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Research Article

Parametric Optimization of Squeeze Cast AC2A-Ni Coated SiC_p Composite Using Taguchi Technique

A. R. Ravikumar,[1] K. S. Amirthagadeswaran,[2] and P. Senthil[3]

[1] *Department of Mechanical Engineering, Sri Shakthi Institute of Engineering & Technology, Coimbatore 641062, India*
[2] *Department of Mechanical Engineering, Government College of Technology, Coimbatore 641013, India*
[3] *Department of Mechanical Engineering, Coimbatore Institute of Engineering & Technology, Coimbatore 641109, India*

Correspondence should be addressed to A. R. Ravikumar; ravi_9778@yahoo.co.in

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This paper mainly focusses on parametric optimization of squeeze cast AC2A Ni coated SiC_p composite through Taguchi technique. Composite samples have been cast through squeeze casting for each experimental trial based on L16 orthogonal array. From analysis of variance (ANOVA), it has been found that reinforcement percentage, squeeze pressure, and pressure duration were the casting parameters making significant improvement in the mechanical properties such as hardness and ultimate tensile strength. Reinforcement percentage and squeeze pressure have been identified as the most influencing parameters from the percentage contribution analysis. The optimum parametric setting has been determined through Taguchi technique. It has been confirmed that AC2A-Ni coated SiC_p composite obtained for the optimum parametric setting has exhibited better mechanical properties compared to the experimental trials.

1. Introduction

The increase in demand for light weight and energy efficient materials with high strength, stiffness, and wear resistance leads to the development of advanced materials like metal matrix composites (MMCs) [1–3]. Among the various matrix materials available, aluminium alloys are mostly employed in MMCs because of their light weight, economical viability, processing flexibility, corrosion resistance, high thermal conductivity, and heat treatment capability [4–6]. Particle reinforced aluminium metal matrix composites (PAMMCs) are the most attractive materials due to their improved strength, high modulus, and more resistance against wear and corrosion when compared to their monolithic alloy [7]. Even though specific strength of PAMMCs is not as high as that of continuous fiber reinforced MMCs, ease of processing, isotropic properties, and considerable cost make them potential candidates in various applications like aerospace, marine, military, and automobile [7, 8]. Moreover, the particle reinforcements reduce the troubles allied with manufacturing of continuous fiber reinforced MMCs such as fiber mismatch, fiber fracture, and heterogeneity in microstructure [9].

Oxides, carbides, nitrides, and borides are the various groups of ceramic reinforcements used in PAMMCs [10]. In the various groups, silicon carbide finds more application due to its low cost and easy availability [11]. In addition, SiC have been found to have excellent compatibility with the aluminium alloy matrix [12, 13].

MMCs are usually processed either by solid state processes (powder metallurgy) or liquid state processes (casting route) [14, 15]. In the former, distribution of the particle reinforcements is uniform and interfacial reactions can be controlled easily, but cost of the process is high. Casting is the most economical route of transferring the raw materials into the final near net shape and use of wide range of ceramic reinforcements is possible, but has difficulties like non uniform distribution of particles and extensive interfacial reactions [16]. Also the conventional casting has major drawbacks like porosities, hot tears, and so forth. Squeeze casting is known as very promising route of manufacturing near net shape MMCs

Table 1: Chemical composition of AC2A aluminium alloy.

Element	Si	Cu	Fe	Mg	Mn	Ti	Pb	Zn	Ni	Sn	Al
Standard (wt%)	4–6	3–4.5	<0.75	<0.25	<0.55	<0.2	<0.15	<0.55	<0.30	<0.05	Rest
Ingot analysis (wt%)	4.81	3.69	0.24	0.16	0.11	0.04	0.027	0.02	0.011	0.009	91

economically in single step. In this process, solidification of melt takes place under high pressure, which eliminates formation of porosities caused by shrinkage and gas and also saves material by eliminating runner and riser. Moreover, shape tolerance, surface finish, and mechanical properties are highly improved with fine microstructure and adhesion of molten metal with reinforcement [11].

Seo and Kang [16] have reported that hardness and tensile strength of squeeze cast Al-SiC_p composite were improved with application of pressure up to 100 MPa. They have also noticed the fractures and split of many particles under an applied pressure of 130 MPa. Onat et al. [11] have noted that hardness of squeeze cast Al-SiC_p composite increased with the increase of SiC_p volume fraction and squeeze pressure. Sukumaran et al. [17] have pointed out that squeeze cast Al-SiC_p composite has acquired mechanical properties which can be comparable with properties that are obtainable by hot working and also observed reduction in defect level due to applied pressure. Daoud et al. [18] have informed that application of squeeze pressure eliminated the excesses porosity and improved the hardness in the case of squeeze cast Al7075- Al_2O_3 composite.

Yue and Chadwick [19] have stated that there is no real value in manufacturing of particle reinforced composite castings with porosity, since the porosity dominates the mechanical responses during loading. Further, they declared that squeeze casting has a clear merit over its alternative techniques due to zero porosity. Suresh et al. [20] have identified that the squeeze pressure increased the mechanical properties of squeeze cast Al-Beryl composite compared to gravity cast composite. Kalkanli and Yilmaz [9] have observed that squeeze cast Al7075-SiC_p composite revealed a maximum tensile strength when reinforcing 10% SiC_p and also noticed that several samples were found with agglomerations. Kaynak and Boylu [21] have inferred that addition of Mg while processing squeeze cast Al-SiC_p composite improved the wettability which resulted in certain bonding at the matrix-particulate interface. But, insufficient interfacial bond strength was noted under high stress level, which initiated crack at the interface.

However, there exist several problems in producing good quality PAMMCs. The main problem is the high reactivity (interfacial reaction) of SiC_p with aluminium alloy to form aluminium carbide (Al_4C_3) which results in reinforcement degradation and reduction of composite strength. Another problem is poor wettability of ceramic particles in liquid aluminium alloy [22]. Particularly in Al-Si/SiC_p composites, less silicon content leads to enhanced interfacial reactions and lack of wettability at the interface of the reinforcement and Al matrix. Ren et al. [23] have showed that the composite exhibited poor wettability, higher porosity, and poor thermophysical properties when Si content of Al alloy was lower than 6%. Samuel et al. [15] have made comparison of four composites and stated that low silicon content in the aluminium alloy accelerated the formation of Al_4C_3, while high silicon content decelerated the same. According to the research works [5, 24, 25], it is evident that the formation of Al_4C_3 could be suppressed by having a matrix alloy containing higher silicon content.

Metallic coating of the reinforcement is one of the successful methods to reduce or eliminate the interfacial reactions and promote wettability between SiC_p and Al matrix. [5]. Tekmen and Cocen [26] have reported that squeeze cast Al alloy- (Al-7% Si-0.7% Mg) Ni coated SiC_p composite showed improvement in the interfacial bonding and elimination of Al_4C_3. Ramesh et al. [27, 28] have reported that uniform distribution and excellent interfacial bonding of silicon nitride particles were highly achieved by good wettability of Ni-P coated silicon nitride (Si_3N_4) particles with Al matrix during the preparation of Al6061-Si_3N_4 composite. Also, they have stated that both mechanical and tribological properties were considerably improved with Ni-P coating. Yu et al. [29] have stated that tensile strength of squeeze cast Al6061-Y_2O_3 coated Al_2O_3 composite could be improved by 27% when compared to the uncoated one. Dikici et al. [30] have studied the effect of particle sol-gel coating on SiC_p with A380 aluminium alloy composite and found clean and sharp interface between matrix and reinforcement. Ramesh et al. [31] have indicated that Ni-P coating on SiC_p showed an appreciable improvement in mechanical properties of Al6061-SiC_p composite.

From the literature, it was noted that Al- (less than 6%) Si alloy has not been considered as metal matrix with SiC_p through squeeze casting process. In this direction, AC2A aluminium alloy has been considered as matrix and Ni coated SiC_p as reinforcement for the production of squeeze cast AC2A-Ni coated SiC_p composite in this study. The chemical composition of AC2A as per Japanese Industrial Standard (JIS H5202) is given in Table 1.

AC2A alloy is widely used for producing automotive components such as brake cylinder, master cylinder, engine brackets, cylinder heads, and rear axle housings. Senthil and Amirthagadeswaran [32] have stated that squeeze casting is a very effective technique to process AC2A aluminium alloy for the production of brake cylinder with improved mechanical properties. It is expected that the mechanical properties may be increased further while processing this alloy with the addition of Ni coated SiC_p through squeeze casting. In order to improve the quality of castings, the casting parameters have to be carefully controlled and optimized. Taguchi technique was employed to find out the optimum parametric setting in this study.

2. Taguchi Technique

Taguchi technique is a powerful offline quality control concept used to design high quality systems. This technique offers a simple, systematic, and efficient way to optimize designs for improved performance and quality with reduced experimental time and cost [33, 34]. It utilizes robust design to solve lot of complex problems in manufacturing industries for product or process. The methodology is effective to deal with responses that are influenced by multivariables (parameters). This technique significantly reduces the number of experiments which are required to model the response function compared with the full factorial design of experiments. Further, this technique determines the most influential parameter of the system, which, on control, would result in significant improvement in the performance [25].

Taguchi technique employs a special design of orthogonal arrays to study the entire parameter space with only a small number of well balanced experiments and signal-noise (S/N) ratio as the quality characteristic of choice [35]. S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The quality characteristics normally used are lower-the-better, larger-the-better, and nominal-the-best [36]. This technique is executed with the following steps.

(i) Identify process parameters influencing output response of the process.

(ii) Choose a suitable orthogonal array to carry out experiments.

(iii) Examine the results to find out optimum parametric setting.

(iv) Execute a statistical analysis of variance (ANOVA) to find significant parameters.

(v) Run a confirmatory test using the optimum setting.

Five casting parameters, namely, reinforcement percentage, pouring temperature, mould temperature, squeeze pressure, and pressure duration, each at four levels were selected. A four level $L_{16}(4^5)$ orthogonal array with sixteen experimental runs was selected. Hardness and ultimate tensile strength were considered as quality characteristics with the concept of the "larger the better." Mathematical equation of the S/N ratio used for these types of response is given in

$$S/N\,(\text{dB}) = -10\,\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{R_i^2}\right), \quad (1)$$

where $i = 1, 2, \ldots, n$ and R_i is the response value for an experimental condition repeated n times.

3. Experiments and Tests

3.1. Experimental Details

3.1.1. Ni Coating on SiC_p. Silicon carbide powder (SiC_p) with particle size of range 5–40 μm was used as reinforcement. Silicon carbide particles were cleaned, sensitized, and activated with acetone, $SnCl_2$, and $PdCl_2$, respectively. Then, the activated particles were coated by using electroless plating bath containing 25 g $NiSO_4{\cdot}6H_2O$, 9 g $NaC_2H_3O_2$, 23 g $NaH_3PO_2{\cdot}H_2O$, and 0.001 g Pb^{2+} dissolved in 1litre distilled water (Figure 1).

Figure 1: Electroless nickel coating.

Figure 2: Addition of reinforcement.

3.1.2. Squeeze Casting of AC2A-Ni Coated SiC_p Composite. AC2A aluminium alloy was used as metal matrix. 5 Kg AC2A was melted in a graphite crucible by using an electric induction furnace and we waited until a homogeneous liquid phase is obtained. During melting, the surface of the melt was covered by coverall flux in order to avoid the entrapment of gases into the melt. After getting homogeneous liquid phase, the melt was degassed by using hexachloroethane degasser. The pure melt after degassing was agitated by using mechanical stirrer rotating at a speed of 300 rpm to create fine vortex. While stirring constantly for 10 minutes, Ni coated SiC particles were gradually added into the fine vortex. The addition of reinforcement is shown in Figure 2.

Blue Star universal testing machine (Model: UTE-40) of 40 tonne capacity with little modification shown in Figure 3 was employed to apply pressure on the liquid melt in the mould cavity for direct squeeze casting. SG400 spheroidal graphite iron (split mould material), EN8 alloy steel (punch material), and Dycote D140 (coating material on surfaces of mould cavity) were used during the conduct of experiments.

Table 2: Levels for process control parameters.

Casting parameter	Notation	Level 1	Level 2	Level 3	Level 4
Reinforcement percentage (%)	*A*	2.5	5	7.5	10
Pouring temperature (°C)	*B*	675	700	725	750
Squeeze pressure (MPa)	*C*	50	75	100	125
Mould temperature (°C)	*D*	200	250	300	350
Pressure duration (s)	*E*	25	35	45	55

Figure 3: Squeeze casting setup.

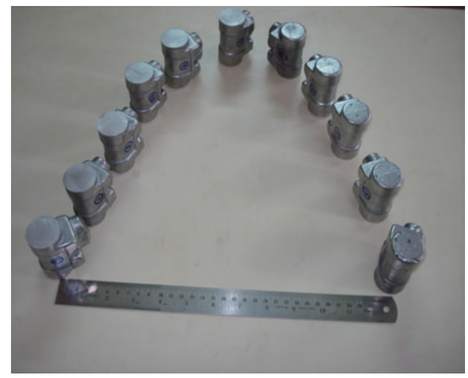

Figure 4: Squeeze cast samples.

Two electrical heaters were employed to preheat split mould assembly and punch. The composite melt was poured into the preheated mould cavity. Pressure was applied on the melt through the preheated punch and maintained until solidification was completed. Punch was then withdrawn and the casting was separated from the mould assembly.

3.1.3. Parametric Constraints. The reinforcement (Ni coated SiC_p) less than 2.5 wt% did not show any appreciable improvement in mechanical properties and the reinforcement greater than 10 wt% led to agglomerations in the castings. So, the addition of reinforcement was varied from 2.5 wt% to 10 wt%. Pouring temperature of 675°C was required for the effective reinforcement of SiC_p in the melt. When pouring temperature was raised above 750°C, Ni coating on SiC_p got degraded. The mould assembly was designed to withstand maximum squeeze pressure of 125 MPa. It was observed that there was an existence of micro pores in the castings for pressures below 50 MPa. The mould temperatures below 200°C resulted in premature solidification and temperatures above 350°C increased solidification time leading to loss in production and decreased life of the mould assembly. It was experimentally found that pressure duration from 25 seconds to 55 seconds exhibited an appreciable improvement in mechanical properties. Hence, the bounds for all these casting parameters were set as follows.

Reinforcement weight percentage, A (%): $2.5 \leq A \leq 10$,

pouring temperature, B (°C): $675 \leq B \leq 750$,

squeeze pressure, C (MPa): $50 \leq C \leq 125$,

mould temperature, D (°C): $200 \leq D \leq 350$,

pressure duration, E (s): $25 \leq E \leq 55$.

All process parameters were fixed at four levels within the above bounds to conduct experiments according to L_{16} (4^5) orthogonal array. The details of all parameters and their levels are given in Table 2. Brake cylinder samples were cast for each experimental condition based on the array. A set of samples is shown in Figure 4.

3.2. Testing

3.2.1. Hardness Test. For Brinell hardness test, 250 kg load was applied through a ball indenter of 5 mm diameter on polished surface of the specimen and hardness values (BHN) were measured in four spots of functional areas as shown in Figure 5.

3.2.2. Tensile Test. INSTRON universal testing machine was employed for performing tensile test on the specimens. Four tensile test specimens, each of 4.53 mm diameter with a gauge length of 16 mm, were prepared and readings were noted.

4. Results and Discussion

4.1. S/N Ratio Response. The S/N ratios for hardness and ultimate tensile strength were calculated using (1) for each parametric setting and their values are given in Table 3.

Table 3: Design of experiments using $L_{16}(4^5)$ array.

Ex no.	Parametric setting	Hardness (BHN)				Ultimate tensile strength (MPa)				S/N ratio for hardness	S/N ratio for ultimate tensile strength
		R_1	R_2	R_3	R_4	R_1	R_2	R_3	R_4	(dB)	(dB)
1	$A_1B_1C_1D_1E_1$	91	87	91	90	259	248	259	256	39.0562	48.1437
2	$A_1B_2C_2D_2E_2$	110	104	108	107	313	296	308	305	40.6026	49.6948
3	$A_1B_3C_3D_3E_3$	124	118	123	122	350	333	347	344	41.7047	50.7139
4	$A_1B_4C_4D_4E_4$	112	106	111	110	319	302	316	313	40.8023	49.8914
5	$A_2B_1C_2D_3E_4$	117	111	115	116	333	316	328	330	41.1898	50.2791
6	$A_2B_2C_1D_4E_3$	115	109	113	112	328	310	322	319	40.9988	50.0908
7	$A_2B_3C_4D_1E_2$	127	121	126	125	362	345	359	356	41.9164	51.0125
8	$A_2B_4C_3D_2E_1$	128	122	126	124	365	347	359	353	41.934	51.0244
9	$A_3B_1C_3D_4E_2$	140	134	138	137	399	382	393	390	42.747	51.8403
10	$A_3B_2C_4D_3E_1$	121	116	121	120	345	330	345	342	41.5434	50.6379
11	$A_3B_3C_1D_2E_4$	120	114	117	120	342	325	333	342	41.4133	50.508
12	$A_3B_4C_2D_1E_3$	127	121	126	125	362	345	359	356	41.9164	51.0125
13	$A_4B_1C_4D_2E_3$	138	133	138	136	393	379	393	387	42.6837	51.7737
14	$A_4B_2C_3D_1E_4$	142	136	140	139	404	387	399	396	42.8727	51.9617
15	$A_4B_3C_2D_4E_1$	122	118	121	120	347	336	345	342	41.5997	50.6913
16	$A_4B_4C_1D_3E_2$	121	117	121	120	345	333	345	342	41.563	50.6587
Mean										$\overline{Y_h} = 41.53$	$\overline{Y_t} = 50.62$

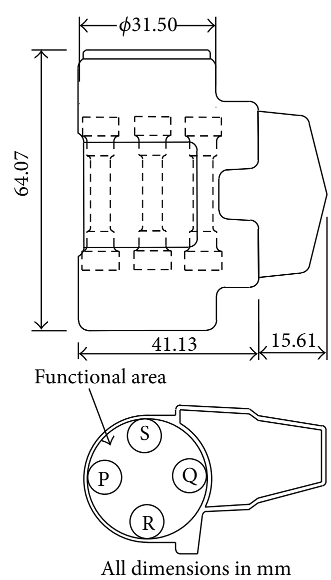

Figure 5: Locations of test specimens.

Mean value of S/N ratios was also calculated for hardness and ultimate tensile strength and their values ($\overline{Y_h}, \overline{Y_t}$) are given in Table 3. Consider

$$\text{Mean}, \overline{Y} = \frac{1}{N}\left(\sum_{j=1}^{N} Y_j\right), \quad (2)$$

Table 4: Average S/N ratio response for hardness.

	A	B	C	D	E
Level 1	40.5415	41.4192	40.7579	41.4404	41.0333
Level 2	41.5098	41.5044	41.3271	41.6584	41.7072
Level 3	41.905	41.6585	42.3146	41.5002	41.8259
Level 4	42.1798	41.5539	41.7365	41.537	41.5696
Max-Min	1.63833	0.23934	1.55676	0.21799	0.79258
Rank	1	4	2	5	3
Optimum level	A_4	B_3	C_3	D_2	E_3

where $j = 1, 2, \ldots, N$ (here $N = 16$) and Y_j is S/N ratio for jth parametric setting. In order to find optimum level of the process parameters, average S/N ratio response was estimated for every level of each parameter and the corresponding details are given in Tables 4 and 5. Based on the highest value of S/N ratio, an optimum level for each parameter (A: 4th level; B: 3rd level; C: 3rd level; D: 2nd level; and E: 3rd level) was noted. The optimum casting condition $A_4B_3C_3D_2E_3$ (reinforcement percentage of 10%, pouring temperature of 725°C, squeeze pressure of 100 MPa, mould temperature of 250°C, and pressure duration of 45 s) was noted to be same for both output responses. This is due to both output responses being often related in all aluminium alloy composites. The response graphs shown in Figures 6 and 7 described the variation of each process control parameter on the performance of the squeeze casting process. From the response graphs, it was observed that parameters B and D showed lesser variations on the output responses compared to

Table 5: Average S/N ratio response for ultimate tensile strength.

	A	B	C	D	E
Level 1	49.6109	50.5092	49.8503	50.5326	50.1243
Level 2	50.6017	50.5963	50.4194	50.7502	50.8016
Level 3	50.9997	50.7314	51.3851	50.5724	50.8977
Level 4	51.2713	50.6467	50.8289	50.6284	50.66
Max-Min	1.6604	0.22218	1.53478	0.21766	0.7734
Rank	1	4	2	5	3
Optimum level	A_4	B_3	C_3	D_2	E_3

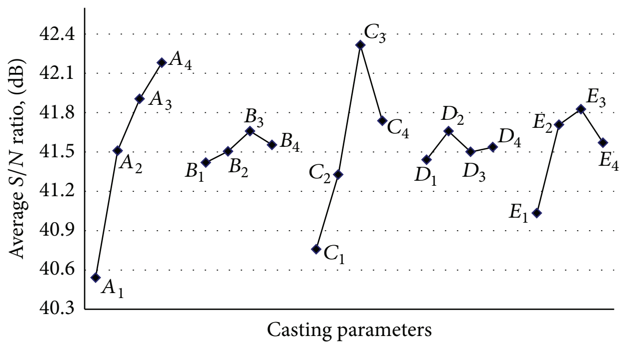

Figure 6: Response graph for hardness.

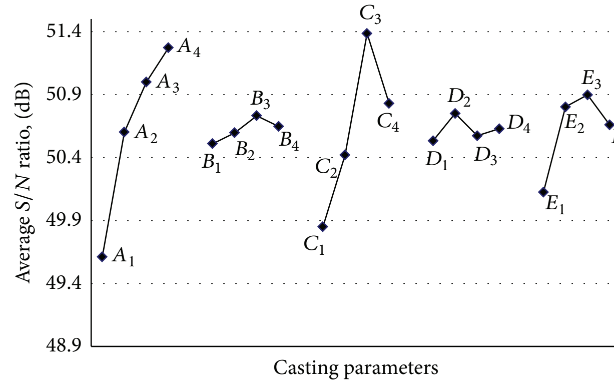

Figure 7: Response graph for ultimate tensile strength.

other parameters. Therefore, analysis of variance (ANOVA) and F test were used to analyze the experimental data.

4.2. Analysis of Variance. Analysis of variance was performed on signal to noise ratios to find the significance of the process control parameters and their contribution in the process performance. The following terms were calculated and their values are given in Tables 6 and 7.

(i) Sum of squares due to mean:

$$\mathrm{SS}_m = N\overline{Y}^2. \tag{3}$$

(ii) Sum of squares due to parameter A:

$$\mathrm{SS}_A = n_{A1} \times \overline{A_1}^2 + n_{A2} \times \overline{A_2}^2 + n_{A3} \times \overline{A_3}^2 + n_{A4} \times \overline{A_4}^2 - \mathrm{SS}_m. \tag{4}$$

Similarly, sum of squares due to parameters B, C, D, and E were calculated. Sum of squares due to parameters B and D were found to be less in this study. Therefore, their effects on the output responses were assumed to be negligible and treated as an error (pooled error). Sum of squares due to pooled error was also calculated as follows:

$$\mathrm{SS}_{\text{pooled error}} = \mathrm{SS}_B + \mathrm{SS}_D. \tag{5}$$

(iii) Total sum of squares:

$$\mathrm{TSS} = \mathrm{SS}_A + \mathrm{SS}_B + \mathrm{SS}_C + \mathrm{SS}_D + \mathrm{SS}_E. \tag{6}$$

(iv) Degree of freedom for parameter: $\mathrm{DOF}_{\text{parameter}}$ = Number of levels of parameter − 1. Degree of freedom for pooled error: $\mathrm{DOF}_{\text{pooled error}} = \mathrm{DOF}_B + \mathrm{DOF}_D$.

(v) Mean sum of squares due to parameter A:

$$\mathrm{MSS}_A = \frac{\mathrm{SS}_A}{\mathrm{DOF}_A}. \tag{7}$$

Similarly, mean sum of squares for all other parameters and pooled error were calculated.

(vi) F ratio for parameter A,

$$F_A = \frac{\mathrm{MSS}_A}{\mathrm{MSS}_{\text{pooled error}}}. \tag{8}$$

Similarly, F ratio was calculated for parameters C and E. The calculated F ratio for parameters A, C, and E was found to be greater than the F distribution value ($F_{1,6}$ = 5.9874 at 5% level of significance). Therefore, the parameters A, C, and D were confirmed as significant parameters in this study.

(vii) Pure sum of squares due to parameter A:

$$\mathrm{PSS}_A = \mathrm{MSS}_A - \mathrm{DOF}_A \times \mathrm{MSS}_{\text{pooled error}}. \tag{9}$$

(viii) Percentage contribution of parameter A,

$$\mathrm{PC}_A = \frac{\mathrm{PSS}_A}{\mathrm{TSS}} \times 100\%. \tag{10}$$

Similarly, pure sum of squares and percentage contribution of parameters C, E, and pooled error were calculated. The percentage contribution of pooled error was noted to be less than 5% for both output responses in this study. The percentage contribution of all significant parameters is clearly shown in Figure 8.

Table 6: ANOVA for hardness.

Source	Pool	SS	DOF	MSS	F ratio	PSS	PC (%)
A		6.16166	3	2.05389	55.6621	6.051	46.4248792
B	Yes	0.11986	3	0.03995			
C		5.18222	3	1.72741	46.8141	5.072	38.9102514
D	Yes	0.10154	3	0.03385			
E		1.46861	3	0.48954	13.2669	1.358	10.4183344
Pooled error		0.2214	6	0.0369		0.553	4.24653502
TSS		13.0339				13.03	

Table 7: ANOVA for ultimate tensile strength.

Source	Pool	SS	DOF	MSS	F ratio	PSS	PC (%)
A		6.34772	3	2.11591	60.0074	6.242	47.8843
B	Yes	0.10382	3	0.03461			
C		5.04659	3	1.6822	47.7073	4.941	37.9028
D	Yes	0.10774	3	0.03591			
E		1.42958	3	0.47653	13.5144	1.324	10.1554
Pooled error		0.21156	6	0.03526		0.529	4.05748
TSS		13.0355				13.04	

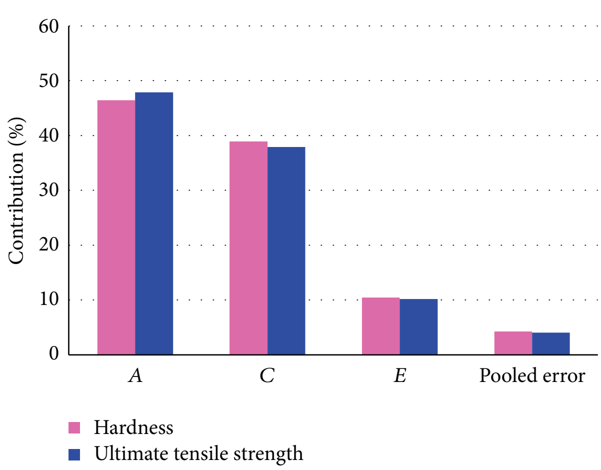

Figure 8: Percentage contribution.

4.3. Predicted Mean and Confidence Interval. Predicted mean (μ) for hardness and ultimate tensile strength and confidence interval (CI) for the predicted mean were determined by using the following:

$$\mu_{\text{hardness}} = \overline{A_4} + \overline{C_3} + \overline{E_3} - 2\overline{Y_h}, \tag{11}$$

$$\mu_{\text{ultimate tensile strength}} = \overline{A_4} + \overline{C_3} + \overline{E_3} - 2\overline{Y_t}, \tag{12}$$

$$\text{CI} = \pm\sqrt{F_{0.05,1,6} \times V_e \times \frac{1}{N_{\text{eff}}}}, \tag{13}$$

where $V_e = \text{MSS}_{\text{pooled error}}/\text{DOE}_{\text{pooled error}}$ and N_{eff} = (Number of experiments)/(1 + Total DOF associated with μ).

The confidence interval for hardness and ultimate tensile strength was noted to be ±0.37 dB and 0.36 dB, respectively, at 5% level of significance. The predicted mean of hardness (43.26 dB) showed the variation from 42.89 to 43.63 dB. The predicted mean of ultimate tensile strength (52.31 dB) showed the variation from 51.95 to 52.67 dB.

4.4. Confirmation Experiments. Two samples were made for the optimum parametric setting. The values of hardness and ultimate tensile strength measured in the functional volume were found to be 147, 141, 145, and 144 BHN and 419, 402, 414, and 410 MPa, respectively, and their S/N ratios were 43.18 dB and 52.28 dB, respectively. These S/N ratio values were found within the confidence interval limits. A comparison was made for different casting conditions (A_4B_3C: 0.1 MPa D_2E_3, $A_1B_1C_1D_1E_1$, $A_4B_2C_3D_1E_4$, and $A_4B_3C_3D_2E_3$) in the microstructural aspect as shown in Figure 9. The castings obtained for optimum condition showed better grain refinement and uniform distribution of reinforcements when compared with other conditions.

5. Conclusion

Taguchi technique was employed to find the optimum parametric setting of squeeze casting process for producing high quality castings of AC2A-Ni coated SiC_p Composite. The optimum parametric setting was found as follows:

reinforcement percentage: 10%,

pouring temperature: 725°C,

squeeze pressure: 100 MPa,

mould temperature: 250°C,

pressure duration: 45 seconds.

This setting was verified through the confirmation experiments. The castings produced for the optimum setting were found to be defects free and sound. From the ANOVA,

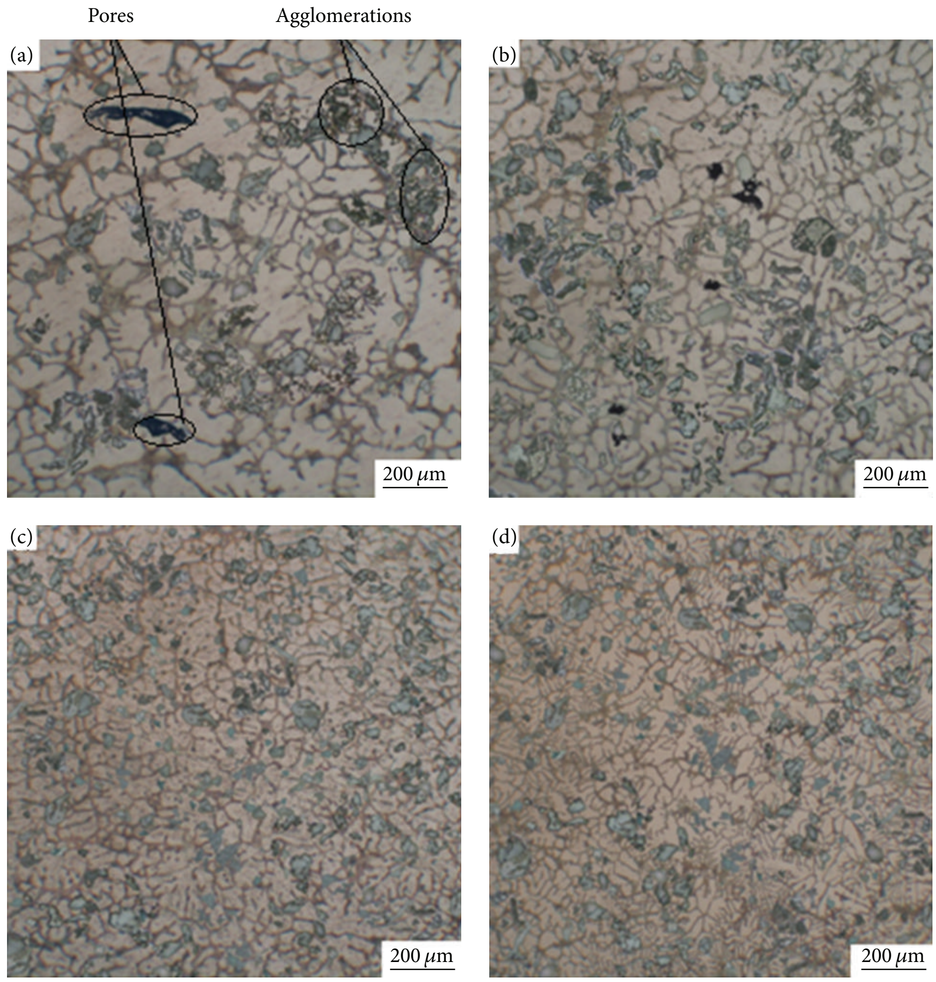

Figure 9: Microstructures. (a) Gravity cast at A_4B_3C: 0.1 MPa D_2E_3, (b) squeeze cast at low level $A_1B_1C_1D_1E_1$ within DOE, (c) squeeze cast at better level $A_4B_2C_3D_1E_4$ within DOE, (d) squeeze cast at optimum level $A_4B_3C_3D_2E_3$.

reinforcement percentage, squeeze pressure, and pressure duration were identified as significant casting parameters in this study. From the percentage contribution analysis, it was noted that reinforcement percentage and squeeze pressure were the most important parameters for the improvement of mechanical properties.

Nomenclature

BHN: Brinell hardness number
DOF: Degree of freedom
DOE: Design of experiments
gpl: Gram per litre
MSS: Mean sum of squares
N: Number of experiments
n: Number of observations
PC: Percentage contribution
PSS: Pure sum of squares
R_1: Readings measured in spot P
R_2: Readings measured in spot Q
R_3: Readings measured in spot R
R_4: Readings measured in spot S
SS: Sum of squares
TSS: Total sum of squares.

Conflict of Interests

The authors declare that they have no conflict of interests regarding the publication of this paper.

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