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# Effect of Processing Parameters on Metal Matrix Composites in Stir Casting Process Using Taguchi Technique

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**Abstract:** *The mechanical properties of composites not only depend on the volume of reinforcements, but also on the distribution of reinforcements. Al6063 alloy, reinforced with mixture of Silicon Carbide (SiC) and Alumina (Al<sub>2</sub>O<sub>3</sub>) particles, known as hybrid composites have been fabricated by stir casting technique and optimized at different parameters like stirring speed, processing temperature, reinforcement preheat temperature and percentage addition of SiC (5%, 10% and 15%) by Taguchi method L9 Orthogonal array. Optimum Brinell hardness (BHN), Ultimate tensile strength (UTS) and Yield strength (YS) have been found under the influence of stirring speed, processing temperature, reinforcement preheat temperature and percentage addition of SiC. Finally, confirmation test has been carried out to verify the experimental results.*

**Key words:** *Hybrid Composite, Orthogonal Array, Ultimate Tensile Strength, Brinell Hardness, Stir casting Technique.*

## I. INTRODUCTION

Composite materials are made from two or more constituent materials and distinct on a macroscopic level within the finished structure. They do not dissolve or blend with each other. Composite materials play an important role in the field of engineering as well as advance manufacturing in response to unprecedented demands from technology due to rapidly advancing activities in aircrafts, aerospace and automotive industries. Stir casting technique is one of the popular Liquid Metallurgy Route (LMR) and also known as a very promising route for manufacturing near net shape hybrid metal matrix composite components at a normal cost. The stir casting furnace is mounted on the floor and the temperature of the furnace is precisely measured and controlled in order to achieve sound quality composite. Two thermocouples and one PID controller were used for this purpose. As mild steel materials are having high temperature stability, they are selected as stirrer rod and impeller [1].

The porosity can be reduced by constant stirring, maintaining the optimum melt temperature and using sand mold. The addition of SiC as secondary ceramic reduces the coefficient of friction there by reduction in the noise and vibration during the motion [2]. The ceramics used are soft and hard nature, the hard ceramics increases the wear resistance and strength whereas the soft ceramics increases the lubrication effect, reduces the noise and vibration etc. Metal matrix composites (MMCs) provide a combination of the metallic properties of the matrix (high toughness) with the ceramic properties of the reinforcement (high strength and high modulus) to give a material greater strength and stiffness, higher temperature capabilities and more excellent wear resistance than a similar monolithic material [3,4]. The Argon gas was supplied into the near the crucible during the stirring to avoid the formation of oxide layer on the surface of matrix melt. From the microstructure analysis, the particles were distributed uniformly in the processing temperature 750°C and 800°C. The particles agglomerations were found in the processing temperature of 700°C, 850°C and 900°C due to the changes of viscosity in liquid Al matrix [5,6]. At full liquid condition it is difficult uniform distribution of the reinforcement in the molten metal. Preheating of mold helps in reducing porosity as well as increases mechanical properties. Uniform dispersion of material blade angle should be 45° or 60° & no of blade should be 4 [7].

## II. EXPERIMENTAL WORK

In the present investigation, tensile test and hardness test were performed on SiC and Al<sub>2</sub>O<sub>3</sub> particulates reinforced Al6063 alloy matrix composite. The matrix material was loaded in a graphite crucible and it was placed inside a top loaded resistance furnace at different process parameters like stirring speed (A), processing temperature (B), reinforcement preheat temperature (C) and percentage addition of SiC (D) (5%, 10% and 15%) by Taguchi method L9 Orthogonal array.

Constant parameters:

Stirring time: 6min.

Al<sub>2</sub>O<sub>3</sub>: 3%

Table 1.Taguchi Runs

RUN	A	B	C	D
1	400	750	600	5%
2	400	800	650	10%
3	400	850	700	15%
4	500	750	650	15%
5	500	800	700	5%
6	500	850	600	10%
7	600	750	700	10%
8	600	800	600	15%
9	600	850	650	5%

### III. RESULTS AND DISCUSSION

The machined specimen has been tested for tensile test and hardness test (Brinell test) to identify the mechanical properties then regression equation is formed by using Minitab17 software.

#### A. Tensile Test (Ultimate Tensile Strength)

Table 2.SN ratio Ultimate Tensile Strength

Run	A	B	C	D	UTS	YS	SNRA UTS	SNRA YS
1	400	750	600	5	270	262.5	48.62	48.38
2	400	800	650	10	265	260	48.46	48.29
3	400	850	700	15	234	224	47.38	47.00
4	500	750	650	15	244.5	218	47.76	46.76
5	500	800	700	5	269	262	48.59	48.36
6	500	850	600	10	270	256	48.62	48.16
7	600	750	700	10	281	271	48.97	48.65
8	600	800	600	15	239	230.5	47.56	47.25
9	600	850	650	5	273	264.5	48.72	48.44

Table 3.Response for Signal to Noise ratio and Means (UTS)

Level	A	B	C	D
1	48.16	48.46	48.27	48.65
2	48.33	48.21	48.32	48.69
3	48.42	48.24	48.32	47.57
DELTA	0.26	0.25	0.04	1.12
RANK	2	3	4	1

Level	A	B	C	D
1	256.3	265.2	259.7	270.7
2	261.2	257.7	260.8	272.0
3	264.3	259.0	261.3	239.2
DELTA	8.0	7.5	1.7	32.8
RANK	2	3	4	1

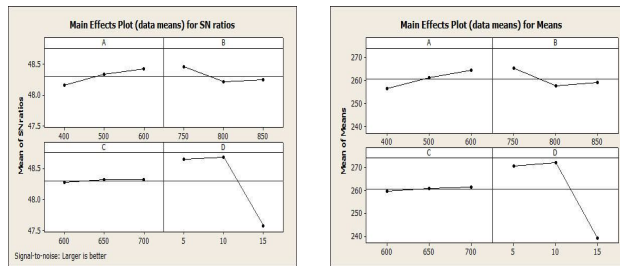


Figure 1 Main effect plots for S/N ratio and mean (UTS)

It is evident from the tables that, among these parameters, percentage addition of Silicon carbide (5%, 10% and 15%) is a dominant factor on the ultimate tensile strength.

Table 4. Response for Signal to Noise ratio and Means (YS)

Level	A	B	C	D
1	248.8	250.5	249.7	263.0
2	245.3	250.8	247.5	262.3
3	255.3	248.2	252.3	224.2
DELTA	10.0	2.7	4.8	38.8
RANK	2	4	3	1

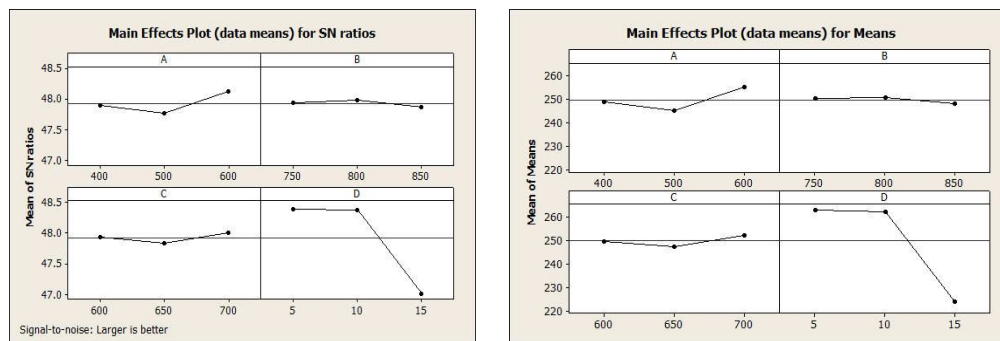


Figure 2 Main effect plots for S/N ratio and mean (YS)

It is evident from the tables that, among these parameters, percentage of addition of Silicon carbide (5%, 10% and 15%) is a dominant factor on the yield strength.

Based on the analysis of these experimental results with the help of signal to noise ratio, the optimum condition resulting in Ultimate tensile strength and yield strength are shown in the figure 1 and 2. The figure clearly indicate that the third level of stirring speed, first level of processing temperature, third level of reinforcement pre-heat temperature and second level of percentage addition of SiC.

B. Hardness Test (BHN)

Table 5.SN ratio Brinell hardness number

RUN	A	B	C	D	BRINELL HARDNESS	SNRA
1	400	750	600	5%	178.66	45.04
2	400	800	650	10%	178.33	45.02
3	400	850	700	15%	172.66	44.74
4	500	750	650	15%	174.33	44.82
5	500	800	700	5%	183.66	45.28
6	500	850	600	10%	190.33	45.59
7	600	750	700	10%	191.66	45.65
8	600	800	600	15%	168.90	44.55
9	600	850	650	5%	188.66	45.51

Table 6.Response for Signal to Noise ratio and Means (BHN)

Level	A	B	C	D
1	44.94	45.17	45.06	45.28
2	45.23	44.95	45.12	45.42
3	45.24	45.28	45.23	44.71
DELTA	0.30	0.33	0.16	0.71
RANK	3	2	4	1

Level	A	B	C	D
1	176.6	181.6	179.3	183.7
2	182.8	177.0	180.4	186.8
3	183.1	183.9	182.7	172.0
DELTA	6.5	6.9	3.4	14.8
RANK	3	2	4	1

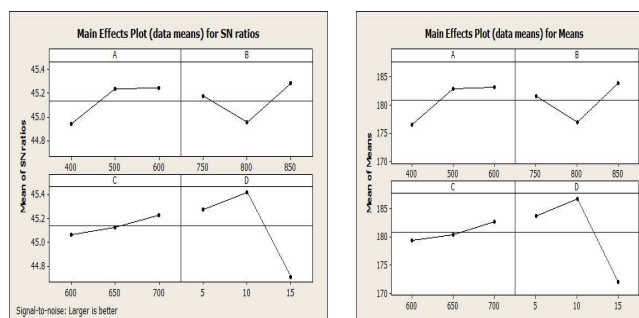


Figure 3 Main effect plots for S/N ratio and mean (BHN)

It is evident from the tables that, among these parameters, percentage of addition of Silicon carbide (5%, 10% and 15%) is a dominant factor on the hardness [7].

Based on the analysis of these experimental results with the help of signal to noise ratio, the optimum condition resulting in Brinell hardness number are shown in the figure 3. The figure clearly indicates that the third level of stirring speed, third level of processing temperature and reinforcement pre-heat temperature and second level of percentage addition of SiC.



Table 7.Optimum Level Process Parameter

RUN	A	B	C	D	SNRA UTS	SNRA YS	SNRABHN
7	600	750	700	10	48.97	48.65	45.65

C. Multiple Linear Regression Models

Statistical software MINITAB17 is used for developing a multiple linear regression equation.This developed model gives the relationship between independent/predictor variable and a response variable by fitting a linear equation to the measured data.

The regression equation developed for UTS is,

$$UTS (MPa) = 311 + 0.0400 A - 0.062 B + 0.017 C - 3.15 D$$

$$R-Sq = 92.5\% \quad R-Sq (adj) = 85.0\%$$

The regression equation developed for YS is,

$$YS (MPa) = 274 + 0.0325 A - 0.023 B + 0.027 C - 3.88 D$$

$$R-Sq = 94.0\% \quad R-Sq (adj) = 88.0\%$$

The regression equation developed for BHN is,

$$BHN = 136 + 0.0326 A + 0.0233 B + 0.0336 C - 1.17 D$$

$$R-Sq = 91.6\% \quad R-Sq (adj) = 82.2\%$$

D. Confirmation Experiment

Confirmation test is the last step in analysis process and the parameter values for four different factors are shown in table 8 and the results of confirmation test are shown in table 9.

Table 8.Confirmation Experiment Parameters

FACTORS	A	B	C	D
VALUES	600	750	700	10%

Table 9.Results of Confirmation Experiment

Response	Predicted	Confirmator y	Units	%Error
UTS	268.9	262.2	N/mm <sup>2</sup>	6.7
YS	256.35	253.32	N/mm <sup>2</sup>	3.03
Hardness	184.85	183.13	BHN	1.72

The results of confirmation experiments and their comparison with regression model which helps to identify the optical parameter values from the experimental analysis are shown in table 9. From the analysis the percentage error is too small indicate the Taguchi method is suitable for calculating ultimate tensile strength and hardness.

IV. CONCLUSION

This investigation is focused on the optimization of stir casting parameters for improving mechanical properties of Al6063-SiC-Al<sub>2</sub>O<sub>3</sub> composite. The experiments were conducted according to Taguchi design of experiments (L9 Orthogonal array) by considering four factors stirring speed, processing temperature, reinforcement preheat temperature and percentage addition of Silicon Carbide (5%,10% and 15%). The optimum conditions for ultimate tensile strength, yield strength and Brinell hardness number are identified. The following are the conclusions drawn from the present study.

Optimum ultimate tensile strength, yield strength and Brinell hardness number obtained from the experiment,that the third level of stirring speed, second level of processing temperature, third level of reinforcement pre-heat temperature and second level of percentage addition of Silicon Carbide are the optimum points, it was found that the seventh run is optimum.

The multiple regression equations for ultimate tensile strength, yield strength and Brinell hardness number have been obtained.

From confirmation test, the error associated with ultimate tensile strength is 6.7%, yield strength is 3.03% and Brinell hardness number is 1.72%, resulting in the conclusion that the design of experiment by Taguchi method was successful for calculating ultimate tensile strength, yield strength and Brinell hardness number from the regression equation.



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