Effect of SiC on Mechanical, Microstructure and Tribological properties of Aluminum MMC processed by Stir Casting

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Abstrac t. Stir casting process is an effective manufacturing technique for producing metal matrix co mposites. The extensively use reinforcing materials for the alu minu m mat rix composites are silicon carbide, alu minu m o xide and graphite in the variety of particles . In this work, the effect of addit ion of SiC reinforcement on the microstructure, mechanical and wear properties of the Al5083-SiC MM Cs has been studied. Aluminum matrix co mposite has been prepared by adding 3, 5 and 7 wt . % SiC through Stir casting process. The wear t ests have been conducted using a pin on disc configuration under normal loads of 10, 20 & 30 N. The tribological behaviour was evaluated at a sliding velocity of 3.14 m/s and distance of 942 m. After the wear tests, the worn out surface of test specimens have been observed with Olympus inverted optical microscope to analyse the wear mechanis ms. Microhardness tests were emp loyed to measure the microhardness number (VHN) of Al 5083-SiC MMCs by indenting the diamond indenter. The tensile tests were conducted on universal testing machine to know the improvements in the strength. Microstructures are observed by using SEM and XRD analysis.The Tribological properties are superior with the increasing of addit ion of SiC particles to the alu minu m matrix. The images of scanning electron microscopy shows a uniform d istribution of SiC particles in the alu min iu m metal matrix.

Key Words: Al-5083; SiC; Stir casting; Micro structure; Wear properties; Mechanical properties

1.Introduction

Now a day's metal matrix composites were the reliable source to meet the demands of developments of advanced engineering materials for various engineering applications. Stir casting is a simple and economical process is suitable for producing of composites with up to 30% volume fractions of reinforcement. V. Bharath et al.(2014) studied the mechanical properties and characterization of Al-6061 MMC with Al_2O_3 as particulate reinforcement [1]. The contrasted with unreinforced Al-6061 alloy, additionally increasing level of reinforcement hardness and tensile properties are superior in case of composites when has brought about further increment in both hardness and tensile strength [2, 3].In 2013**,** M.M. Boopathi et al, were conducted a study on valuation of Mechanical Properties of Al-2024 alloy reinforcement with SiC and Fly Ash Hybrid MMC [4]. Increment in region division of fortification in grid result in enhanced elasticity, yield strength and hardness. [5]In 2012, Kumar et al. explored the mechanical conduct of blend threw Al-6061 with nano particles has achieved extreme elasticity and yield quality of the composite was superior. [6] In 2012, V. N. Gaitonde1, S. R. Karnik and M. S. Jayaprakash were led a few examinations on Wear Properties of Al/Al2O3/Graphite Hybrid Composites. The impacts of reinforcement and molecule estimate on arranged examples of composites have been considered on mechanical, wear and corrosion properties. The test comes about on Al-5083 hybrid composites uncovered that the expansion of support enhances the hardness. [7] In 2010, G. B. Veeresh Kumar et al. revealed that the SiC and Al_2O_3 result in getting better the hardness and density of their respective composites[8, 9]. In manufacturing a composite material by stir casting, functioning parameters are playing a key role. The objective of this work is to examine the microstructure, mechanical and wear properties of Al 5083-SiC composites. The effect of addition of 3, 5 and 7 wt. % SiC particles on the micro structure and wear properties of Al-5083 metal matrix composites processed by stir casting process has been studied.

2. Material Selection

For manufacturing a composite material, the primary importance is given to the selection of Matrix and Reinforcement materials. In this work, Al-5083 alloy was selected as the matrix material and Silicon carbide was taken as reinforcement and composition was shown in table 1 for the Al-5083 alloy.

Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
0.4	0.4	0.1	0.4-1.0	4.0-4.9	0.25	0.15	0.05-0.25	Balance

Table.1: Composition (wt. %) of Al-5083 alloy

The property of having light weight is the main advantage of using aluminum as matrix material. Al-5083 was used in various applications like Structures, equipment, Automotive, Railway and Machinery applications due to its resistance against sea water and chemical environment..Al-5083 alloy was mostly used in ship building, vehicle bodies and pressure vessels. Silicon carbide is composed of carbon and silicon atoms and produces a very rigid and tough material and increases the abrasive wear resistance.

3. Experimental Procedure

The experimental procedure involves Pre heating of SiC & preparation of molten Aluminum-5083, Stir casting process, mould preparation, microstructure characterization (SEM & XRD), hardness, tensile and wear tests.

3.1 Preheating of SiC and preparation of molten Al-5083

The reinforcement SiC particles (3, 5 & 7 wt. %) were preheated to a temperature of 700°C about 2 hours to remove the moisture. The required quantity of matrix material Al-5083 alloy was cut from the raw material and cleaned to remove dust particles. Al-5083 was heated to a temperature of 650°C in a resistance heated muffle furnace and degassed by using Argon gas.

3.2 Stir casting process

After complete melting of matrix material, stir casting process was carried out in muffle furnace. The muffle furnace was shown in figure 1. It consists of conical shaped graphite crucible which is used for fabrication of metal matrix composites. It withstands high temperatures more than required temperature. After reaching the required melting temperature of furnace, the reinforcement was feed into molten matrix by using hopper. Magnesium (4%) was added to the molten slurry to retain the Mg quantity in the composite material. Then stirring was carried manually by mechanical stirrer to disperse the silicon carbide particles in the aluminum matrix material. After completion of stirring action the molten slurry was taken into semi solid form by reducing temperature of furnace.

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3.3 Mould preparation

The moulding die was shown in figure 2. The slurry is maintained in molten condition because of the preheating of mould at a temperature of 500°C. Finally, mould was quick quenched in the air and produced Al-SiC (3, 5 & 7 wt. %) metal matrix composites with 15 mm diameter and 130 mm length. The final stir casted metal matrix composite specimens were shown in figure 3.

3.4 SEM and XRD Analysis

Prior to SEM test, samples were polished using emery papers and disc polishing. The polished samples were dipped for 30 sec in an etchant solution.XRD analysis has been performed to identify the phase. In this work, the X-ray scanning was carried in angles in between 10 and 90 degrees.The scanning speed of 2 degree/min was used in this work.

Fig. 1 Stir Casting Furnace

Fig. 2 Molding Die

Fig.3 Casted Composites

3.5 Microhardness & Tensile test

The microhardness tests were carried on Vickers hardness testing machine. The Vickers hardness test was performed by applying a load of 1000 gm for 15 sec. The diamond indenter was pressed into the material surface with a penetrator. Universal testing machine was used for the tensile tests and gauge length of 36 mm and diameter of 6 mm was used in tensile specimen. The holder le ngth of tensile specimen was 15 mm and diameter was 13mm.

3.6 Wear test

Tribological properties are evaluated by conducting tests on Pin on disc tribometer. The specimens with 10 mm diameter and 25 mm length was followed as per the ASTM standards. Prior to each test, the samples and disc were cleaned in acetone. Wear tests were performed with normal loads of 10, 20 and 30 N. The sliding velocity of 3.14 m/sec and sliding distance of 942 m were used throughout the experiment. The wear rate and coefficient of friction between samples were recorded using computer controlled pin on disc apparatus.

4.Results And Discussion

4.1 SEM Analysis

The microstructure of the Al 5083-SiC (3, 5 & 7 wt. %) composites was observed by scanning electron microscope at 500X magnification. The SEM micrographs reveales the fine uniform dispersion of SiC particles in the Al 5083 matrix achieved due to uniform stirring action. The SEM micrographs of Al 5083-SiC (3, 5 & 7 wt. %) composites were shown in figure 4.

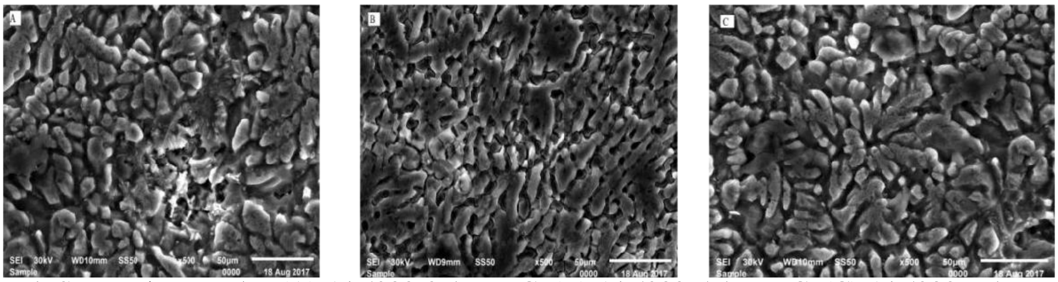

Fig. 4: SEM Micrographs; (A) Al 5083-3% MMC, (B) Al 5083-5% MMC, (C) Al 5083-7% MMC

In SEM images, the white regions shows the SiC particles and black regions shows inter metallic Mg_2Si phases. Presence of entrapped air during casting resulted in the porosity in the casted composite materials. Grain refinement was observed by adding SiC to the aluminum matrix. The SiC particles were homogeneously distributed due to the uniform stirring action. The uniform dispersion of SiC particles was increased by increasing the addition of SiC to the aluminum matrix.

4.2 XRD Analysis
Figure 5 shows the XRD profile of Al5083-3% SiC composite material. The major high intensity peaks of Aluminum and SiC particles were observed in the Al5083-3% SiC MMC. Weak peaks of Mg_2Si were observed in the composite material. The formation of inter metallic compounds Mg_2Si in composite. The high peak of aluminum was observed at 37.49 degrees and SiCat $44.51^0$of diffraction angles. The weak peaks of inter metallic compound Mg_2Si was observed at 64.06^0 and 77.85^0.The X-ray diffraction analysis revealed that the distribution of SiC particles and Mg_2Si inter metallic compound in the aluminum matrix.

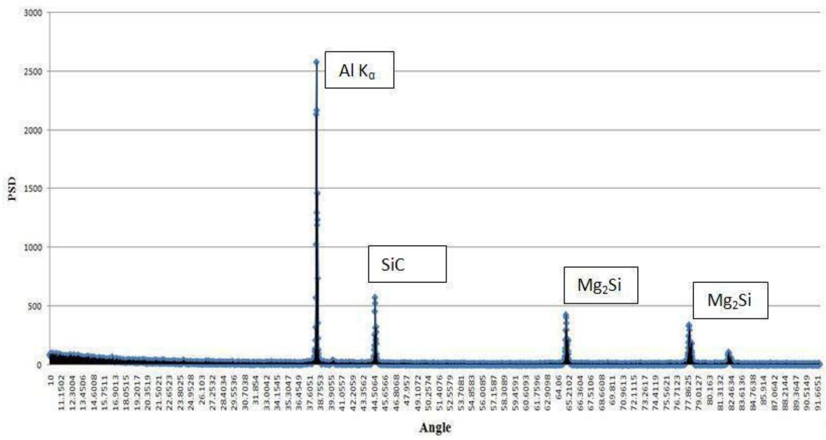

Figure 5. XRD image of Al 5083-3%SiC MMC

4.3 Mechanical Properties

4.3.1 Microhardness test
The microhardness was improved with addition of weight percentage of SiC particles to the aluminum matrix. The microhardness was gradually improved from 72 to 96 HV by adding 3 wt. % SiC particles to the Al 5083 alloy. By adding 5 wt. % SiC particles, the microhardness was slightly improved. The maximum value of microhardness was 112 HV, and it was observed for Al 5083-7% SiC MMC. The variation of microhardness with addition of weight percentage of SiC particles to the Al alloy was

shown in figure 6. The SiC particles were highly stiffer and stronger than Al 5083 alloy and gave better mechanical properties to the Al 5083-SiC composite material.

4.3.2 Tensile test

The casted Al 5083 alloy has the ultimate tensile strength of 175 MPa. By adding 3% SiC particles to the Al 5083 alloy, the ultimate tensile strength of the Al 5083-3% SiC metal matrix composite has become 198 MPa. Slight increment in UTS has been observed by adding 5 wt. % SiC particles to alloy. The Al 5083-7% SiC metal matrix composite has the maximum strength of 226 MPa than other composites and Al 5083 alloy. Because of the strong bonding nature, the Al 5083-7% SiC composite has highest ultimate tensile strength. The formation of clusters in Al 5083-7% SiC composite has been minimized and the SiC particles were distributed uniformly throughout the matrix. The variation of UTS with wt. % of SiC was shown in figure 7. Because of the uniform dispersion of SiC particles, composite has highest ultimate tensile strength by adding 7 wt. % of SiC particles to the Al 5083 alloy.

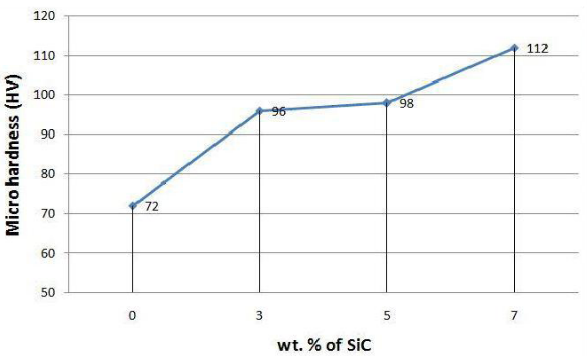

Fig. 6: Variation of microhardness with wt. % SiC

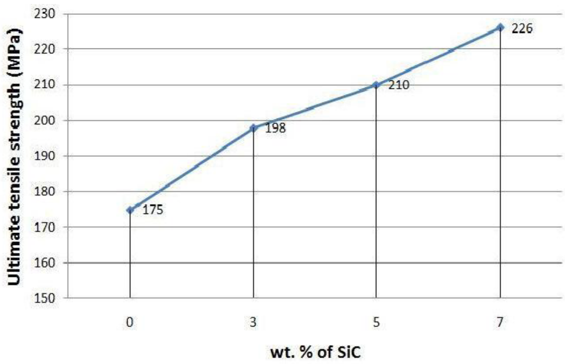

Fig.7: Variation of UTS with wt. % SiC

4.3.3 Wear Test

Tribological properties are evaluated by conducting tests on Pin on disc tribometer. The normal loads of 10,20 and 30N were selected for conducting wear test with sliding velocity of 3.14 m/sec and sliding distance of 942 m were used throughout the experiment. The change of wear rate with applied load for Al 5083-SiC (0, 3, 5 & 7 wt. %) composites was shown in figure 8. The casted Al-5083 has high wear rate than Al 5083-SiC MMCs. By adding SiC particles to the Aluminum matrix the wear rate has been reduced.

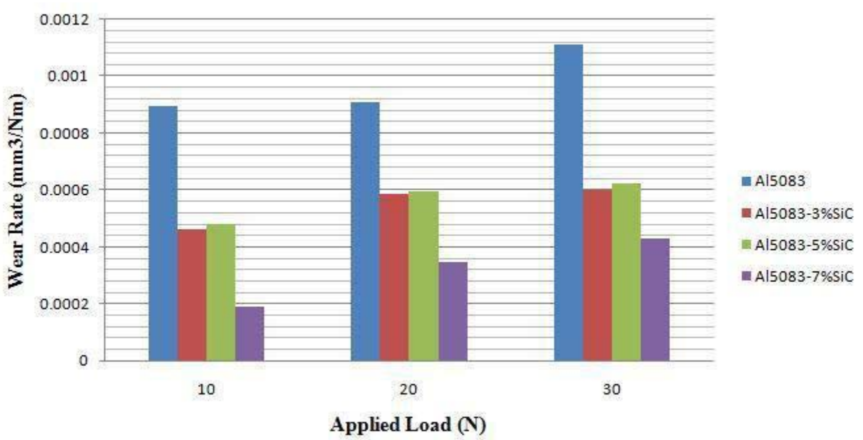

Fig.8: The variation of Wear rate with applied load for Al5083-SiC (0, 3, 5 & 7 wt. %) MMC

Casted Al-5083 alloy has wear rate of 0.000894, 0.00091 and 0.00113 mm^3/Nm at the normal loads of 10, 20 and 30 N respectively. The wear rate was drastically reduced by adding 3 wt. % of SiC to the Aluminum matrix. By adding 5 wt. % SiC particles to the matrix, we did not observed much reduction in wear rate. The wear rate was again reduced by adding 7 wt. % SiC to the Al matrix. The wear rate was reduced by increasing the addition of wt. % SiC to the aluminum matrix. The wear rate was increased by increasing the applied load. The minimum wear rate of 0.00019mm^3/Nm was observed for Al5083-7% SiC composite material at 10 N applied load.The wear resistance of the composite material was enhanced by increasing the addition of wt. % SiC to matrix due to the self lubricating property of SiC particles. SiC itself acts as a lubricant. Al5083-7% SiC composite has minimum wear rate and high wear resistance.

The variation of Coefficient of friction with applied load for Al5083-SiC (0, 3, 5 & 7 wt. %) composites was shown in figure 9. The casted Al-5083 has higher frictional force than Al5083-SiC composites.By adding SiC particles to the aluminum matrix the frictional force was reduced. The coefficient of friction was reduced by increasing the percentage addition of SiC to the Al matrix. The coefficient of friction was reduced by adding 3 wt. % SiC to the matrix and further more reduction was observed by adding 7 wt. % SiC to the Al matrix. The optimum value of frictional coefficient of 0.370476 was observed for Al 5083-7% SiC composite material at 10 N applied load.Al 5083-7% SiC composite materials have better Tribological properties than Al5083, Al5083-3% SiC and Al5083-5% SiC composite materials.

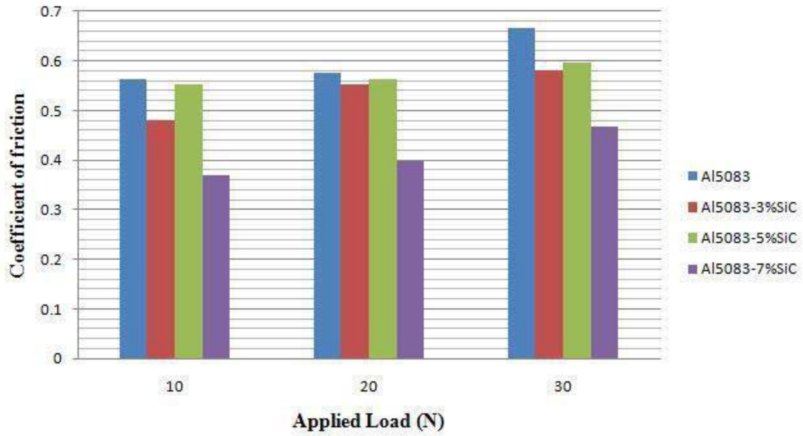

Fig. 9: The variation of Coefficient of friction with applied load for Al5083-SiC (0, 3, 5 & 7 wt. %) MMC

4.3.4 Worn surfaces & Wear morphology

The wear mechanism of samples was easily understood by studying the worn surfaces and wear debris. The optical microscopy was used to analyze the wear surfaces of specimens. The worn surfaces of the Al5083-SiC (3, 5 & 7 wt. %) composite specimens was shown in figure 8. The casted Al5083-3% SiC composite has low wear resistance than other two composite materials. High wear rate was observed during the wear test. Wear surface revealed that small cracks and grooves were takes place on surface of sample.

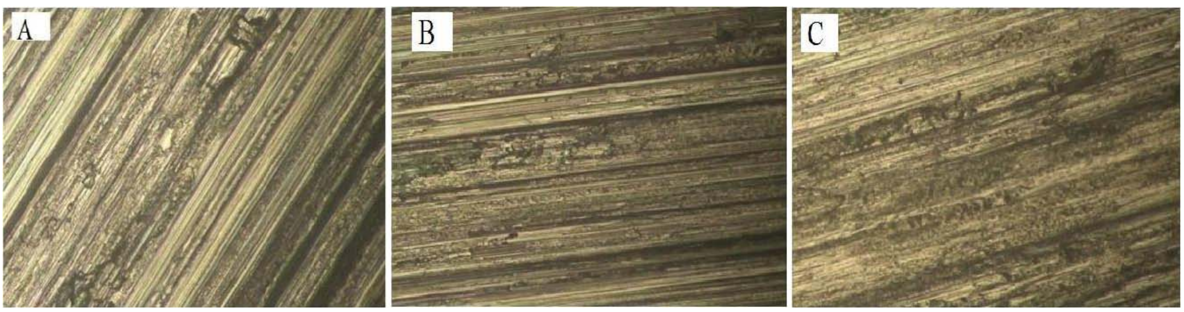

Figure 10: Wear surfaces of (A) Al5083-3% SiC, (B) Al5083-5% SiC, (C) Al5083-7% SiC composites

The worn morphology of Al 5083-5% SiC was exhibited scratches with rows of furrows and parallel grooves in deformed regions. The contact between the steel disc and Al MMC specimen pin was resulting the abrasive wear due to the parallel grooves and scratches on the worn surface. The worn surface of Al5083-7% SiC was showed less wear than other materials.Because of inter metallic phases the Al5083-3% SiC composite showed high wear rate and low wear resistance.The presence of inter metallic phase was reduced and SiC particles were uniformly distributed in Al5083-7% SiC composite materials.Because of the uniform distribution of SiC and presence of low inter metallic phases Al5083-7% SiC composite exhibited better wear resistance and low abrasive wear.

5. Conclusions

In this work metal matrix composite was prepared by using Al 5083 alloy as matrix and SiC as reinforcement. The microstructure of composites was investigated by SEM and X-ray diffraction techniques. The wear tests were conducted on pin on disc equipment at different normal loads and worn out surfaces were analyzed by using optical microscope. From the experimentation work we concluded the following results:

- The X-ray diffraction analysis revealed the distribution of SiC particles and Mg_2Si inter metallic compound phases in the aluminum matrix.
- The SEM micrographs of the composites revealed the uniform distribution of SiC particles in the Al matrix. This was attributed to the effective and uniform stirring action.
- Agglomeration of particles was observed in some regions and this is due to presence of porosity associated to it.
- The microhardness improved after addition of SiC particles to the Al 5083 alloy. The maximum hardness value of 112 HV was observed for Al 5083-7% SiC MMC material.
- By adding 7 wt. % of SiC particles to the aluminum alloy matrix, the microhardness of the Al 5083- 7% SiC MMC has been improved about 55% than Al 5083 alloy.
- The ultimate tensile strength of the aluminum alloy improved with increasing the addition of weight percentage of SiC particles. The maximum ultimate tensile strength of 226 MPa was obtained after addition of 7 wt. % of SiC particles to the aluminum alloy.
- By adding 7 wt. % of SiC particles to the aluminum alloy matrix, the ultimate tensile strength of the Al 5083- 7% SiC MMC has been improved about 29% than Al 5083 alloy.
- By adding SiC reinforcement particles to the Aluminium matrix, the wear resistance of composite specimens has been increased.
- The Tribological properties were improved by increasing the addition of wt. % SiC particles to Al matrix because of self-lubricating property of SiC particles.
- It was found that wear resistance was decreased with increasing the applied load because of more volume loss has been taken place on contact surface between specimen and disc.
- The Olympus inverted micrographs revealed, the abrasive contact between the steel disc and Al 5083-SiC composite specimen pin was result the abrasive wear due to the parallel grooves and scratches on the worn surface.
- The Al 5083-7% SiC MMC material has high mechanical properties and better wear properties due to fairly uniform distribution of SiC particles in the aluminum matrix.

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