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Study and Comparison Of AL-SIC Composite With Pure As Cast Aluminium For Wear Behavior

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Abstract: **Silicon carbide exists in about 250 crystalline forms [3]. Alpha silicon carbide (α-SiC) is the most commonly encountered polymorph; it is formed at temperatures greater than 1700 °C and has a hexagonal crystal structure. The high sublimation temperature of SiC (approximately 2700 °C) makes it useful for bearings and furnace parts. Silicon carbide does not melt at any known pressure. Aluminium (Al) alloys are gaining more recognition as a lighter structural material for light weight applications, due to their low density and high stiffness-to-weight ratio. As summarized from the literature Metallic Carbides or Oxides are most commonly used reinforcements in aluminium matrix. Silicon Carbide was used in the current research work as reinforcement for Aluminium matrix, mainly because of its high wear resistance and high hardness applications. Al-SiC Composite was fabricated using cost effective stir casting technique and dry sliding wear testing was performed on a pin on disk type wear testing machine. Optical macrographs and SEM images were taken to study the wear pattern and particle distribution in the cast composite. Results shown that Al-SiC composite material was found to be more wear resistant than pure as cast aluminium with uniform particle distribution. So it can be recommended for wear resistance applications and more experiments can be planned to find out the optimum configuration to be used for fabricating Al-SiC composite materials.**

I. INTRODUCTION

A composite material is made by combining two or more dissimilar materials. They are combined in such a way that the resulting composite material or composite possesses superior properties which are not obtainable with a single constituent material. So, in technical terms, we can define a composite as “a multiphase material from a combination of materials, differing in composition or form, which remain bonded together, but retain their identities and properties, without going into any chemical reactions” [1].

In general composites are broadly classified at two distinct levels. The first level of classification is usually made with respect to the matrix constituent. The major composite classes include organic-matrix composites (OMC’s), metal-matrix composites (MMC’s), and ceramic-matrix composites (CMC’s). The term organic-matrix composite is generally assumed to include two classes of composites: polymer matrix composites (PMC’s) and carbon matrix composites (commonly referred to as carbon-carbon composites). The second level of classification refers to the reinforcement form: particulate reinforcements, whiskers, continuous fiber laminated composites, and woven composites (braided and knitted fiber architectures are included in this category) [2].

Composite materials are made from constituents which can be grouped as (i) matrix/binders, (ii) reinforcements and/or (iii) fillers, additives and auxiliary chemicals [1].

Aluminium matrix composites (AMC’s) refer to the class of light weight high performance aluminium centric material systems. The reinforcement in AMC’s could be in the form of continuous/discontinuous fibers, whisker or particulates, in volume fractions ranging from a few percent to 70%. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route [3].

Aluminum is the most popular matrix for the metal matrix composites (MMC’s). The aluminium alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix [4].

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Silicon carbide exists in about 250 crystalline forms [5]. Alpha silicon carbide (α-SiC) is the most commonly encountered polymorph; it is formed at temperatures greater than 1700 °C and has a hexagonal crystal structure (similar to Wurtzite) [6].

Pure SiC is colorless. The brown to black color of industrial product results from iron impurities. The high sublimation temperature of SiC (approximately 2700 °C) makes it useful for bearings and furnace parts. Silicon carbide does not melt at any known pressure. It is also highly inert chemically. There is currently much interest in its use as a semiconductor material in electronics, where its high thermal conductivity, high electric field breakdown strength and high maximum current density make it more promising than silicon for high-powered devices [7].

Engineered composite materials must be formed to shape. The reinforcement can be introduced to the matrix before or after the matrix material is placed into the mould cavity. The matrix material experiences a melting event, after which the part shape is essentially set. Depending upon the nature of the matrix material, this melting can occur in various ways such as chemical polymerization or solidification from the melted state. A variety of molding methods can be used according to the finish product requirements [8].

Stir casting is the simplest and the most cost effective method of liquid state fabrication. A dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. Liquid state composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies [9]. "Figure 1" shows the various parts of a stir casting apparatus, which are: 1-Motor with height adjustment, 2-Heating Furnace, 3-Crucible, 4-Stirring blade [10].

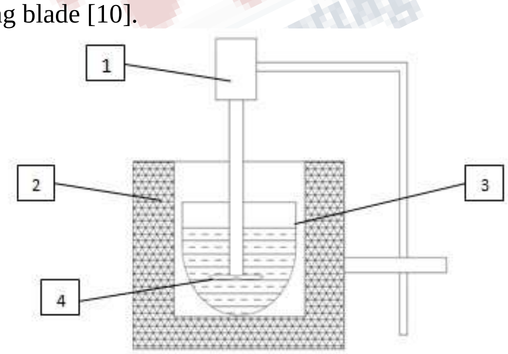

Figure 1: Stir casting set up

II. EXPERIMENTAL WORK

The matrix material used in the experimental investigation was 90% commercially pure aluminium bar of 0.5 kg weight and Silicon Carbide reinforcement size used was 220 mesh. A box type casting furnace with temperature adjustment was used for the experimental work. A stirrer was used separately with the furnace having height adjustment and running at a constant rpm of 200.

Al-SiC metal matrix composite was prepared using cost effective stir casting technique. For this 500gm of commercially pure aluminum and 220gm (10% by wt.) of reinforcement particles were taken. Commercially pure aluminum was melted in a box type furnace. The melt temperature was raised up to 700 to 800°C. Then the melt was stirred with the help of a mild steel turbine blade stirrer. The stirring was done at an impeller speed of about 200 rpm. The melt temperature was maintained 650 to 700°C during addition of reinforcement particles. The dispersion of reinforcement particles were achieved by the vortex method. The melt with reinforced particulates were poured into the lubricated permanent metallic mold and was allowed to solidify.

Cast aluminium matrix composite with SiC as particle reinforcement was taken for observing their wear behavior and comparing it with pure as cast aluminium. All the cast samples were finish machined to make pins of 8mm diameter and 40 mm along length. The surface of some of the specimens was prepared to see their microstructure. The wear testing was performed on a pin on disk type wear testing machine. The rpm of the machine was kept constant at 200 and testing was performed for 16 minutes duration with a sliding time of 2 minutes, taking 8 readings of each sample. Testing was done at four different parameters, at two different loads of 30N & 50N and at two different wear track diameters of 100mm and 130mm. SEM images were taken (at 100x and at 1000x) after wear testing for studying the wear behavior of the composite material and for observing the wear patterns.

III. RESULTS AND DISCUSSIONS

The pure aluminium and aluminium based composites were fabricated using stir casting technique by the procedure discussed earlier in experimental work.

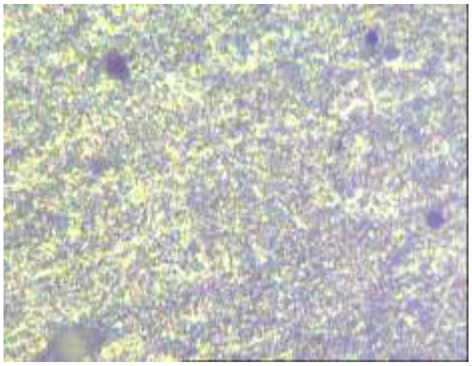

Figure 2: Shows the optical macrographs of Aluminium-Silicon carbide composite material

The distribution of the reinforcement particles can be clearly seen in the macrographs of the cast composites material shown in "Figure 2". The macrographs show almost uniform distribution of reinforcements in the Al-SiC composite materials. The dark spots indicate the position of reinforcement particles in the aluminium matrix material.

Sliding wear testing was carried out on the prepared specimens from the cast composites using a pin on disk apparatus as per the procedure explained in experimental work section. The wear tests were done for two normal loads of 30N and 50N at a constant time interval of 2 minutes and at two different wear track radius of 100mm and 130mm. The variation of cumulative wear rate (CWR) and weight loss with sliding distance has been discussed in the subsequent paragraphs for the various cases under investigation.

Figure 3: Comparison of wear behavior at a load of 30N & disk diameter of 100mm

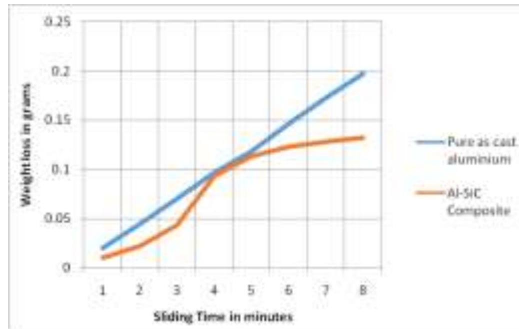

Figure 4: Comparison of wear behavior at a load of 50N & disk diameter of 100mm

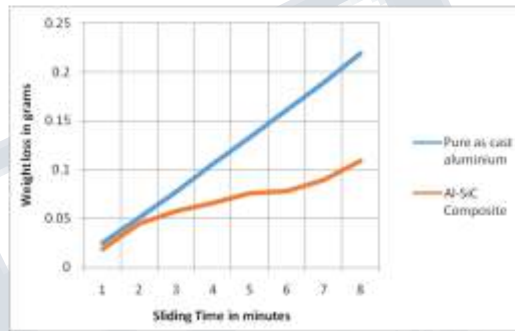

Figure 5: Comparison of wear behavior at a load of 30N & disk diameter of 130mm

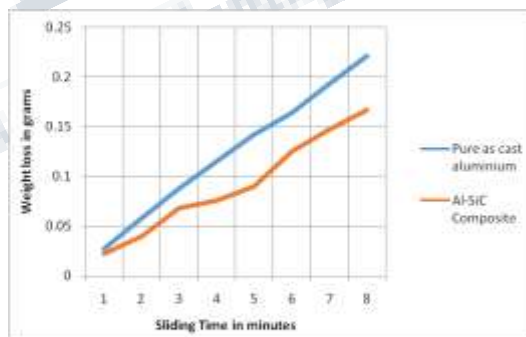

Figure 6: Comparison of wear behavior at a load of 50N & disk diameter of 130mm

Weight loss data of Al-SiC composite was plotted against the sliding time to generate the graphs of cumulative wear rate at all the four test conditions and to study the wear trend. The wear rate of Al-SiC composite was very-very less as compared to pure as cast aluminium. It can be seen from "Figure 3" that at the first 5 minutes of testing the wear rate was almost uniform and then it suddenly increased up to 6^{th} minute of testing then again the wear rate becomes uniform. The same trend of wear rate can be seen in all the four graphs generated at four different test conditions. Weight loss at maximum load conditions are shown by "Figure 6" in

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which the reduced difference in the weight loss of the two materials can be clearly seen.

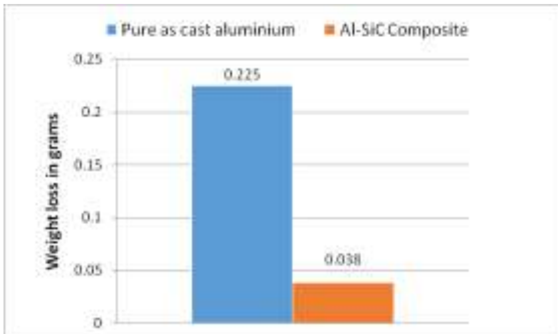

Figure 7: Comparison of total weight loss at a load of 30N & disk diameter of 100mm

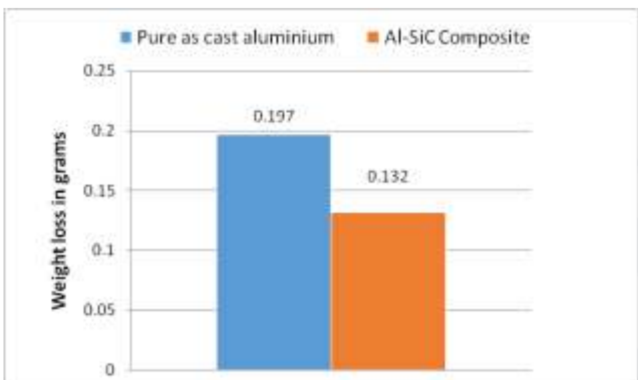

Figure 8: Comparison of total weight loss at a load of 50N & disk diameter of 100mm

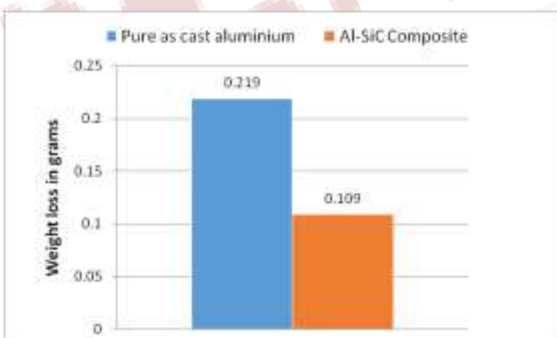

Figure 9: Comparison of total weight loss at a load of 30N & disk diameter of 130mm

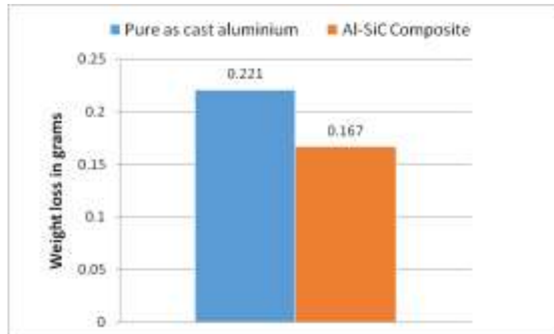

Figure 10: Comparison of total weight loss at a load of 50N & disk diameter of 130mm

To understand the wear mechanisms, the worn surfaces of the specimens corresponding to maximum load conditions i.e. at normal load of 50N and at disk diameter of 130mm, were investigated by SEM. A large number of grooves on the entire surface of the worn specimens can be clearly seen from the SEM images. From “Figure 11 & Figure 12” abrasive wear is evidently clear due to the presence of deep groves in the surface and delamination due to abrasive wear is also present. From the higher resolution image the loose particles causing the surface grooves and the delaminated layers can be seen clearly. Adhesive wear is also present to a some extent.

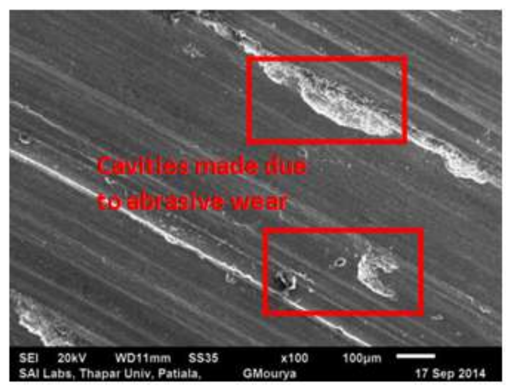

Figure 11: SEM images of Al-SiC composite at a magnification of 100x

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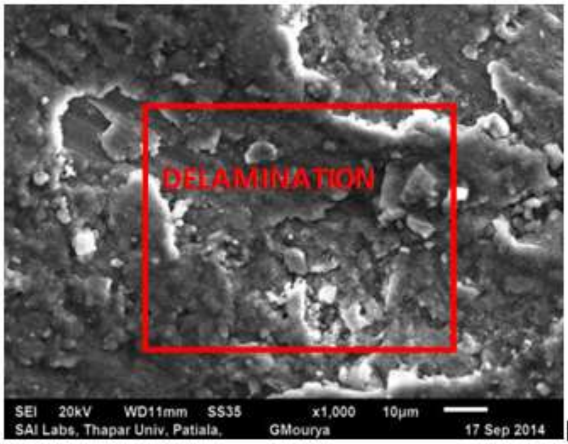

Figure 12: SEM images of Al-SiC composite at a magnification of 1000x

IV. CONCLUSIONS

- When the diameter of disk was more in contact with pin surface then the wear rate was more and vice-versa. Further with increase in dead weight the wear rate was found to have increased.
- The least weight loss was 0.038 grams at disk diameter of 100mm and normal load of 30N and weight loss was found maximum i.e. 0.167 grams at disk diameter of 130mm and normal load of 50N.
- At a disc diameter of 100mm and normal load 30N Al-B_4C Composite showed 83.11% less weight loss than pure as cast aluminium.
- At disc diameter of 100mm and normal load 50N Al-B_4C Composite showed 32.99% less weight loss than pure as cast aluminium.
- At disc diameter of 130mm and normal load 30N Al-B_4C Composite showed 50.22% less weight loss than pure as cast aluminium.
- At disc diameter of 130mm and normal load 50N Al-B_4C Composite showed 24.43% less weight loss than pure as cast aluminium.
- Reinforcement particle distribution was found uniform, as observed from Optical macrographs and SEM images.
- Adhesive wear seems more prominent when we look at the SEM images.

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