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Experimental Study to Analyze the Effect of Silicon Carbide on the Mechanical Properties on AA3103

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***Abstract:** Metal matrix composites (MMCs), such as SiC particle reinforced Al, are one of the widely known composites because of their superior properties such as high strength, hardness, stiffness, wear, and corrosion resistance. These MMC's are widely used in aircrafts, automobiles, electronic equipment's, and sporting goods. Hence a solution is needed to solve the issues like selection of material based on their mechanical properties. In this study aluminum (Al-3103)/SiC Silicon carbide reinforced particles metal-matrix composites (MMCs) are fabricated by induction casting and manual stirring. The MMCs bars are prepared with varying the reinforced particles by weight fraction ranging from 5%, 10%, and 15%. Different tests are carried out on these MMC and base alloy to study the mechanical properties like tensile strength, hardness, and wear rate. It is observed that the addition of silicon carbide increased the tensile strength and hardness and also the wear resistance*
***Keywords:** AA 3103, Silicon carbide, Tensile strength, wear resistance*

I. INTRODUCTION

Aluminum and its alloys possess excellent properties such as low density, good plasticity and ductility and good corrosion resistance. They find extensive applications in aeronautics, astronautics, and automobile and high-speed train fields. However, low hardness and poor impact resistance results in their limited application in heavy duty environments.

Like all composites, aluminum-matrix composites are not a single material but a family of materials whose stiffness, strength, density, thermal and electrical properties can be tailored. The matrix alloy, the reinforcement material, the volume and shape of the reinforcement, the location of the reinforcement, and the fabrication method can all be varied to achieve required properties. Regardless of the variations, however, Al composites offer excellent thermal conductivity, high shear strength, excellent abrasion resistance, high temperature operation, non-flammability, minimal attack by fuels and solvents, and the ability to be formed and treated on conventional equipment. Silicon carbide (SiC) is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. SiC is not attacked by any acids or alkalis or molten salts up to 800 ^{o}C. In air, SiC forms a protective silicon oxide coating at 1200 ^{o}C and is able to be used up to 1600 ^{o}C. The high thermal conductivity coupled with low thermal expansion and high strength gives this material exceptional thermal shock resistant qualities. SiC ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600 ^{o}C with no strength loss. Metal matrix composites (MMCs), such as SiC particle reinforced Al are one of the widely known composites because of their superior properties such as high strength, hardness, stiffness, wear, and corrosion resistance.

SiC particle reinforced Al based MMCs are among the most common MMC and available ones due to their economical production. They can be widely used in the aerospace, automobiles industry such as electronic heat sinks, automotive drive shafts, or explosion engine components. Process variables such as stirring speed, power input, holding temperature, solidification time and stirring technique are considered as important factors in the production of cast metal matrix composites.

The objective of the present study is to find the effect of silicon carbide with varying proportions on properties of Aluminum 3103 alloy by conducting various mechanical tests. Till now analysis on the properties of aluminum alloys by adding silicon carbide was found in literature survey but not much research is done on finding the effect of SiC on AA3103 alloy. The proposed work is taken up to find the effect on aluminum AA3103 alloy by adding silicon carbide in varying proportions by making a composite material using induction casting and conducting various tests such as tensile test, hardness test and wear test.

The results obtained will be compared with properties of base material to find any variation in mechanical properties. The results obtained are expected to be useful in many applications such as aeronautics, heat exchangers, automobiles, military applications, etc. Depending upon properties obtained the material can be recommended for any suitable application. In the present study silicon carbide is added to the base material of Al3103 by varying the compositions between 5 to 15 percent and the mechanical properties are analyzed.

II. LITERATURE REVIEW

Lot of research is conducted to understand the behavior of Aluminum alloys by varying the composition of SiC in base metal. However not much work is reported on the addition of silicon carbide to A3103 alloys. A brief survey on the researcher carried out on the preparation of alloys and material characterization is presented below. Kiran Kumar B, Ragu Chand R etal [1] indicated that the method used like Stir casting technique is successfully adopted in the preparation of Al-2014-B_4C composites. The EDS and Scanning Electron Micro photographs revealed the uniform distribution of B_4C particles in the Al-2014 alloy matrix system. The hardness of Al-2014 alloy increased by increasing the wt. % of B_4C particulates. The ultimate tensile strength and yield strength increased with the increase in B_4C content. K. Santhosh Kumar, V. Sridhar Patnaik etal [2] have concluded that the 2024 Al/B_4C composites of combinations 1%, 2%, 3%, 4% & 5% were produced through stir casting method. The mechanical properties like hardness, yield strength, ultimate tensile strength and % of elongation and wear properties of the samples are evaluated and found to be better than base metal properties. Neelima Devi Chinta, V. Mahesh , N. Selvaraj [3] have explained that at constant weight percentage i.e. 4% of Tungsten carbide with the increase of Red mud percentage (2%,4%,6%) it is 3724 observed that the wear rate is decreasing, that means the wear resistance of the material is increasing. The maximum wear resistance is obtained for 0.042micron level of 6% red mud, and is 0.119×10^{-6}N/m. It is also observed that, for the same weight fraction of red mud, the hardness is higher for the nano structured reinforcement than micro structured reinforcement.

Charles Edrard, N. Kapilan, Mervina Herbert [4] have conducted experimentation on synthesis and characterization of Al6061-graphite composites resulted in an increase in tensile strength. N. B. Dhokey, K.K. Rane [5] have conducted research on Al-MMCs and its relative comparison with gray cast iron and concluded that mechanical properties are strongly affected by TiB_2 content and wear rate decreased with an increasing TiB_2 content. Md. Habibur Rahmana, H.M. Mamun Al Rashed [6] have conducted experimental study on AMC by varying the SiC content (0, 5, 10 and 20 wt. %) using stir casting fabrication technique. Based on experimental evaluation, it was observed that addition of silicon carbide in Al matrix increased the Vickers hardness and tensile strength and wear resistance.

III. EXPERIMENTAL STUDY

Aluminum 3103 alloy is prepared by melting the materials in the inductive furnace at a temperature approximately above 700C according to required composition as mentioned for that alloy. Then the preheated silicon carbide is combined macroscopically in the furnace according to required composition and stirring is carried out manually as well as using high frequency current for about 10minutes.The current and power maintained for melting the two constituents is 21.8KVA and 9.2KW respectively.

After stirring process the mixture is poured into a mould of length 150mm and diameter 20mm to get desired shape of specimen and allowed it to solidify under atmospheric conditions. After solidification, the composite material is removed from the mould and allowed it to cool in atmospheric air. The machining is carried out for making the specimens of required dimensions by using lathe machine, bench grinder and other finishing tools. The microstructure of the specimens is obtained under electronic microscope. The specimens are prepared from machining processes with a dimension of 10mm width and 15mm diameter and they are polished using emery paper and dual disc polishing machine. They are dipped in an etchant of 5%hydrochloric acid and 98%distilled water and are placed under the microscope. The structure is observed using 100X magnification lens. The below figures 3.1 and 3.2 show the picture of electronic microscope and microstructure specimens.

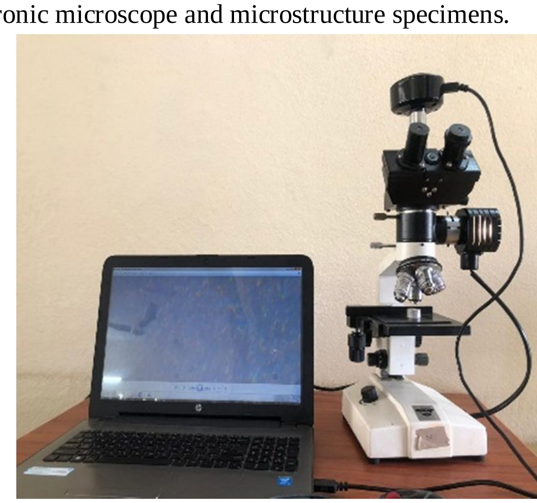

Fig 3.1 Microscopic Analysis

Fig. 3.2 Microstructure Specimens

Tensile tests were used to assess the mechanical behavior of the composites. The solid round dog bone shaped composite specimen were machined to tensile specimen with a diameter of 10mm and gauge length of 50mm as per ASTM-E8 standard. The tensile test is carried out under Universal testing machine. During tensile testing of material sample, the load vs cross head travel (CHT) curve is obtained in a graphical representation. The initial and final diameter, gauge length, final area, maximum load and maximum elongation were recorded. This testing is carried out under the supervision of an expert in material testing. The maximum load applied is 400KN for all specimens and the values are recorded in computer. Depending upon the load applied, specimen dimensions and composition of material the values are recorded and the machine is stopped automatically when the specimen is broken. The UTM and tensile specimens are shown in below figures 3.3 and 3.4.

Fig. 3.3 UTM Machine

Fig. 3.4 Tensile test specimens

A Rockwell hardness tester machine (Fig. 3.5) is used for hardness measurement. The surface being tested generally requires a metallographic finish and it was done with the help of 100,220,400,600 and 1000 grit size paper. In this hardness test, an indenter is allowed to penetrate on to the specimen using standard load. The load used on Rockwell's hardness tester was 250Kgf at dwell time of 10 seconds for each sample and values shown on red scale (HRC) were recorded. The hardness machine and hardness samples are shown in below figures.

Fig. 3.5 Hardness testing machine

Fig. 3.6 Hardness test specimens

Wear resistance testing is done on Pin-On-Disc machine at load of 0.981N and rotational speed of disc rotational speed of disc of 1440rpm. As per ASTM G-04-04 Standard cylindrical pin wear testing sample is prepared on the lathe machine having dimensions of 9mm diameter and 60mm height as shown in Fig. 3.6

Following parameters are used to perform wear test:

Load (N):0.981Newton, Disc rotation speed-1440rpm, Wear track radius-72.5mm, Disc diameter-250mm, Abrasive grades-120, Time -15seconds. The specimen is weighed before placing on disc and the load is applied. The disc is rotated at 1440rpm for 15seconds and stopped. The weight of specimen is measured after the test and interpreted the results.

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Fig 3.7 shows the wear test specimens and Fig 3.8 shows the wear testing machine on which wear test is carried out and

Fig. 3.7 Wear test specimen

Fig3.8 Pinon disc wear testing equipment

IV. RESULTS AND DISCUSSIONS

The microstructure investigation of the cast Al3103/5%SiC, Al3103/10%SiC and Al3103/15% MMC has been carried out by electronic microscope. The microstructures with varying composition of SiC are shown in below figures at 100x.The micrographs of the cast composite revealed that the agglomerations of SiC particles are uniformly distributed in that matrix. It is apparent from the microstructure that the distributions of reinforcement particles become more uniform in the matrix as their weight percentage increases. The black spots in composition of Al-SiC represents the amount of silicon carbide distributed in the mixture and white color represents the Al3103alloy.

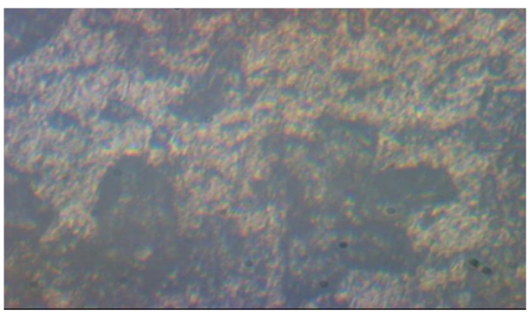

Fig 4.1 a (0% SiC)

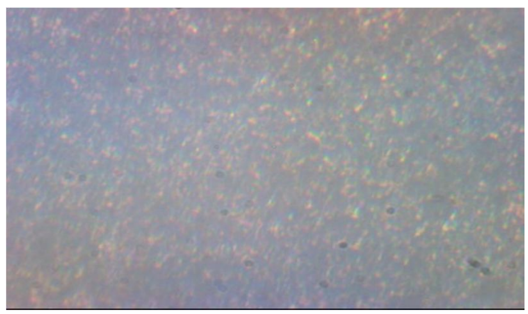

Fig 4.1 b (5 % SiC)

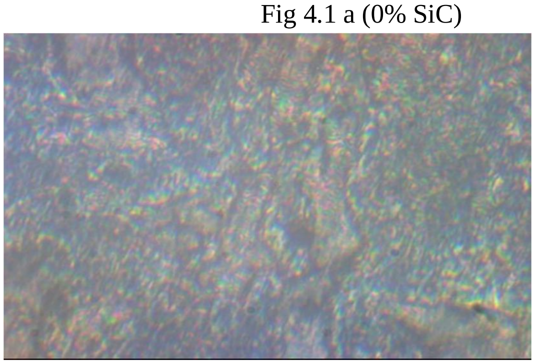

Fig. 4.1 c (10% SiC)

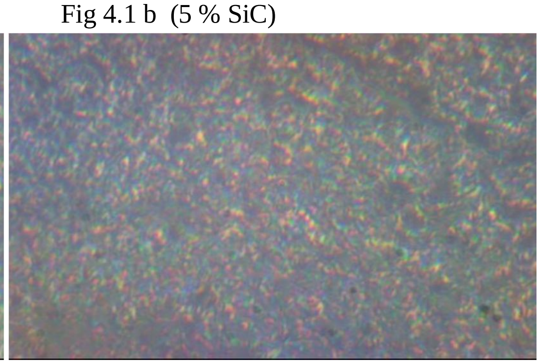

Fig. 4.1 d (15% SiC)

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Tensile test is carried on UTM and the results are shown below. Table 4.1 illustrates the results of tensile test in which % of elongation, yield stress, ultimate tensile strength are defined. Table 4.2 illustrates the results of hardness test in which hardness in terms of HRC is defined. Fig. 4.2 shows thw plot between tensile strength and varying proportions of SiC.

Table 4.1 Results of Tensile Test

Samples	%Elongation (%)	Yield stress (MPa)	Ultimate tensile strength(MPa)
Al3103-5%SiC	1.80	98.049	122.562
Al3103-10%SiC	1.46	97.717	123.825
Al3103-15%SiC	1.72	92.509	116.191

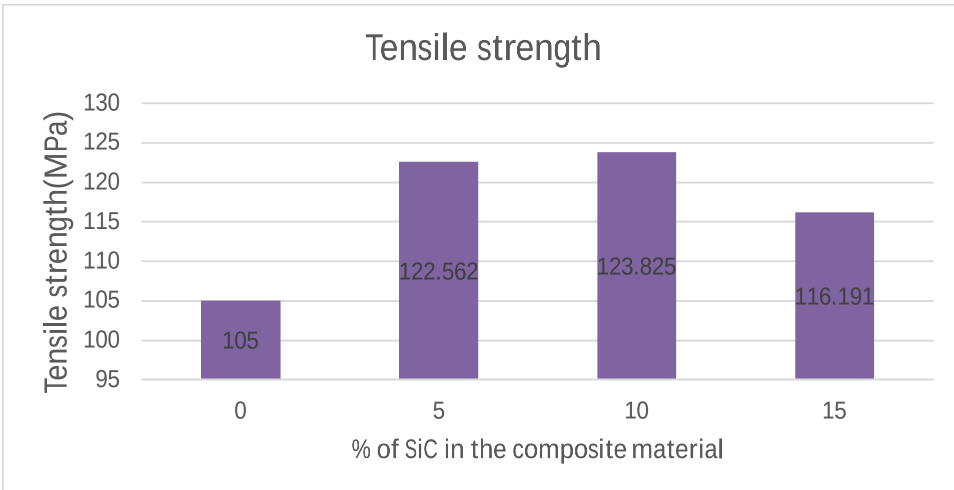

Fig 4.2 Bar Graph showing the Tensile Strength Vs Varying Composition of SiC

Table 4.2 Results of Hardness Test

S.No	Samples	Hardness (HRC)
1	Al3103-0%SiC	34.75
2	Al3103-5%SiC	44.25
3	Al3103-10%SiC	47.0
4	Al3103-15%SiC	45.3

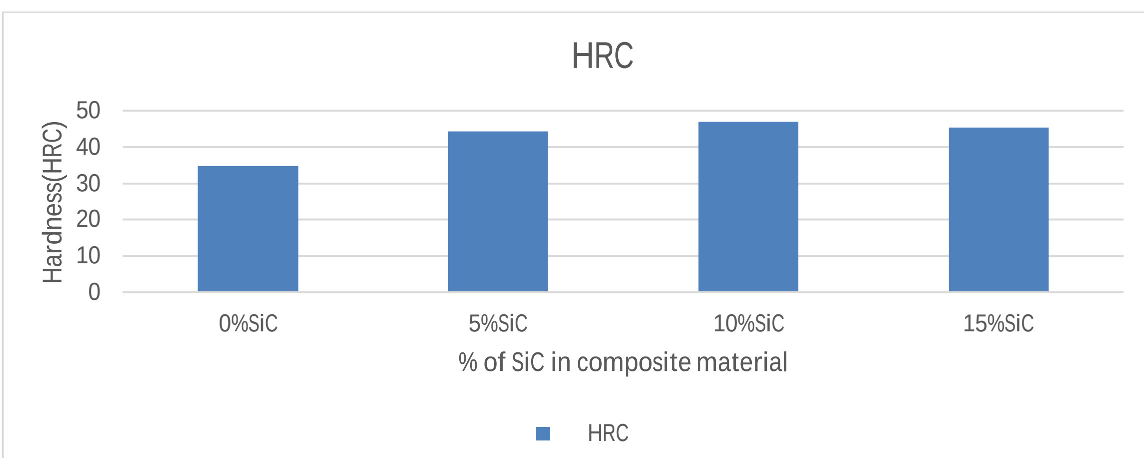

Fig. 4.3 Bar Graph showing the Hardness Value with Varying Composition of SiC

The graphs 4.3 and 4.4 indicates the bar graph and x-y plot graph on which % of SiC is plotted on X-axis and specific wear rate on Y-axis respectively showing the hardness and specific wear rate. Table 4.3 defines the results of wear test in which volume loss of material during wear test and specific wear rate are mentioned.

Table 4.3 Results of Wear Test

S.No	Samples	Volume loss (mm3)	Load *time (N-min)	Specific Wear rate (mm3 / N-Min)
1	Al3103-0%SiC	11.85	0.24525	48.3
2	Al3103-5%SiC	7.407	0.24525	30.2
3	Al3103-10%SiC	3.704	0.24525	15.1
4	Al3103-15%SiC	4.07	0.24525	16.59

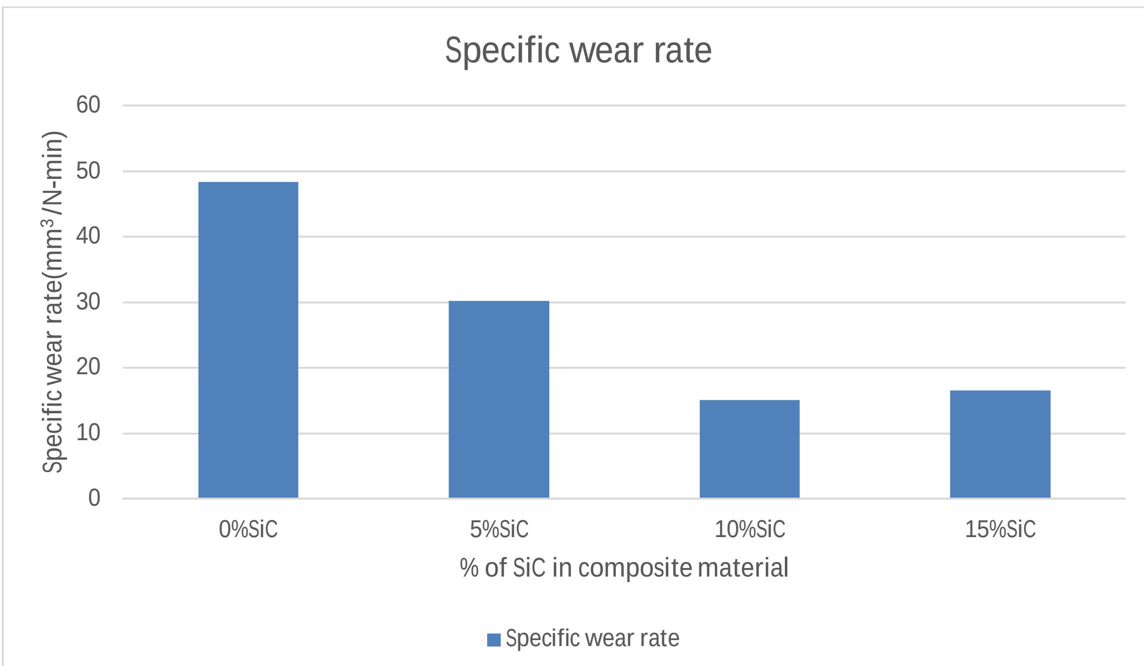

Fig 4.4 Graph showing the Specific Wear Rate Vs Varying Composition of SiC

V. CONCLUSIONS

The results confirmed that Al 3103 with SiC reinforced material is clearly superior to pure aluminum and Al3103 alloy in terms of tensile strength, hardness and specific wear rate. The microstructure investigation revealed uniform distribution of SiC particles into Al matrix. It is observed that tensile strength and hardness increased with increase in SiC weight up to 10 percent. It is also observed that specific wear rate decreased by 50% up to 10%wt SiC and increased to 25% as SiC% is increased up to 15% .

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