j) - \min X_i(j)} \quad \text{(iii)}$$

Consider the lower-the-better characteristic of normalization equation no 4.

$$X_i^*(j) = \frac{\max X_i(j) - X_i(j)}{\max X_i(j) - \min X_i(j)} \quad \text{(iv)}$$

where X_i (j) is the value after the grey relational generation, max X_i (j) is the most significant value of X_i (j) , minX_i (j) is the smallest value of X_i (j), and X is the desired value.

Step 2 Calculation of the Grey relation coefficients and grey relation grade in this step, **GRC** expresses the relationship between the ideal (best) values and actual normalized values for all the combinations. GRC can be calculated using the following equation no 5[24].

$$\xi_i(j) = \frac{\Delta\min + \zeta\Delta\max}{\Delta i(j) + \zeta\Delta\max} \quad \text{(v)}$$

where ζ (ε 0,1)=distinguished coefficient, ζ =0.5 is generally used. $\xi_i(j)$ is grey relational coefficient, Δ_{min} is the smallest value of $\Delta_{oi}(j)$, Δ_{max} is the largest value of $\Delta_{oi}(j)$, $\Delta_{oi}(j)$ is the deviation sequence of the reference sequence $X_i^*(j)$, and the comparability sequence $X_i^*(j)$[21],

$$\Delta_{oi}(k) = |X_i^*(j) - X_i(j)|$$

$$\Delta_{max} = \max_{\forall j e i} \max_{\forall k} |X_o^*(j) - X_n^*(j)|$$

$$\Delta_{min} = \min_{\forall j e i} \min_{\forall j} |X_o^*(j) - X_n^*(j)|$$

The grey relation coefficient is obtained, and the grey relation grade is to be calculated by following equation (8)

$$\gamma_i = \frac{1}{n} \sum_{n=1}^{n} \xi i(j) \quad (8)$$

Where γ_i is the grey relation grade for the *i*th experiment and n is the number of performance characteristics.

4. Results and Experimental Discussion

Equitation (3), the experimental results are normalized per the GRA. After normalizing the experimental results, the normalized results are changed into a grey relational coefficient to study the relationship between the actual data and desired one. The normalization and deviation sequence are shown in table 4. Then averaging the grey relation coefficient and calculating the grey relational grades and their ranks are shown in Table 5.

Table 4. Normalized Mechanical properties and Deviation Sequences

Ex.No.	Normalization			Deviation sequences		
	Tensile Strength	Compressive Strength	Hardness	Tensile Strength	Compressive Strength	Hardness
1	0.1463	1.0000	0.4739	0.8537	0.0000	0.5261
2	0.2047	0.8959	0.7583	0.7953	0.1041	0.2417
3	0.1321	0.8569	0.0000	0.8679	0.1431	1.0000
4	0.2755	0.9602	0.5687	0.7245	0.0398	0.4313
5	0.3401	0.7168	0.6398	0.6599	0.2832	0.3602
6	0.4467	0.6791	0.0474	0.5533	0.3209	0.9526
7	0.0000	0.6941	0.2607	1.0000	0.3059	0.7393
8	0.0967	0.7212	0.3555	0.9033	0.2788	0.6445
9	0.0924	0.5699	0.4976	0.9076	0.4301	0.5024
10	0.2394	0.7851	0.5727	0.7606	0.2149	0.4273
11	0.1886	0.8688	0.7370	0.8114	0.1312	0.2630
12	0.4335	0.8482	0.8578	0.5665	0.1518	0.1422
13	0.5271	0.5385	0.6493	0.4729	0.4615	0.3507
14	0.4037	0.5504	0.8474	0.5963	0.4496	0.1526
15	0.6989	0.6143	1.0000	0.3011	0.3857	0.0000
16	0.5286	0.6351	0.6922	0.4714	0.3649	0.3078
17	0.3411	0.5942	0.9647	0.6589	0.4058	0.0353
18	0.4319	0.5461	0.9218	0.5681	0.4539	0.0782
19	1.0000	0.3861	0.4550	0.0000	0.6139	0.5450
20	0.7559	0.4073	0.6090	0.2441	0.5927	0.3910
21	0.6957	0.2760	0.6280	0.3043	0.7240	0.3720
22	0.9451	0.1753	0.5491	0.0549	0.8247	0.4509
23	0.7356	0.6215	0.6232	0.2644	0.3785	0.3768
24	0.7433	0.4157	0.6493	0.2567	0.5843	0.3507
25	0.8684	0.0000	0.5007	0.1316	1.0000	0.4993
26	0.4655	0.1075	0.5727	0.5345	0.8925	0.4273
27	0.7896	0.1287	0.6441	0.2104	0.8713	0.3559

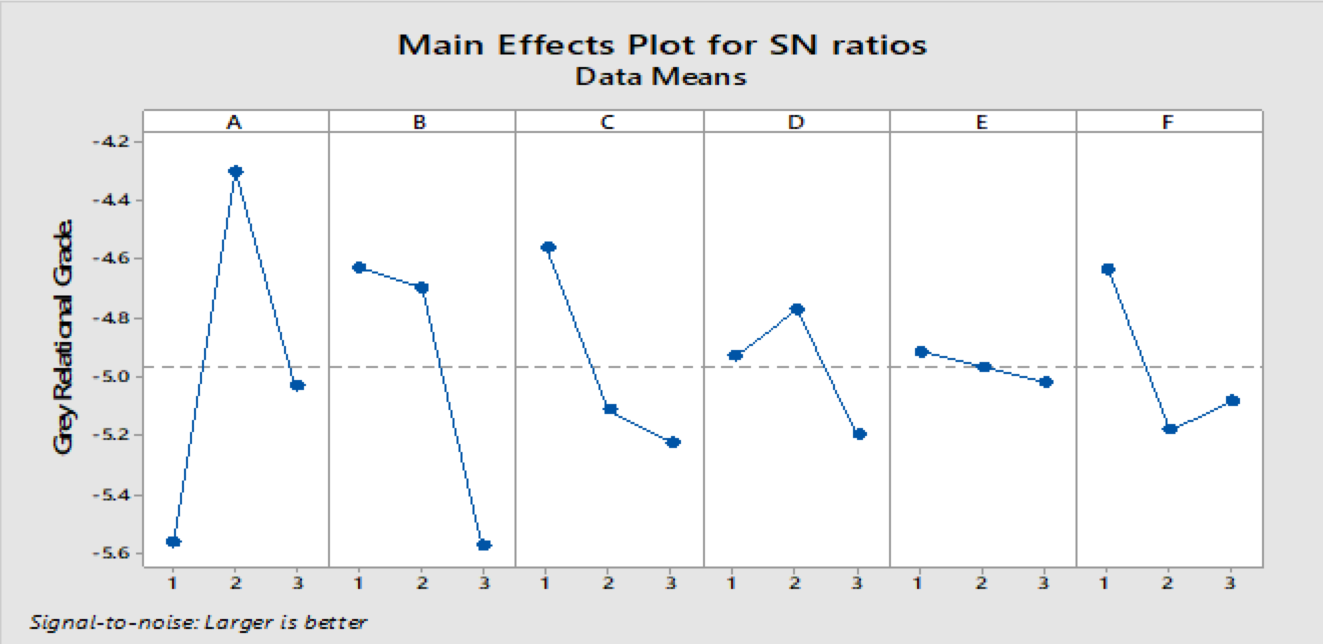
Table 5: The Grey relational coefficient, Grey relational Grade, and Rank.

Ex.No.	Grey relational coefficient			Grey relational grade	Rank
	Tensile Strength	Compressive Strength	Hardness		
1	0.3694	1.0000	0.4873	0.6189	8
2	0.3860	0.8276	0.6741	0.6292	5
3	0.3655	0.7775	0.3333	0.4921	22
4	0.4083	0.9263	0.5369	0.6238	6
5	0.4311	0.6384	0.5813	0.5502	17
6	0.4747	0.6091	0.3442	0.4760	24
7	0.3333	0.6204	0.4034	0.4524	27
8	0.3563	0.6420	0.4369	0.4784	23
9	0.3552	0.5376	0.4988	0.4639	25
10	0.3966	0.6994	0.5392	0.5451	18
11	0.3813	0.7921	0.6553	0.6095	9
12	0.4688	0.7671	0.7786	0.6715	2
13	0.5139	0.5200	0.5877	0.5406	20
14	0.4561	0.5265	0.7662	0.5829	12
15	0.6241	0.5645	1.0000	0.7296	1
16	0.5147	0.5781	0.6189	0.5706	13
17	0.4314	0.5520	0.9340	0.6392	4
18	0.4681	0.5242	0.8648	0.6190	7
19	1.0000	0.4489	0.4785	0.6424	3
20	0.6720	0.4576	0.5612	0.5636	15
21	0.6217	0.4085	0.5734	0.5345	21
22	0.9010	0.3774	0.5258	0.6014	10
23	0.6541	0.5692	0.5703	0.5979	11
24	0.6608	0.4611	0.5877	0.5699	14
25	0.7916	0.3333	0.5004	0.5418	19
26	0.4833	0.3591	0.5392	0.4605	26
27	0.7038	0.3646	0.5842	0.5509	16

Table 6: The Response table for grey relational grade

Parameter	L-1	L-2	L-3	Delta(Max-Min)	Rank
Temperature(A)	0.5317	**0.6120***	0.5625	0.0803	1
Stirring Speed(B)	**0.5897***	0.5858	0.5307	0.0589	2
Stirring Time(C)	**0.5931***	0.5588	0.5542	0.0389	4
Weight(D)	0.5718	**0.5799***	0.5544	0.0255	6
Size of Nanoparticles(E)	**0.5708***	0.5679	0.5675	0.0033	5
Nanoparticles(F)	**0.5930***	0.5522	0.5610	0.0409	3

In table no.6, the grey relation grade was shown in bold* and the improved multiple performance characteristics [22]. The optimal values of the governable process parameters are as follows, temperature 800^0C (Level 2), stirring speed 600 rpm (Level 1), stirring time 10 min (Level 1), weight 6% of total weight (Level 2), size of nanoparticles 80 (TiO_2) & 50 (BN) (Level 1) and nanoparticles TiO_2+BN (Level 1) and the relation of the grey relation was shown in graph 1.



Graph 1: Grey relational grade graph.

5. The Analysis of Variance (ANOVA) on Grey Grade.

Anova is the technique used to study interpretation between the output parameter. In the present work, the grey relational grades were analyzed by using ANOVA. The ratio of influence of each process parameter in the total sum of the squared deviations was used to evaluate the status of the well-behaved parameter changed on the performance characteristics.

In table 7, the ANOVA results of grey relation grade values are shown. The results show the percentage of contribution of the temperature, stirring speed, stirring time, and nanoparticles are 23.62%, 15.62%, 6.50%, and 6.65% correspondingly. These four parameters significantly influenced the grey relation grade. The temperature is the most influenced parameter for multiple performance characteristics from this four. And the weight of reinforcement and size of the nanoparticles does not have a statistically significant influence on the numerous performance characteristics. Noted that the temperature might not have the same essential attributes on individual performance or different combination process parameters, all these responses are considered together as observed in the current research work [23].

Table 7:The Analysis of Variance on grey grade Results.

Source	DF	Seq SS	Adj MS	F-ratio	contribution
A	2	0.029566	0.014783	3.66	23.62%
B	2	0.019549	0.009774	2.42	15.62%
C	2	0.008131	0.004065	1.01	6.50%
D	2	0.003051	0.001525	0.38	2.44%
E	2	0.000057	0.000029	0.01	0.05%
F	2	0.008318	0.004159	1.03	6.65%
Residual Error	14	0.056483	0.004034		
Total	26	0.125154			

DF- Degree of freedom, SS- Sum of the square, MS-Mean Square.

6. Predicting optimal value and confirmation test

Optimal levels are identified from the parameters, and a confirmation test was carried out to predict and know the significance of optimal levels of design parameters. The expected grades of the optimal levels of the stir casting are calculated using the equation (8).

$$\hat{\gamma} = \gamma_t + \sum_{i=1}^{p}(\gamma_i - \gamma_t) \qquad (8)$$

Where γ_t is the total mean grey relation grade, γ_i Is the mean grey relation grade at the optimum level, and 'p' is the number of principal parameters that significantly affect the multiple performance characteristics.

The A2B1C1D2E1F is an optimal parameter of the reinforcement of the stir casting process obtained through GRA and considered a confirmation test. From equation (8), the projected GRG will be received. Table 8 shows the validation test results of the optimal process parameters. The tensile and compressive strength were improved slightly from 248.40 to 256.3 and 216.58 to 230.5, and the hardness was reached near the value. Finally, it shows clearly that multiple performances of stir casting reinforcements were improved by 0.1536. An excellent improvement was observed in the experiment, and predicted GRG was seen.

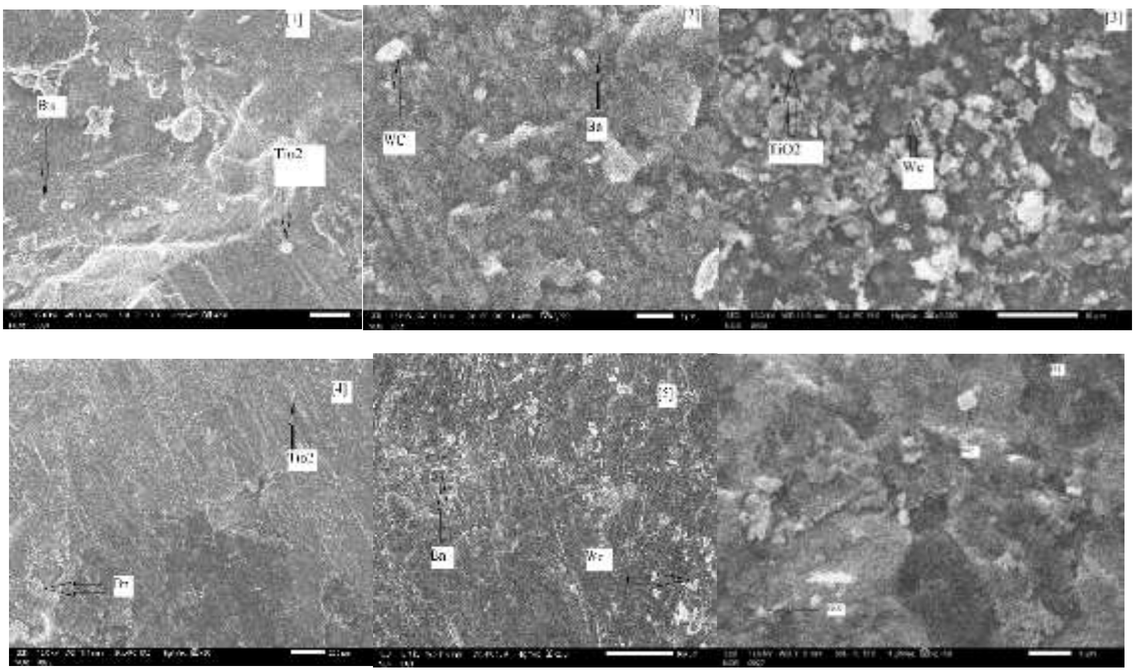
Table: 8 Results of the confirmation test

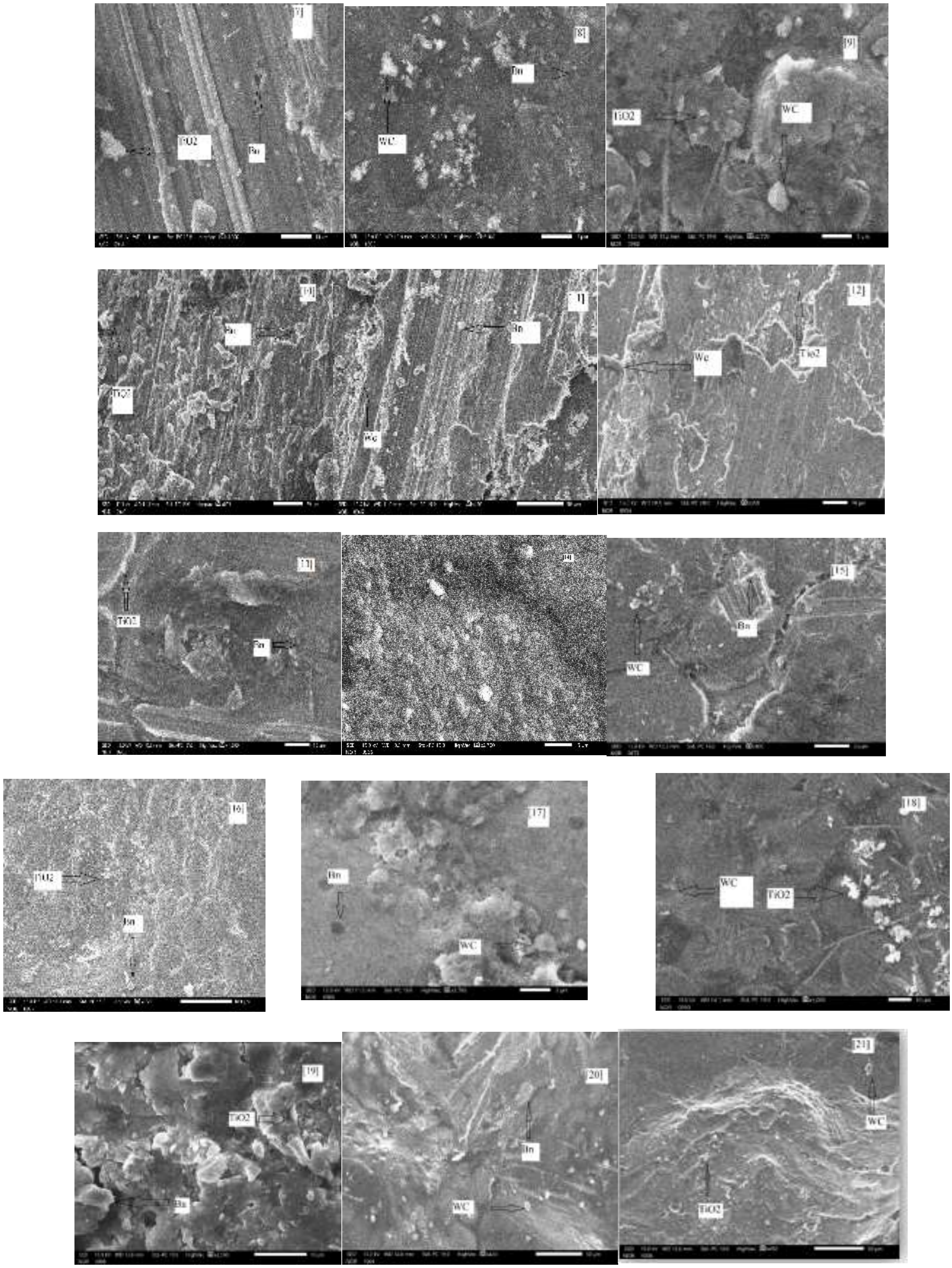
		Setting level	Tensile Strength	Compressive Strength	Hardness	GRA	Improvement in GRA
Initial controllable parameters		A2B2C3D1E3F1	248.40	216.58	83.2	0.7296	
Optimal controllable parameters	Prediction	A2B1C1D2E1F1				0.6948	
	Experiment	A2B1C1D2E1F1	256.3	230.5	82.45	0.8832	0.1536

8. Microstructural Studies of hybrid Composite.

The specimens were fabricated 10*10*10 mm for scanning microstructures of Al7075 Tio2/BN/WC hybrid composite under Scanning Electron Microscopy (SEM). And the scanning was performed at more than 1000X magnification. It is observed that the reinforcements were evenly distributed hybrid composite. At 600 rpm stirring speed and 10 min of string time, the reinforcements were observed better performances on mechanical properties. The SEM images show better relation between the Al7075 and Tio2/BN at those stirring speeds and time, shown in figures 1-27.

The SEM analyses of the conformation test explain that the Bn and Tio2 nanoparticles were bonded with good porosity with Al7075 alloy and improved the hardness 82.45 and compressive strength 230.5 of the hybrid composite. At the same time, the Tio2 partials show in enhancing the tensile strength up to 256.3 of the hybrid composite shown in figure no 28.




[8]
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Bn
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TiO2
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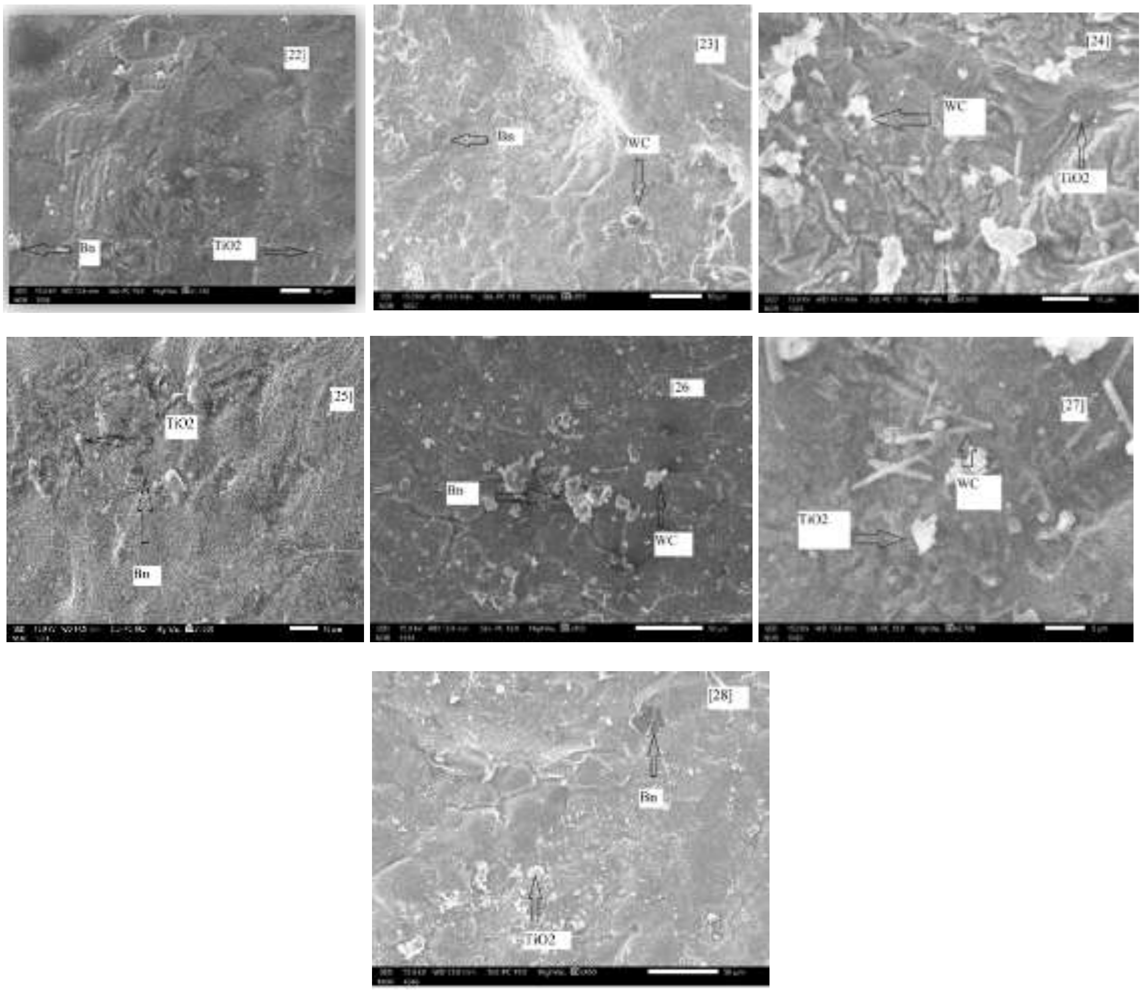

Figures. SEM microstructure of the Al7075/ TiO2+Bn/ Bn+Wc/ Wc+TiO2 MMCs with 1. 3% (TiO2+BN) 2. 3% (BN+WC) 3. 3% (WC+TiO2) 4. 6% (TiO2+BN) 5. 6% (BN+WC) 6. 6% (WC+TiO2) 7. 9% (TiO2+BN) 8. 9% (BN+WC) 9. 9% (WC+TiO2) 10. 9% (BN+WC) 11. 9% (WC+TiO2) 12. 9% (TiO2+BN) 13. 3% (BN+WC) 14. 3% (WC+TiO2) 15. 3% (TiO2+BN) 16. 6% (BN+WC) 17. 6% (WC+TiO2) 18. 6% (TiO2+BN) 19. 6% (WC+TiO2) 20. 6% (TiO2+BN) 21. 6% (BN+WC) 22. 9% (WC+TiO2) 23. 9% (TiO2+BN) 24. 9% (BN+WC) 25. 3% (WC+TiO2) 26. 3% (TiO2+BN) 27. 3% (BN+WC) 28. 6% (TiO2+BN).

8. Conclusion

I the present research work, to find out the optimum hybrid composites of Al7075 reinforcement for knowing the best mechanical properties by using Taguchi's orthogonal array with grey relation analysis. The conclusions were concluded for the present work as follows.

A stir casting process effectively prepared the hybrid composites. And the study of SEM (scanning electron microscope) images explains the even distribution of the BN, Tio2, and WC in the AL7075 matrix alloy.

GRA in the Taguchi method is a valuable tool for predicting the optimization of the multi-response problems of the Al7075/ Tio2/BN/WC hybrid metal matrix composites.

The ANOVA observed that the temperature (23.62%) influences more on the multi-performance characteristics of Al7075/ Tio2/BN/WC hybrid metal matrix composites followed by stirring speed (15.62%), stirring time (6.51%), and nanoparticles (6.65%).

The mechanical properties were improved in the conformation test (A2B1C1D2E1F1), and it is observed that in SEM images, the Tio2/BN was uniformly distributed in the Al7075 composite.

9. References

1. Mohammed Imran and Dr A.R Anwar Khan, Mechanical Properties and Microstructure of Al-7075-BA hybrid composites, International Research journal of engineering and technology:2017, e-ISSN 2395-0056

2. Poovazhagan. L and Kalaichelvan. K, characterization of hybrid silicon carbide and Boron carbide Nanoparticles-Reinforced aluminium alloy composites, Design and Manufacturing, IConDm 2013.

3. B.Ravi, Fabrication and Mechanical Properties of Al7075-SiC-Tic hybrid Metal Matrix Composites, International Journal of Engineering Science Invention, ISSN 2319-6726

4. Gupta Manoj Kumar, Characterization of Al-6063/TiB_2 /Gr hybrid Composite fabricated by the stir casting process. Metal Power Report, the year 2020

5. K.Srivallirani and M.Venkateswara Rao, fabrication and mechanical characterization of Al7050/TiO2/Bn Hybrid metal matrix Composites. Material Today,2020.

6. P Vamsi Krishna and RN Rao, Two-body abrasive wear behaviour of AA6061-2SiC-2Gr hybrid Nanocomposite fabricated through ultrasonically assisted stir casting, Journal of Composite Materials: 2019, DOI:10.117/00219983 I 8822723.

7. S. Suresh1 .G. Harinath Gowd and M. L. S. Deva Kumar, Mechanical Properties of AA 7075/Al2O3/SiC Nano-metal Matrix Composites by Stir-Casting Method, J. Inst. Eng. India Ser. D: 2018,https://doi.org/10.1007/s40033-019-00178-1

8. K.Gurusami, S.Shalini and T.Sathish Optimization of stir casting for corrosion rate analysis of AA7086-Boron carbide composites, Materials Today: https://doi.org/10.1016/j.matpr.2020.08.302

9. Hashim Hanizam and Mohd sukor Salleh Optimisation of mechanical stir casting parameters fro fabrication of carbon nanotube-aluminium alloy composite though Taguchi method, Jmr&t https://doi.org/10.1016/j.jmrt.2019.02.008

10. M.Ravichandran, M.Meignanamoorthy and G.P.Chellasivam Effect of Stir Casting Parameters on Properties of Cast Metal Matrix Composite Meterialstoday : (2020) 2606–2613

11. Johan Victor Christy and Ramanathan Arunachala Processing, Properties and microstructure of recycled aluminium alloy composites produced through an optimized stir and squeeze casting process. https://doi.org/10.1016/j.jmapro.2020.09.067, Journal of Manufacturing Processes: 2020.

12. V.Mohanavel and S.Prasath Optimization of wear parameters of aluminium composites
(AA7150/10 wt%WC) employing Taguchi approach Materials Today:2020.

13. Abid Ustaoglu and Bilal Kursunch Performance optimization and parametric evaluation of the cascade vapour compression refrigeration cycle using Taguchi and ANOVA methods

14. L Narayan and M.Senthil Kumar An integrated artificial neural network and Taguchi approach to optimize the squeeze cast process parameters of AA6061/Al2O3/SiC/Gr hybrid Composites prepared by novel encapsulation feeding technique, Materials Today Communications: 2020

15. E.Naveen and SIlangovan Optimization of hardness and wear parameters of Al-Cu-Si alloy
Using the design of experiments Materials Today: 2019.

16. A.S.Canbolat and A.H.Bademlioglu Performance optimization of absorption refrigeration systems using Taguchi, ANOVA, and Grey Relational Analysis methods. Journal of Cleaner Production: 2019, https://doi.org/10.1016/j.jclepro.2019.05.020.

17. T.Sathish and S.Karthick Wear behaviour analysis on aluminium alloy 7050 with reinforced SiC through Taguchi approach, Journal of Materials research and technology: 2020, https://doi.org/10.1016/j.jmrt.2020.01.085.

18. K. Ch. APPA RAO, Anil Kumar BIRRU, QFD-Taguchi based hybrid approach in die casting process optimization, Nonferrous Met. Soc. China 27(2017) 2345−2356, DOI: 10.1016/S1003-6326(17)60260-7.

19. Mohammed Imran and A.R.Anwar Khan, Characterization of Al-7075 metal matrix composites: a review, Journal of Materials research and technology: 2019.

20. Mulugundam Siva Surya & G. Prasanthi, Physical and Mechanical Characterization
of Al7075/SiC Functionally Graded Materials Fabricated by Powder Metallurgy Route, https://doi.org/10.1080/2374068X.2020.1835022, Taylor and Francis:2020.

21. Poovalingam Muthu Multi-objective optimization of wear behaviour of Aluminum MMCs using Grey-Taguchi method https://doi.org/10.1051/mfreview/2020013, Manufacturing review 2020.

22. Sonja Jozic and Drazen Bajic Application of compressed cold air cooling: achieving multiple performance characteristics in end milling process, Journal of Cleaner Production 2015.

23.M.Arockia Jaswin and D.Mohan Lal Optimization of the Cryogenic Treatment Process for En 52 Valve Steel Using the Grey-Taguchi Method, https://doi.org/10.1080/10426910903536766, 2010, Materials and Manufacturing Process Taylor and Francis.

24. P.Meramma, D.Ravikanth, and Dr MLS Deva Kumar A Novel approach for Multi-Objective Optimization of End Milling Using Grey-ANFIS Method, International Journal of Research in Advent Technology, Special Issue, March 2019 E-ISSN: 2321-9637