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Comparision of Mechanical Characterization of Al Metal Matrix Composites and Grey Cast Iron of an Automobile Brake Rotor

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***Abstract* – A Composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Composites are commonly classified at two distinct levels. The first level of classification is usually made with respect to the matrix constituent; the second level of classification refers to the reinforcement form. The matrix in a metal matrix composite (MMC) is usually an alloy, rather than a pure metal. Aluminum metal matrix are being considered as a group of new advanced materials for its light weight, high strength, high specific modulus, low co-efficient of thermal expansion and good wear resistance properties. Aluminum matrix composites have been used for the automobile products such as engine piston, cylinder liner, brake disc/drum etc. Particulate reinforced Al composites can be processed more easily by liquid state process. Melt stirring casting is an attractive processing method since it is relatively inexpensive and offers a wide selection of materials and processing conditions. The present work focuses on the fabrication of aluminum 6061 matrix composites reinforced with various weight percentage of SiC particulates (75µm) by stir casting method. The mechanical properties of the fabricated composites are analyzed and compared it with Grey Cast Iron. Optical microscope images reveal that SiC particulates are uniformly distributed in the aluminum matrix. The mechanical properties like Wear resistance, hardness, surface roughness and energy absorption have improved with increase in weight percentage of SiC particulates in the aluminum matrix.**

***Keywords* – Al-6061-SiC, Brinell Hardness, Stir Casting, Wear Test.**

I. Introduction

Aluminum matrix composites (AMCs) are the competent material in the industrial world. Due to its excellent mechanical properties, it is widely used in aerospace, automobiles, marine etc. [1–3]. The aluminum matrix is getting strengthened when it is reinforced with the hard ceramic particles like Sic, Al_2O_3, B_4C etc. resulting in enhanced wear resistance and strength to weight ratio than the conventional alloys [3,4]. Based on the type of reinforcement, size and morphology, the AMCs are fabricated by different methods such as stir casting, squeeze casting, spray deposition, liquid infiltration, and powder metallurgy [5,6]. In casting process, the reinforcing elements such as metal carbides, metal borides, metal nitrides and metal oxides are dispersed within molten alloy matrix under atmospheric pressure. But in the powder metallurgy route, the reinforcing elements are blend with matrix powder and distributed evenly throughout matrix and it is subjected to sintering as followed by plastic working. Among the manufacturing processes, the conventional stir casting is an attractive processing method for producing AMCs [7] as it is relatively inexpensive and offers a wide selection of materials and processing conditions [8,9]. Stir casting offers better matrix particle bonding due to stirring action of particles into the melts. The recent research studies reported that the homogeneous mixing and good wetting can be obtained by selecting appropriate processing parameters.

Conventional stir casting involves adding ceramic particles into the melt in the crucible which is kept inside the furnace. The melt is transferred to permanent mould after stirring. A limited research work has been reported on AMCs reinforced with SiC[10]. Due to higher raw material cost and poor wetting. SiC is a robust material having excellent chemical and thermal stability, high hardness, and low density, and it is used for manufacturing automobile parts. In the present work an attempt is made to synthesize 6061Al-SiC composites by stir casting method. Further the prepared composites are subjected to micro-structural characterization and evaluation of mechanical properties

II. Experimental Procedure

2.1. *Fabrication of Al-6061-SiC Composites by Stir Casting Method*

The proposed AMC was produced using Al6061 alloy as a matrix material having the chemical composition as shown in Table 1. The composites were produced by conventional method of stir-casting. Melting of aluminum alloy matrix is carried out in an electrical resistance furnace. The alloy is super-heated to 725°C and temperature was controlled to an accuracy of ±1^{0}C using digital temperature controller. Once the required temperature is reached, the melt is agitated with the help of a graphite coated stirrer to form a fine vortex. Through this vortex mixtures of preheated SiC (200°C for 1hour) particles was added at a constant feed rate. During addition of mixture a novel two stage mixing is adopted. The process parameters employed during preparation of composites are given in Table 2. After stirring the molten mixture, it was poured down into the preheated permanent mould as shown in Fig.1. The AMCs having different weight percentages (5, 10, and 15) of SiC were fabricated by the same procedure.

2.2. *Micro Structural Characterization and Evaluation of Mechanical Properties*

Micro structural characterization of the prepared composites was carried out using optical microscope in order to ensure dispersion and distribution of SiC in 6061 Al matrix. For this purpose specimens were cut from center of the casting and were polished as per the standard metallographic procedure and were etched using Keller's reagent. The microstructures of etched specimens were recorded using an optical microscope (Olympus Microscope) attached with CCD camera. Brinell hardness measurements were carried out on the prepared composites. For this specimen of dimensions 25mm diameter and 20 mm length was taken from the castings and is polished using metallographic procedure till mirror finish surface is obtained. The micro hardness of polished samples was measured using Brinell hardness tester, a load of 100Kgf and dwell time of 15 sec. The hardness measurements were carried out at 3 different locations and average of 3 readings was reported. The Wear resistance of the composites was measured using a Pin on Disc Machine as per ASTM E08 standard [18]. The dimensions of the specimen are shown in Fig. 3. The wear testing was carried out on three specimens for each composition and average value is reported.

Table 1: Shows chemical composition of Al6061 alloy Matrix used in the present study

Elements	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr	Al	Others
Amount (wt%)	0.8-1.2	0.4-0.8	Max 0.7	0.15-0.40	Max 0.25	Max 0.15	Max 0.15	0.04-0.35	Bal	0.05

Table 2: Showing the details of various process parameters adopted during synthesis of 6061Al-SiC composite

Parameters	Values	Parameters	Values
Stirring speed (manual stirring)	Approx. 50RPM	Preheating temperature of SiC particles	200°C
Stirring time	30min	Preheating temperature of mould	250°C
Temperature of the melt	725°C	Pouring temperature of melt	750°C

III. Results and Discussion

3.1. *Evaluation of Surface Roughness and Microstructure*

Aluminum reinforced with SiC particulate composites are successfully fabricated by stir casting process. The application of stir casting method to fabricate aluminum reinforced with variety of ceramic particles The optical photomicrographs of the fabricated AMCs are shown in Fig. 1a–d. It is clear from the figures that the dispersion of SiC particles in 6061 Al matrix is fairly uniform for all weight percentage.

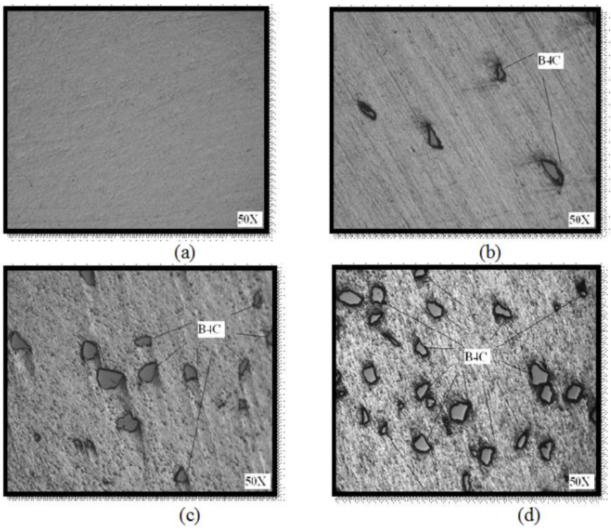

Fig. 1: Showing optical microphotographs of a) as cast Al6061 matrix b) Al6061 with 5wt% SiC c) Al6061 with 10wt% SiC and d) Al6061 with 15wt% SiC.

The size of the SiC particles appears to be uniform throughout the aluminum matrix. This can be attributed to the effective stirring action and the use of appropriate process parameters. Further, it also clear that with increasing wt. % number of particles of SiC also increased.

Surface Roughness Test on AL6061 with different wt % of SiC like 5%, 10%, 15% and gray Cast Iron

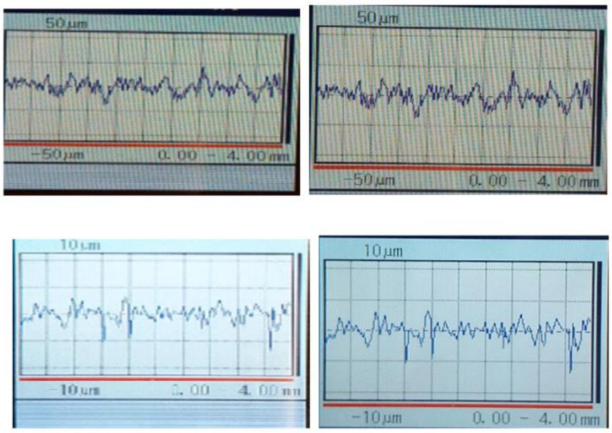

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Table 3: Comparison between AL6061 with %SIC and GCI

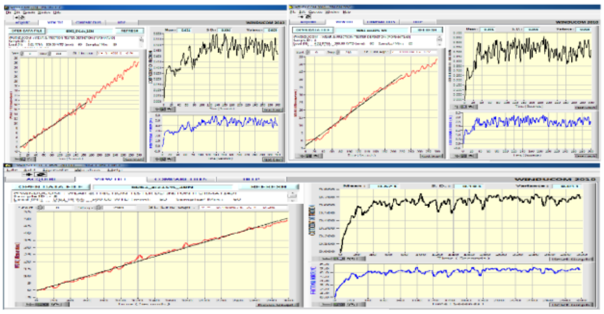
S.No	Specimens	R_a	R_q	R_z
1	S-1 with 5% sic	2.162	2.664	12.901
2	S-2 with 10% sic	4.741	5.936	240329
3	S-3 with 15% sic	5.089	6.329	28.692
4	G.C.I	1.0074	1.283	6.902

3.2. *Evaluation of Mechanical Properties*

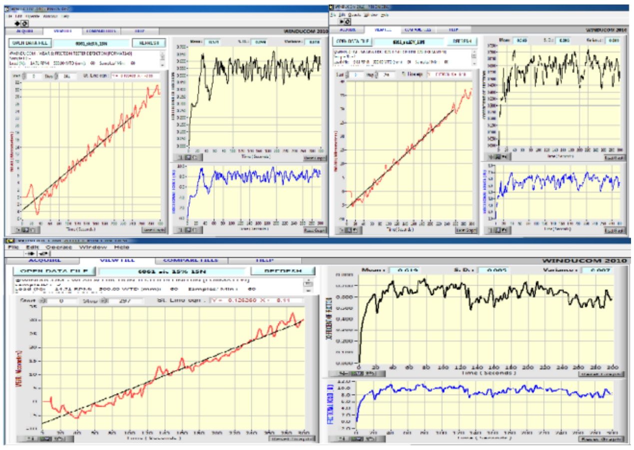
3.2.1. *Wear Test Measurements*

The wear testing was carried out at different normal loads such as 5N,10N,15N. A cylindrical pin of size above >30 mm length and diameter is 6 mm, prepared by turning the material after, was loaded through a vertical specimen holder against horizontal rotating disc. The rotating disc was made of carbon steel of diameter 50 mm and hardness of 64 HRC. To find out the wear rate of AL6061 with different composition of silicon carbide performing in Pin-on-disc machine.

APPLYING THE LOAD OF 5N TO AL6061 WITH 5%, 10% and 15% SiC



APPLYING THE LOAD OF 10N TO AL6061 WITH 5%, 10% and 15% SiC



APPLYING THE LOAD OF 15N TO AL6061 WITH 5%, 10% and 15% SiC

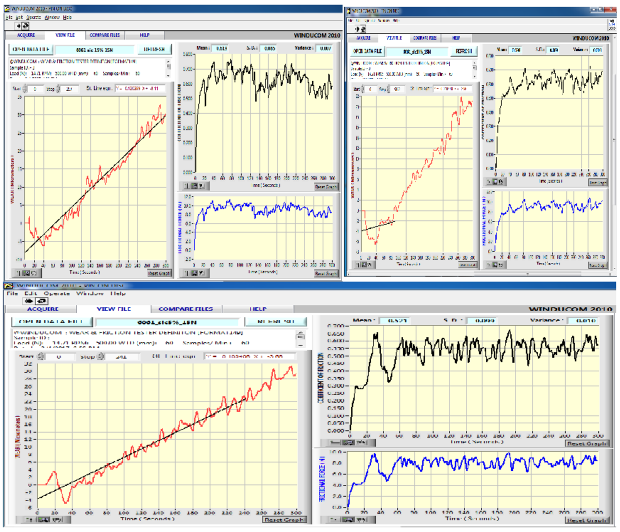


Table 4: Wear rate of AL6061 with different wt % of SiC

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The micro-hardness of the prepared composites was measured using Brinell hardness tester with a load of 100Kgf and dwell time of 15 sec. The hardness measurements were carried out at 3 different locations and average of readings was reported. Table. 5 shows relation between weight percentages of SiC reinforcement particulates and hardness of fabricated AMCs. Table.5. clearly reveals that addition of SiC to 6061Al matrix has resulted in improvement in hardness of the matrix. The increase in hardness is mainly due to particulate strengthening effect. The presence of SiC particles in the Al matrix hinders the movement of dislocations thereby pile of dislocations takes place. The pile up of dislocations is causing increase in hardness. Also, addition of reinforcement particles to the matrix increases the surface area of the reinforcement and the matrix grain sizes are reduced. The presence of such hard surface area of particles offers more resistance to plastic deformation which leads to increase in the hardness of composites. Further, the micro hardness of AMCs increases as the amount of reinforcement particulates increases. It is reported [3] that the presence of hard ceramic phase in the soft ductile matrix reduces the ductility of composites due to reduction of ductile metal content which significantly increases the hardness value.

Table 5: Showing the variation in micro-hardness values of al6061-sic composites for different wt% of sic particulates

BRINELL HARDNESS TEST

SL.no	Specimens	TRAIL-1	TRAIL-2	TRAIL-3	AVGE
1	AL6061 with 5% SiC	B15	B14	B13	B14
2	AL6061 with 10% SiC	B15	B14	B13	B14
3	AL6061 with 15% SiC	B16	B14	B13	B14.33
4	Grey Cast Iron	B10	B11	B12	B11.66

IV. Conclusions

The present work on preparation and characterization of Al-6061-SiC composites by melt stirring method, has led to the following conclusions.

1. The Al-6061-SiC particulate composites containing 5, 10 and 15wt% of SiC were successfully synthesized by Stir Casting method.
2. The Optical microphotographs revealed the fairly uniform distribution of SiC particles in the Al-6061 matrix. Surface Roughness of Al -6061 with different wt % of SiC has poor as compared it with the existing Gray Cast Iron Brake rotor of an Automobile, because of it might be surface finished with sophisticated machining process.
3. From the results it is concluded that the wear rate is reduces in AL6061 with 10 % wt of silicon carbide at 10 N load as compared with all the fabricated specimens, along with existing material GCI.
4. An improvement in micro-hardness of 6061Al matrix was obtained with the addition of SiC particles. Further, the micro hardness of the composites increased with increase in wt % of SiC particles, but the gets the brittle nature.

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