



## Optimization of Process Parameters in Stir Casting of Hybrid Metal Matrix (LM25/SiC/B<sub>4</sub>C) Composite Using Taguchi Method

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### ABSTRACT

Aluminium based composites exhibit many attractive material properties such as increased stiffness, wear resistance, specific strength and vibration damping and decreased co-efficient of thermal expansion compared with the conventional aluminium alloys. Aluminium Matrix Composites consist of non-metallic reinforcement which offers advantageous properties over base material. Reinforcements like SiC, B<sub>4</sub>C and Al<sub>2</sub>O<sub>3</sub> are normally preferred to improve the mechanical properties. Here Aluminum LM25 is selected as matrix material while Silicon carbide and Boron carbide are selected as reinforcement material. The fabrication of aluminium matrix was done by stir casting method. In the present study an attempt has been made to investigate the effect of three major stir casting parameters (stir speed, stir duration and preheated temperature of reinforcement material) on stir casting of Aluminium LM25 - SiC - B<sub>4</sub>C composite. Experiments were conducted based on Taguchi methodology. Taguchi quality design concepts of L<sub>9</sub> orthogonal array has been used to determine S/N ratio and through S/N ratio a set of optimum stir casting parameters were obtained. The experimental results confirmed the validity of Taguchi method for enhancing tensile strength of castings.

### Indexing terms/Keywords

LM25 aluminium alloy, silicon carbide, boron carbide, Taguchi method;

### Academic Discipline And Sub-Disciplines

Mechanical Engineering, Chemistry, Composites

### SUBJECT CLASSIFICATION

Hybrid Metal Matrix (LM25/SiC/B<sub>4</sub>C) Composites

### TYPE (METHOD/APPROACH)

Characterization and Analysis

### 1.INTRODUCTION

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical property of steel are similar to those of pure iron). Favorable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc.

S.Senthilraja et al.[1] Studies on Machining Parameters of Cast Aluminium Alloys|| studied the development of empirical mathematical model and detailed study about the various machining parameters to minimize the surface roughness in drilling of LM25 reinforced with boron carbide and silicon carbide using the response surface methodology (RSM). The Drilling parameters are cutting speed, Depth of cut, feed rate and environmental conditions. The process can do with help of vertical CNC machining Centre and the tool used for this work is Solid carbide TiN coated tool. Tribological behavior of LM 25 and SiC||, studied the aluminium casting alloys, Al-SiC base alloys are perhaps most common particularly due to very attractive characteristics such as high strength to weight ratio, good workability, excellent castability, good thermal conductivity and corrosion resistance. In this paper Aluminium LM25+SiC composites containing three different weight percentages 5%, 10%, and 15% of SiC have been fabricated by casting method. Friction and wear characteristics of Al LM25+SiC composites have been investigated under dry sliding conditions and compared with those observed in pure aluminium LM25.

Dry sliding wear tests have been carried out using pin-on-disk machine at normal loads of 1, 2 and 3 Kg and analysis is done by using Design Expert 7 Software. Pins of Alloy are prepared in sizes of diameter 8mm and length 30mm. The testing is done on above material by varying load, speed and sliding distance. It appears that the pin-on-disc test can give considerably useful and informative friction and wear results. It was observed that the wear rate varies linearly with normal load but lower in composite compared to that in base material. Further it was found from experimentation that the wear rate decreases linearly with increasing weight fraction of SiC. The best results have been obtained at 10% weight fraction of SiC.

Mahesh Babu et al. 2012, [3] studied the characteristics of surface quality on machining hybrid aluminium-B4C-SiC metal matrix composites using Taguchi method. It was found that feed rate was the most important parameter followed by the cutting speed. Moreover it was concluded that the feed rate does not have a significant effect on surface quality. Barbara Previtali et al. 2008, [4] investigated the effect of application of traditional investment casting process in aluminium metal matrix composites. Aluminium alloy reinforced with SiC and B4C were compared and the experiments showed the wear resistance of SiC reinforced MMC is higher than that of B4C reinforced MMC.

Saikeerthi. S.P et al. 2014, [5], —Experimental Evaluation of the Mechanical Properties of Aluminium 6061- B4C -SiC Composite|| studied the mechanical properties like tensile strength and Hardness can be increased by reinforcing 6061 Al matrix with Boron Carbide (B4C) and Silicon Carbide (SiC) particles. In this project, the fabrication of aluminium 6061 with boron carbide and aluminium 6061 with silicon carbide is done by stir casting process, which is a liquid state material fabrication and cost effective method. Then, the samples are tested for mechanical properties like tensile, hardness, impact, flexural. Finally the Scanning Electron Microscope (SEM) analysis is done, which helps to study topography of composites and it produces images of a sample by scanning it with a focused beam of electrons.

Pavan Kumar et al.2013,[6], —Optimization of casting parameters for casting of Al/Rha/Rm hybrid composites using Taguchi method|| studied to optimize tensile strength and hardness of the stir casted LM 26 Al/RHA/RM hybrid composites by Taguchi method. Taguchi's L9 orthogonal array is used for experimental design. Overall performance of the stir casting method is improved significantly by combining the experimental and analytical concepts and the most important parameter is determined on the result response.

Jalees Ahemad et al 2013,[7], —Development of Al/SiC5%, Al/SiC10%, Al/SiC15%, Metal Matrix Composite and Its Comparison with Aluminium Alloy – LM25 On Tribological Parameters|| studied Friction and wear characteristics of Al LM25+SiC composites have been investigated under dry sliding conditions and compared with those observed in pure aluminum LM25. Dry sliding wear tests have been carried out using pin-on-disk machine at normal loads of 1, 2 and 3 Kg and analysis is done by using Design Expert 7 Software. Pins of Alloy are prepared in sizes of diameter 8mm and length 30mm. The testing is done on above material by varying load, speed and sliding distance. It appears that the pin-on-disc test can give considerably useful and informative friction and wear results .it was observed that the wear rate varies linearly with normal load but lower in composite compared to that in base material. Further it was found from experimentation that the wear rate decreases linearly with increasing weight fraction of SiC. The best results have been obtained at 10% weight fraction of SiC.

Behera et al, 2011, [8], studied LM6 based composites reinforced with different weight fraction of SiC particles was produced by stir cast technique and the effect of reinforced ratios on the forgeability and the machinability was examined. The test results show that the increment in weight fraction of reinforcement particles in the matrix metal produced better mechanical property like hardness but the forgeability of the cast MMCs decreases. The forgeability of the as cast MMCs were also varied with the change in thickness of the casting. The results show that the forgeability of cast metal matrix composites at the mid-section of the casting is minimum compared to both end section of a three-step casting. Srinivasa et al, 2013,[9], reported that hardness and wear studies were carried out to judge the surface mechanical properties of the composites prepared. It has been found from this study that percentage of reinforcement in the composite cause's changes in its hardness and wear properties.

From the literature survey it has been observed that only very little work has been reported on the studies of mechanical properties of Aluminium alloy (LM25) with reinforcement material SiC and B4C. Hence the present study is aimed at experimental evaluation on the above materials by testing its mechanical properties like hardness, tensile test, impact test, etc.

## 2 EXPERIMENTS AND TESTS

### 2.1 Stir Casting Experimental Setup

The experimental setup shown in Figure 1 consists of bottom pouring electric furnace, preheaters, split mould set, punch and hydraulic circuit. The furnace capable of heating upto 1200°C was used to melt the metal (LM25) at the desired temperature. A pathway with a preheater arrangement of 500°C capacity is inbuilt in this setup to maintain the fluidity of the molten metal during transferring from the furnace to the mould cavity. A permanent split mould set specially made of H13 die steel and core of mild steel were designed for making hollow cylindrical sample of 50 mm diameter and 200 mm height. A preheater of 500°C capacity with thermocouple arrangement was used to preheat the mould which enables uniform heating. The inner sides of the stainless steel crucible and mould cavity were coated with graphite suspension. LM25 ingots were charged into the crucible in the furnace and the required temperature was maintained. The molten metal was degassed fully using hexachloroethane tablets to remove the entrapped gases and other impurities present. The pure melt after degassing was agitated by using mechanical stirrer rotating to create fine vortex. While stirring constantly at 500 rpm for 10 minutes, reinforcement (SiC and B4C) particles were gradually added into the fine vortex. The molten slurry was transferred from the bottom pouring furnace into the preheated mould through the preheated pathway which connects the melting furnace with the mould. A hydraulic press of 40 ton capacity was used to apply squeeze load on the molten metal by means of a punch which is an integral part of the hydraulic unit. Squeeze load was applied on the melt through the punch and maintained for 45 seconds. Punch was then moved up and the casting was separated from the mould assembly.



Figure 1 Experimental Setup

## 2.1 Taguchi Method

Taguchi method determines process conditions to produce high quality product with low production cost. It suggests a systematic approach to optimize the process for better quality and minimum production cost. Two major tools employed in this method are orthogonal arrays, which contain many control factors with various levels and signal to noise ratio, which evaluates the quality of output response. Generally, there are three categories of quality characteristics such as “larger-the-better”, smaller-the-better and nominal the best. Taguchi’s approach is totally based on the orthogonal array of experiments and the category of output response. Economically, this method satisfies the needs of problem solving in process optimization and also considerably reduces the time required for experimental investigations and production cost.

The bounds for all these process parameters were set as follows.

Stirring speed A (rpm) :  $400 \leq A \leq 800$

Stirring time duration, B (minutes) :  $1 \leq B \leq 5$

Preheating temperature, C ( $^{\circ}$ C) :  $200 \leq C \leq 400$

## 3. RESULTS AND DISCUSSION

All process parameters were fixed at three levels within the above bounds to conduct experiments based on the L9(3)4 orthogonal array. The details of all parameters and their levels are given in Table 2. For each experimental condition, the casting samples were cast and are shown in Figure 2.



Figure 2 Casting samples

Table 2 Process parameters and their levels

Process Parameter	Notation	Level		
		1	2	3
Stirring speed A (rpm)	A	400	600	800
Stirring time duration, B (minutes)	B	1	3	5
Preheating temperature, C ( $^{\circ}$ C)	C	200	300	400



Table 3 Experimental observations and S/N ratio

Ex. No.	Parameters and their levels			Tensile Strength (MPa)	S/N Ratio (dB)
	A	B	C		
1	1	1	1	147.20	43.3582
2	1	2	2	156.72	43.9025
3	1	3	3	161.20	44.1473
4	2	1	2	155.30	43.8234
5	2	2	3	168.25	44.5191
6	2	3	1	171.23	44.6716
7	3	1	3	177.25	44.9717
8	3	2	1	169.50	44.5834
9	3	3	2	174.00	44.8110

Table 4 Response Table for Signal to Noise Ratios (Larger is better)

Level	Stirrer Speed	Stirring Time	Preheating Temperature (oC)
Level 1	43.80	44.05	44.20
Level 2	44.34	44.33	44.18
Level 3	44.79	44.54	44.55
Max-Min	0.99	0.49	0.37
Rank	1	2	3
Optimum Level	800 rpm	5 min	400oC

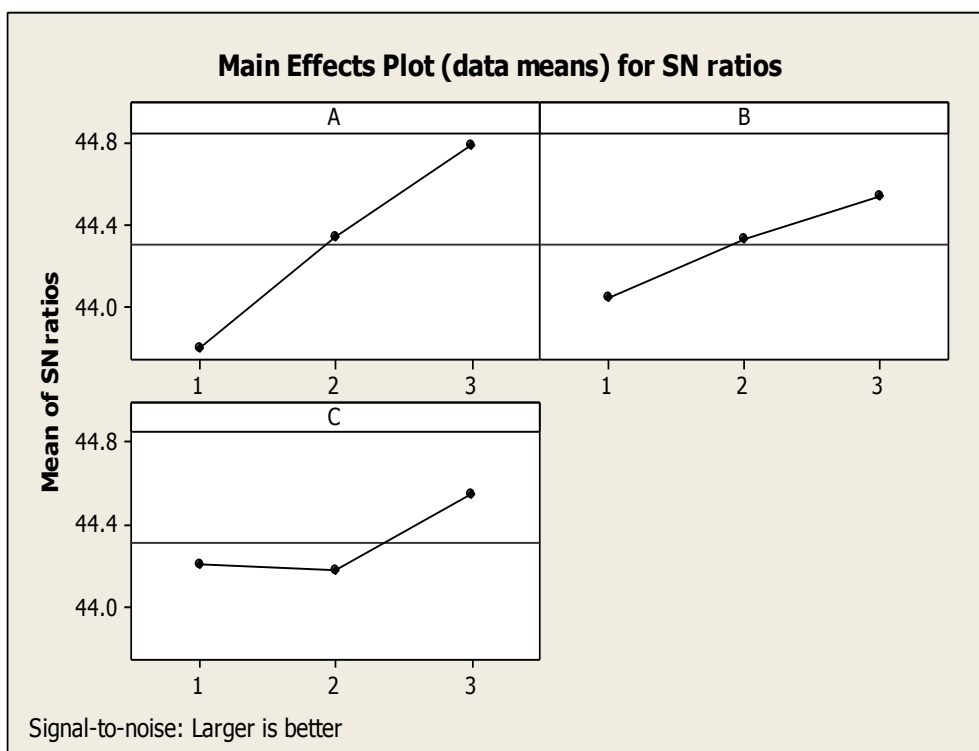


Figure 3 Response graph



, From the results, the parametric optimization of stir casting process for improving hardness, tensile and impact was also carried out. Based on the highest value of S/N ratio, the optimum parametric setting A3B3C3 (stir speed 800 rpm, stir duration 5 min and preheat temperature of reinforcement material 400oC) was obtained for optimum tensile in this study.

#### 4. Conclusion

This work has discussed the application of the Taguchi method for investigating the effects of casting parameters on mechanical properties of LM25/SiC/B4C hybrid composites prepared by stir casting technique. From the analysis of the results in the casting process, using the conceptual signal-to-noise (S/N) ratio approach, The optimum level of casting parameters to obtain good tensile strength for stir casting of LM25/SiC/B4C hybrid composites are stir speed = 800 rpm, stir duration = 5 min and preheated temperature of reinforcement particle = 400oC.

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