Mechanical Characterization and Optimization of Stir Casting Parameters for Al 6063/Al_2O_3 (Alumina) Reinforced Metal Matrix Composites

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ABSTRACT

The present study focused on the mechanical properties of stir cast Al 6063/Al_2O_3 (Alumina) reinforced metal matrix composites. Aluminum-alumina composites are used in various industries including fabrication, aerospace, automobile sectors, etc. The properties like corrosion resistance, low density, and high modulus of elasticity, higher thermal, and electrical conductivity make them the best choice for its applications in various industries. The present work focus on the hardness of Al 6063/Al_2O_3 (Alumina) reinforced metal matrix composites by varying the percentage of the reinforced element alumina in the base matrix alloy Al 6063, stirring speed and stirring time. The thickness of the sample was taken 10mm, width 30mm and length 100mm. Nine samples were prepared by varying the percentage of alumina 2%,4%,6% (wt %), stirring speed of 800,1000 and 1200 (Rpm) And stirring time of 5,10, 15 (minutes). It was shown from the experiment that the hardness value increases with the increase in reinforcement percentage but after that, there was a decrease in hardness value. Also, the optimized value of the stirring speed, reinforcement percentage and stirring time was obtained by analysis of variance using Taguchi's experimental design.

Keywords*: *Aluminum, aluminum oxide, composite materials, stir casting process, hardness test.

1. INTRODUCTION

At present different types of composites are being formed and are being tested. Composites are becoming popular due to its application in different areas. It is becoming an economical material for getting desirable properties. Stir casting is an economical process of making composites. Stir casting methods have different parameters that can be changed for getting composites of different mechanical properties. Few parameters which are considered as important parameters are stirring speed, Stirring time and reinforcement percentage.

Stirring is done mechanically for proper mixing of the base metal and the reinforcement. For making aluminum composites, stir casting is a better option. Aluminum composites are formed with different reinforcement. The stir casting method is easy to control and provides sound casting if done properly. The composites formed by the stirring casting process due to its lightweight, and high strength can be employed for different industrial sectors. In the present study Alumina in varying proportion, 2%, 4%, and 6% are taken as reinforcement and Al 6063 is taken as the base metal. In the present study, attention is focused on the hardness of the stir casted composite. In the present work by changing the stir casting parameters namely stirring speed of 800,1000,1200 rpm, reinforcement percentage of 2%,4%, and 6% and stirring time of 5,10 and 15 minutes are optimized for getting the optimum value of hardness.

1.1 BASE MATRIX ALLOY

In the present study, Al6063 is selected as the base matrix alloy shown in fig 1.1. Few pieces of the Al 6063 plates are shown in the figure. The Al 6063 plates were cleaned before melting in the stir casting set up so that any impurities like sand, dust, etc can be removed.

Fig 1.1: Few pieces of Al 6063 alloy

1.2 CHEMICAL COMPOSITION OF Al 6063

The table 1.1 shows the chemical composition.

Table 1.1: Chemical Composition of Al 6063

Element	Composition
Si	0.6
Fe	0.35
Cu	0.1
Mn	0.1
Mg	0.9
Ti	0.1
Cr	0.1
Al	Balance

1.3 APPLICATIONS OF Al 6063.

It has various applications in different sectors .It find applications in automobile industries, Air craft industries, architectural and also in agricultural sectors. Besides this it is also used for decorative purposes for making doors and windows.

2. EXPERIMENTAL SETUP

The setup for stir casting consists of electric furnaces for melting the base metal and the reinforcement (Alumina). Stir casting setup is shown in figure 2.1.

Fig 2.1: Stir casting setup

For melting the reinforcement metal here it is alumina the electric furnace is shown in fig 2.2.

Fig 2.2 Electric furnace for melting alumina

3. PREPARATION OF METAL MATRIX COMPOSITE

The aluminum matrix was reinforced with Al_2O_3. The size of alumina particles was taken 46 microns. The casting was done in a stir casting setup consisting of the stirrer.The Al 6063 was charged to the stir casting setup for melting and another electric furnace was used to melt the alumina at the same time. The various steps involved in the preparation of metal composites are as follows.

1. Melting of Al 6063 was done at 800^0C for two hours in the stir casting setup.
2. Melting of Alumina was done at 100^0 C at the same time in different furnace.
3. 5gm of coverall, Nuclear & degasser are added in the melt in the stir casting setup.
4. For two hours at 300^0 C dies were preheated at the same time.
5. Now nine different samples were taken at different stirring speeds and different reinforcement percentages and at different intervals of time as defined in L-9 Taguchi orthogonal array design of the matrix.
6. Nine different samples were taken from the stir casting furnace and were poured to the preheated dies and were allowed to solidify.

4. HARDNESS TESTING

The present study focuses on the hardness value so that the optimal value of the process parameters can be defined that will give the optimal value of hardness. For measuring the hardness nine different samples were taken .The aim of testing was to obtain the value of harness of different samples so that its optimal value is find out with different combinations of process parameters.

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For measuring the hardness at a load of 500kgf and time duration of 20 seconds brinell hardness testing machine was used.

Fig 4.1: Brinell hardness testing

Nine samples were prepared by varying the process parameters. Finally, the specimens were tested for finding the hardness by Brinell hardness testing machine.

Fig 4.2: Few samples for finding hardness

Before performing the hardness test the specimens were clean and the surface was prepared by using emery paper of different grades.

Fig 4.3: A sample showing indentation

5. TAGUCHI'S EXPERIMENTAL DESIGN

The orthogonal array (L9) from Taguchi's experiment design was used to obtain the optimal result. Nine specimens were stir cast by using three levels of parameters. The parameters taken are stirring speed of 800,1000, 1200 rpm, the reinforcement percentage 2,4,6 wt % and finally the stirring time of 5,10 and 15 minutes.

Table 5.1: Stir casting parameters and their levels .

		LEVELS		
Factors	**Units**	**1**	**2**	**3**
Stirring Speed	Rpm	800	1000	1200
Reinforcement Percentage	Wt %	2	4	6
Stirring Time	Minutes	5	10	15

Table 5.2: Taguchi's L9 array design of experiment

	Stir Casting Parameters		
S.N0	Stirring Speed (RPM)	Reinforcement (wt %)	Stirring Time (Min)
1	800	2	5
2	800	4	10
3	800	6	15
4	1000	2	10
5	1000	4	15
6	1000	6	5
7	1200	2	15
8	1200	4	5
9	1200	6	10

6. RESULT ANALYSIS AND DISCUSSION

After conducting the experiments the various results of hardness testing are taken and the analysis of the result was done. The analysis includes the analysis of variance with the interpretation of the result. A table is formed in which the various parameters combinations are listed with the value of the hardness obtained This value of hardness is taken as the response factor for the analysis of variance.

Table 6.1: Hardness values (Brinell hardness) Values of Each specimen

S.NO	Stirring Speed (RPM)	Reinforcement (wt %)	Stirring Time (Min)	Hardness (BHN)
1	800	2	5	17
2	800	4	10	16.65
3	800	6	15	15.54
4	1000	2	10	16.25
5	1000	4	15	25.51
6	1000	6	5	19.68
7	1200	2	15	21.76
8	1200	4	5	24.38
9	1200	6	10	15.59

The above-mentioned table shows the Brinell hardness value obtained by the testing machine. The hardness value is taken as the response factor for the analysis using Minitab software for finding the optimum results.

6.1 ANALYSIS OF VARIANCE FOR HARDNESS TESTING

ANOVA which stands for analysis of variance helps in analyzing differences among group means. Through ANOVA we can obtain the percentage contribution of the significant factor that affects the response factor. Through the ANOVA table we compare the f-value and the p-value for finding the significant factor that affects the response factor.

6.2 CALCULATION OF S/N RATIO

S/N ratio was calculated from the software MINITAB by hardness values i.e. the hardness values obtained from different parameter values. Hardness value was taken as the response factor. The larger is better concept was used for calculating the S/N ratio.

Table 6.2: S/N ratio for hardness

S. NO	Stirring Speed (RPM)	Reinforcement (wt %)	Stirring Time (Min)	Hardness	S/N Ratio
1	800	2	5	17	24.6090
2	800	4	10	16.65	24.4283
3	800	6	15	15.54	23.8290
4	1000	2	10	16.25	24.2171
5	1000	4	15	25.51	28.1342
6	1000	6	5	19.68	25.8805
7	1200	2	15	21.76	26.7352
8	1200	4	5	24.38	27.7407
9	1200	6	10	15.59	23.8569

Table 6.2 shows the value of S/N ratio of different samples having different values of process parameters. The S/N ratio shown above is calculated through the Minitab Software. S/N ratio calculation was based on the hardness value which was taken as the response factor which is shown in the table above.

6.3 RESPONSE TABLE FOR MEANS

From the delta and rank values obtained by the response table 6.3 given below for means, it is clear that reinforcement percentage has an enormous impact on the response characteristics, i.e., the hardness. From the response table for means, it can be seen that reinforcement percentage has maximum influence on the response characteristics so is given rank 1 followed by stirring time which is given rank 2 and stirring speed which is given rank 3.

Table 6.3: Response table for means

LEVEL	**Stirring Speed**	**Reinforcement %**	**Stirring time**
1	16.40	18.34	20.35
2	20.48	22.18	16.16
3	20.58	16.94	20.94
DELTA	4.18	5.24	4.77
RANK	3	1	2

6.4 MAIN EFFECT PLOT FOR MEANS

The main effect plot shows a different level of factors in present work, i.e., stirring speed, reinforcement percentage and stirring time which is responsible for affecting the response factor here it is a hardness. The point represents the means of each parameter. Since the lines are not straight, this shows the existence of the main effect as shown in figure.6.1. The interpretation of the main effect plot is based on the highest is the better criteria.

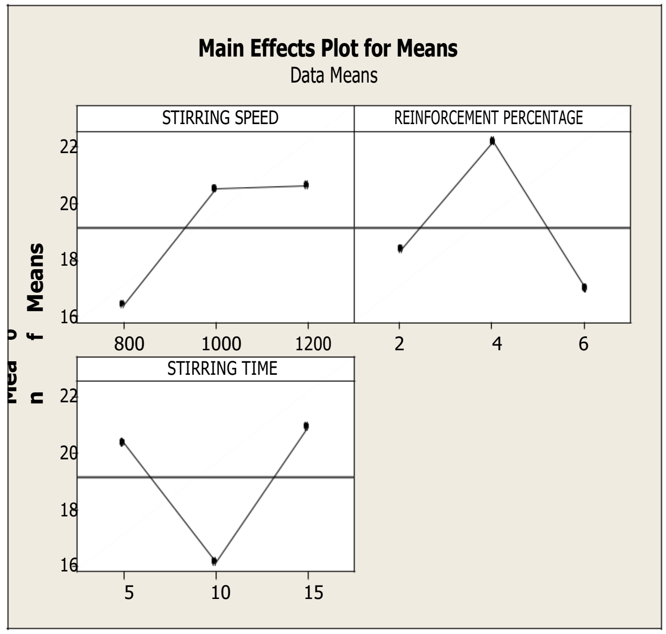

Figure 6.1: Main effect plot for means

From the main effect plot, it can be seen that the stirring speed of 1200 rpm, reinforcement percentage 4 and stirring time of 15 minutes are the higher values.

6.5 RESPONSE TABLE FOR S/N RATIO LARGER IS BETTER

Table 6.4 shows different parameters with different levels along with the calculation of delta statics. The delta statics is obtained by subtracting the lowest from the highest average for each factor. Moreover, the rank is assigned by Minitab by delta statics. From Table 6.4 we can conclude that reinforcement percentage has an enormous influence on the S/N ratio. The stirring time has the next greatest influence and stirring speed has the lowest influence on the S/N ratio.

Table 6.4: Response table for S/N ratio larger is better

LEVEL	Stirring Speed	Reinforcement %	Stirring time
1	24.29	25.19	26.08
2	26.08	26.77	24.17
3	26.12	24.52	26.24
DELTA	1.83	2.25	2.07
RANK	3	1	2

6.6 MAIN EFFECT PLOT FOR S/N RATIO

The main effect plot was plotted between the S/N ratio and the process parameters. The parameters include stirring speed, reinforcement percentage, and stirring time. The higher is better criteria was used for the interpretation of the main effect plot. From figure 6.2, the stirring speed of 1200 rpm, reinforcement percentage of 4 and stirring time of 15 minutes gives the higher values.

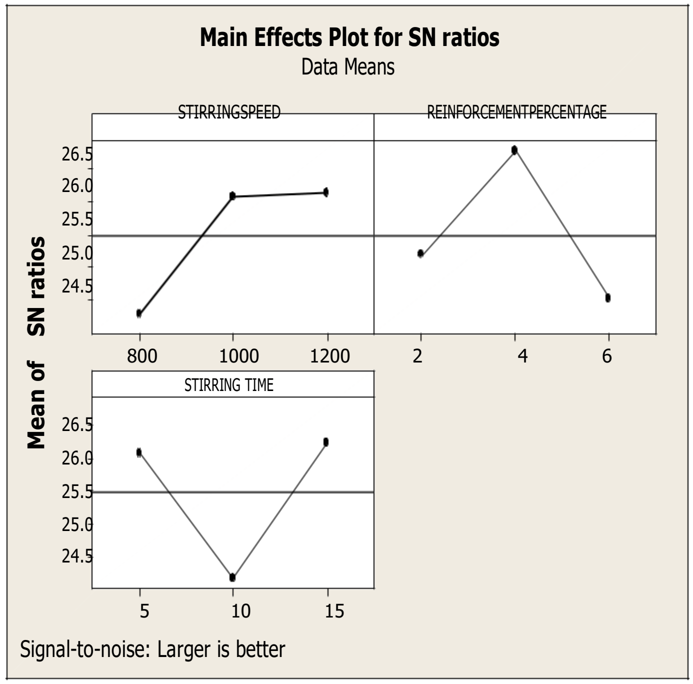

Figure 6.2: Main effect plot for S/N ratio

6.7 Result of analysis of variance for hardness testing

The percentage contribution is obtained from the analysis of variance. The percentage contribution shows the contribution of each significant parameter in percentage which affects the response factor here it is tensile strength. For obtaining the percentage contribution, various values are calculated which is shown in table 6.5.

Table 6.5: Analysis of variance for hardness testing

SOURCE	DF	Adj.SS	Adj.MS	F-VALUE	P-VALUE	% Cont.
Stirring Speed	2	6.5425	3.2712	23.54	0.041	28.75
Reinforcement %	2	7.9723	3.9861	28.69	0.034	35.03
Stirring time	2	7.9623	3.9811	28.65	0.034	34.99
ERROR	2	0.2779	0.1389			
TOTAL	8					

From table 6.5 there are two values F-value and P-values. For the parameters to be significant, the P-value should be low, and F-value should be high. It can be observed from table 6.5 that a reinforcement percentage of 35.03% affects the hardness maximum followed by a stirring time of % and stirring speed of 28.75%.

7. CONCLUSIONS

From the various experiments and from the analysis of variance we obtain the following conclusions.

- The motive of the experiment which focused on the optimization of the process parameters was achieved.
- Out of the three parameters the parameters which has significant effect of hardness was wt % of the reinforcement as it is indicated in the p value of the analysis of variance table.
- Optimal value for the hardness of the composite material is stirring speed of 1200 rpm, reinforcement percentage of 4 wt % and the stirring time of 15 minutes.
- I t was also found that stirring time was next significant parameter after wt% followed by stirring speed.

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