STUDY AND ANALYSIS OF THE HYBRID COMPOSITE MATERIAL BASED ON AL-SIC

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ABSTRACT

Silicon carbide particle reinforced aluminum matrix composites have been developed over past few decades, owing to their excellent properties like light weight, high elastic modulus and wear resistance. Thus, the silicon carbide particle reinforced aluminum matrix composites are expected to have many applications in aerospace, aircraft, automobile and electronic industries. In this study, aluminum metal matrix composites containing several weight percentages of reinforcement particles were prepared by using stir casting method. The experiments were performed on different composition of silicon carbide powder in the composite. The wear resisting behavior of the composites increased with increasing reinforcement particle's addition in it. The Taguchi's L9 orthogonal array is used to design the experiments, with the aim of relating the influence of sliding speed, applied load and sliding distance. The aim of the experimental plan is to find the important factors and combination of factors influencing the wear process to achieve the minimum wear rate and co-efficient of friction.

Key Words: *Metal Matrix Composites MMC's, Silicon Carbide SiC*

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1. INTRODUCTION

Scientific investigations have been continuously directed towards improving the properties and performance of materials. Significant improvements in mechanical, chemical, and physical properties have been achieved through chemistry modifications and conventional thermal, mechanical, and thermo-mechanical processing methods. Composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure.

Composites consist of one or more discontinuous phase (Reinforcement) embedded in a continuous phase (Matrix).Composite results in better properties than that of the constituent materials. The main part of the composite is known as matrix which holds the reinforcing phases. Reinforcing material size and shape ranges from particle to continuous fibers.

Combination of two inherently different materials to produce a material with properties that exceeds the constituent material properties is termed as composite. In today‘s world everyone is looking for light, inexpensive, and easily as well as quickly processed materials in the field of automobiles sector. The answer to all these requirements is composite materials. For composites to be a part of complex structure such as in automobiles to reduce weight and hence improve efficiency; joining is required. Most popular joining techniques for composites are adhesive and mechanical joining. Each of these has its own advantages and disadvantages.

Al-SiC

Al-SiC, pronounced "alsick" is a metal matrix composite consisting of aluminum matrix with silicon carbide particles. It has high thermal conductivity (180–200 W/m K), and its thermal expansion can be adjusted to match other materials, e.g. silicon and gallium arsenide chips and various ceramics (Murty, 2003). It is chiefly used in Micro electronics as substrate for power semiconductor devices and high density multi- chip modules, where it aids with removal of waste heat.

Al-SiC composites are suitable replacements for copper-molybdenum (Cu MO) and copper-tungsten (CuW) alloys; they have about 1/3 the weight of copper, 1/5 of Cu MO, and 1/6 of CuW, making them suitable for weight-sensitive applications; they are also stronger and stiffer than copper. They are stiff, lightweight, and strong. They can be used as heat sinks, substrates for power electronics (e.g. high- power LEDs), heat spreaders, housings for electronics, and lids for chips, e.g. microprocessors. Metal and ceramic inserts and channels for a coolant can be integrated into the parts during manufacture. Al-SiC composites can be produced relatively inexpensively. Parts can be made with sufficiently low tolerances to not require further machining. The material is fully dense, without voids, and is hermetic. High stiffness and low density appears making larger parts with thin wall, and manufacturing large fins for heat dissipation. Al-SiC can be plated with nickel and nickel-gold, or by other metals by thermal spraying. Al-SiC can be also prepared by mechanical alloying.

2. DESIGN OF EXPERIMENTS (DOE)

Design of Experiment is one of the important and powerful statistical techniques to study the effect of multiple variables simultaneously and involves a series of steps which must follow a certain sequence for the experiment to yield an improved understanding of process performance. All designed experiments require a certain number of combinations of factors and levels be tested in order to observe the results of those test conditions. Taguchi approach relies on the assignment of factors in specific orthogonal arrays to determine those test combinations. The DOE process is made up of three main phases: the planning phase, the conducting phase, and the analysis phase. A major step in the DOE process is the determination of the combination of factors and levels which will provide the desired information. Analysis of the experimental results uses a signal to noise ratio to aid in the determination of the best process designs. This technique has been successfully used by researchers in the study of dry sliding wear behavior of composites. These methods focus on improving the design of manufacturing processes. In the present work, a plan order for performing the experiments was generated by Taguchi method using orthogonal arrays. This method yields the rank of various parameters with the level of significance of influence of a factor or the interaction of factors on a particular output response.

3. MATERIAL SELECTION

In the present investigation, Al-SiC alloy was chosen as the base matrix since its properties can be tailored through heat treatment process. The reinforcement was sic, average size of 150 to 160 microns, and there are sufficient literatures elucidating the improvement in wear properties through the addition of SiC. Due to the property of high hardness and high thermal conductivity, SiC after accommodation in soft ductile aluminum base matrix, enhance the wear resisting behavior of the Al – SiC metal matrix composite.

4.1 COMPOSITE PREPARATION

In order to achieve high level of mechanical properties in the composite, a good interfacial bonding (wetting) between the dispersed phase and the liquid matrix has to be obtained. Stir-casting technique is one such simplest and cost effective method to fabricate metal matrix composites which has been adopted by many researchers. This method is most economical to fabricate composites with discontinuous fibers and particulates and was used in this work to obtain the as cast specimens. Care was taken to maintain an optimum casting parameter of pouring temperature (650°C) and stirring time (15 min). The reinforcements were preheated prior to their addition in the aluminum alloy melt. Degassing agent (hexachord ethane) was used to reduce gas porosities. The molten metal was then poured into a permanent cast iron mould of diameter 26mm and length 300mm. The die was released after 6 hours and the cast specimens were taken out.

Figure 4.1 Mold Making

Figure 4.2 Pouring of metal into the mold

4.2 WEAR BEHAVIOR

The aim of the experimental plan is to find the important factors and combination of factors influencing the wear process to achieve the minimum wear rate and coefficient of friction. The experiments were developed based on an orthogonal array, with the aim of relating the influence of sliding speed, applied load and sliding distance. These design parameters are distinct and intrinsic feature of the process that influence and determine the composite

performance. Taguchi recommends analyzing the S/N ratio using conceptual approach that involves graphing the effects and visually identifying the significant factors.
The above mentioned pin on disc test apparatus was used to determine the sliding wear characteristics of the composite. Specimens of size 10 mm diameter and 25 mm length were cut from the cast samples, and then machined. The contact surface of the cast sample (pin) was made flat so that it should be in contact with the rotating disk. During the test, the pin was held pressed against a rotating EN31 carbon steel disc (hardness of 65HRC) by applying load that acts as counterweight and balances the pin. The track diameter was varied for each batch of experiments in the range of 50 mm to 100 mm and the parameters such as the load, sliding speed and sliding distance were varied in the range. A LVDT (load cell) on the lever arm helps determine the wear at any point of time by monitoring the movement of the arm. Once the surface in contact wears out, the load pushes the arm to remain in contact with the disc. This movement of the arm generates a signal which is used to determine the maximum wear and the coefficient of friction is monitored continuously as wear occurs and graphs between co-efficient of friction and time was monitored for both of the specimens i.e., 10 % and 15% SiC / Al-6061 MMCs.

Further, weight loss of each specimen was obtained by weighing the specimen before and after the experiment by a single pan electronic weighing machine with an accuracy of 0.0001g after thorough cleaning with acetone solution. The results for various combinations of parameters weaker obtained by conducting the experiment as per the orthogonal array. The measured results were analyzed using the commercial software MINITAB 15 specifically used for design of experiment applications.

Figure 4.3 Specimen consists 85% Al and 15% SiC

4.4 TAGUCHI EXPERIMENTAL DESIGN AND ANALYSIS

STEPS IN EXPERIMENTAL DESIGN AND ANALYSIS

The important steps in the Taguchi experimental design and analysis are:

1) Select the quality characteristics.

2) Select noise factor and control factor.

3) Select orthogonal array.

4) Conduct the experiments.

5) Analyze the result and determine optimum factor-level combination.

5. RESULT ANALYSES

5.1 INTRODUCTION

The aim of the experimental plan is to find the important factors and combination of factors influencing the wear process to achieve the minimum wear rate and coefficient of friction. The experiments were developed based on an orthogonal array, with the aim of relating the influence of sliding speed, applied load and sliding distance. These design parameters are distinct and intrinsic feature of the process that influence and determine the composite performance. Taguchi recommends analyzing the S/N ratio using conceptual approach that involves graphing the effects and visually identifying the significant factors.

The results for various combinations of parameters were obtained by conducting the experiment as per the orthogonal array. The calculated results were analyzed using the commercial software MINITAB 15 specifically used for design of experiment applications and the graphs for various S/N ratios and mean values for wear and coefficient of friction were obtained by MINITAB 15 as per the response tables.
To measure the quality characteristics, the experimental values are transformed into signal to noise ratio. The influence of control parameters such as load, sliding speed, and sliding distance on wear rate and coefficient of friction has been analyzed using signal to noise response table. The control factors are statistically significant in the signal to noise ratio and it could be observed that the sliding distance is a dominant parameter on the wear rate and coefficient of friction followed by applied load and sliding speed.

5.2 SELECT THE QUALITY CHARACTERISTICS

There are three types of quality characteristics in the Taguchi methodology such as:
1) Smaller-the-better

2) Larger-the-better

3) Nominal-the-best

The goal of this paper was to analyze and determine minimum wear rate with stir casting process. Smaller Ra Values represent better or improved wear resisting condition. Therefore, a smaller-the-better quality characteristic was implemented and introduced in this study.

5.3 SELECT NOISE FACTOR AND CONTROL FACTOR

From the literature survey, we conclude that Load (L), Sliding speed(S) and Sliding distance (D) had significant effect on wear behavior. These factors are controllable factors. Table 5.1

shows all Taguchi design parameters and levels. One of the most important considerable attributes of Taguchi parameter design was S/N ratio. It was differ at the different place.

Controllable factors	A: Load, L (Kg)	B: Sliding speed, S (m/s)	C: Sliding distance, D (m)
Level 1	1.0	1	400
Level 2	1.5	2	600
Level 3	2.0	3	800

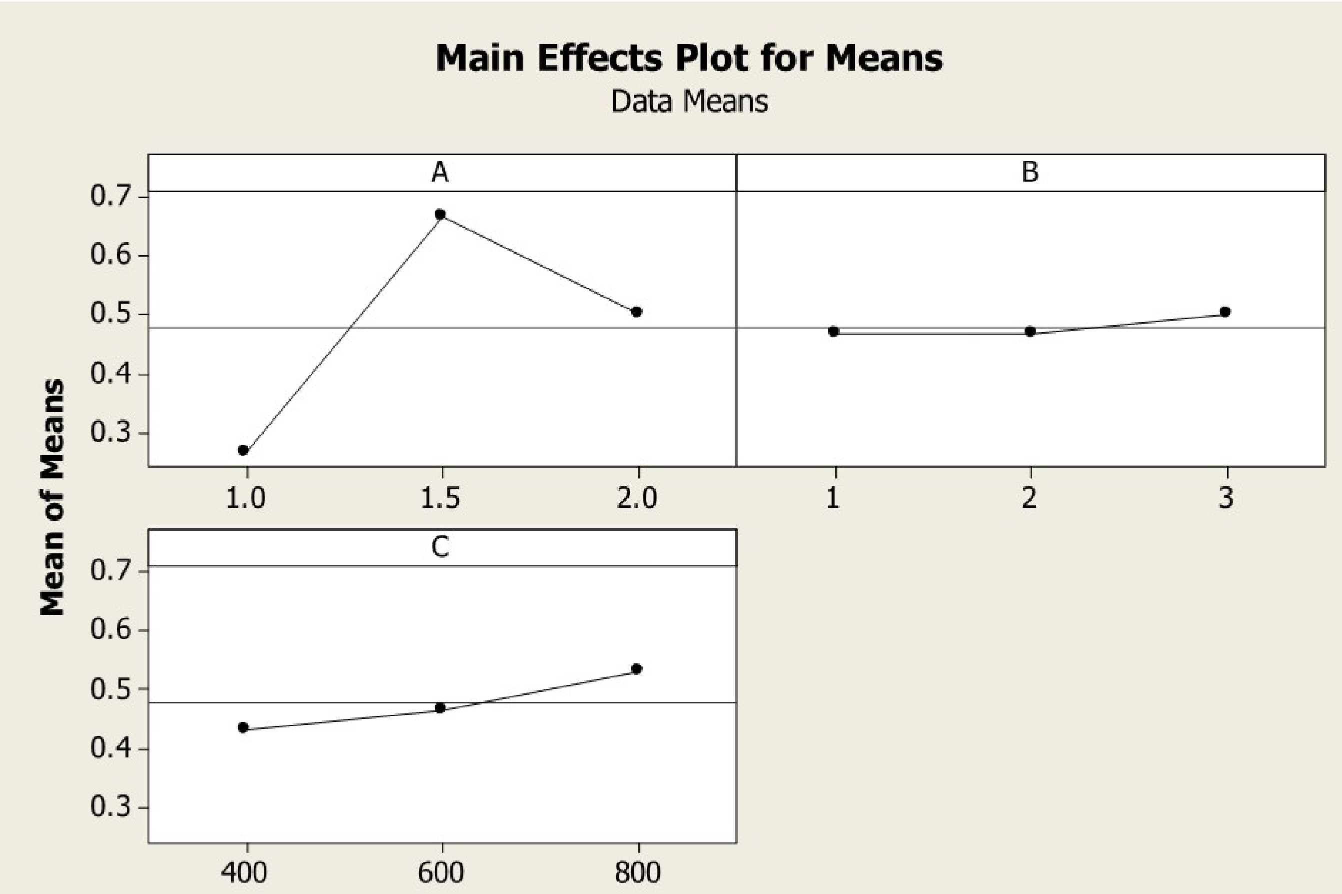
Table 5.1 Selected Factor and level

Sr. No.	Load (N)	Sliding speed (m/s)	Sliding distance (m)
1	1.0	1	400
2	1.0	2	600
3	1.0	3	800
4	1.5	1	600
5	1.5	2	800
6	1.5	3	400
7	2.0	1	800
8	2.0	2	400
9	2.0	3	600

Table 5.2 L9 Orthogonal Array

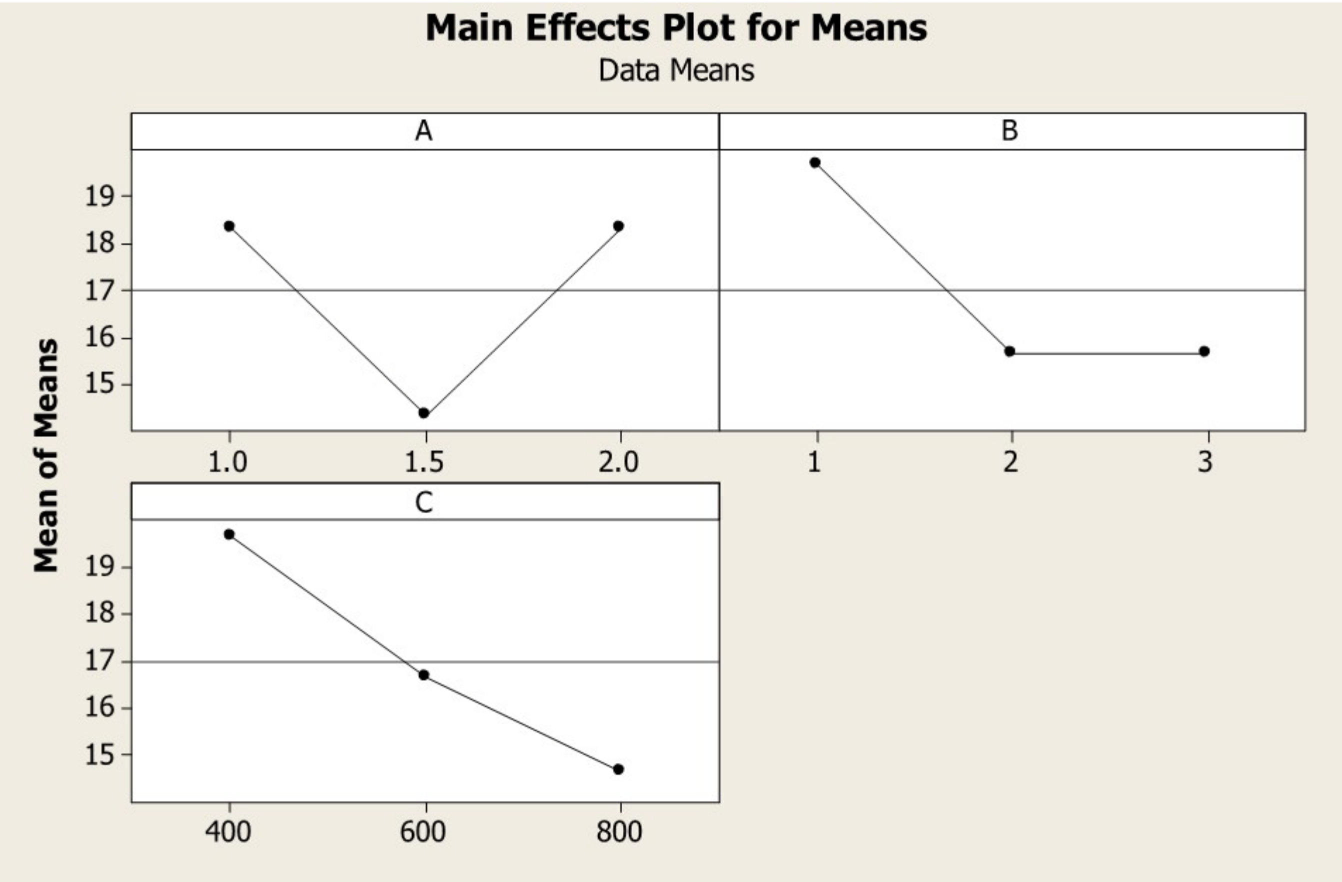
Level	load (A)	Sliding velocity (B)	Sliding distance (C)
1	0.267	0.467	0.433
2	0.667	0.467	0.467
3	0.500	0.500	0.533
Delta(Δ)	0.400	0.033	0.100
Rank	1	3	2

Table 5.3 Average response table for S/N of friction of 15% of SiC



Level	Load (A)	Sliding velocity (B)	Sliding distance (C)
1	18.333	19.667	19.667
2	14.333	15.667	16.667
3	18.333	15.667	14.667
Delta(Δ)	4.000	4.000	5.000
Rank	3	2	1

Average response table for mean value or wear of 15% SiC



Wear rate

For 15%

Predicted mean = $A^2 + B^2 + C^3 - 2\times (Y)$

= 14.333+15.667+14.667-(2×17)

= 44.667-34

= 10.667 mm^3/m

Here, predicted mean = 10.667 mm3/m which show that the parameter we used is within the range of specified machining conditions.

Co-efficient of friction
For 15%
Predicted mean = A2 + B1 + C1 – 2× (Y)
= 0.267+0.467+0.433-(2×0.478)
= 1.167-0.956
= 0.211.
Here, predicted mean = 0.211 which show that the parameter we used is within the range of specified machining conditions.

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