Study of Wear behaviour of Aluminium Metal Matrix Composite Reinforced with SiC

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Abstract - *Metal matrix composites (MMCs) constitute an important class of design and weight-efficient structural materials that are encouraging every sphere of engineering applications. There has been an increasing interest in composites containing low density and low cost reinforcements. Aluminium based metal matrix composites (MMCs) offer potential for advanced structural applications, high specific strength and modulus, as well as good elevated temperature resistance along with light weight and for marine applications. In the present work, aluminium-silicon carbide composite (Al-SiC) developed using a stir casting technique is studied for wear behaviour. The wear behaviour of the composite is investigated at room conditions at four different loads, 70N, 80N, 90N, 100N and with varying sliding speeds, i.e. 200, 300, 400, 500, 600, 700 rpm's, using a pin-on-disk wear testing machine. Variation of cumulative mass loss with the applied load, sliding speed, sliding distance and friction co-efficient was studied from the pin-on-disk experiment. Microstructural characterization of the surfaces, and surface roughness studies of the worn surface are also made.*

Key Words: **Aluminium, Silicon Carbide, stir casting, Wear test, etc.**

1. INTRODUCTION

The advancement of composite materials has turn into a defining moment in the historical backdrop of science and innovation as it allows the synergizing of clear properties of its fixings, namely the reinforcement phase and the bulk matrix phase and suppresses the deficiencies of each of them [1]. The composite materials in light of metals and their alloys which are termed as metal matrix composites (MMCs) have adapted broad research everywhere throughout the world as they are discovered to be suitable competitor materials for basic and mechanical applications in aerospace sector, marine sector, defense sector and general engineering applications. The remarkable capacity of MMCs to bring together the reinforcement properties (high quality and versatile modulus) with that of the metallic stage (high flexibility and durability) makes them fit for bearing higher pressure and shear loadings furthermore sustainability at elevated temperatures[2,3].

The use of aluminum based MMCs (AMCs) is expanding in a variety of industries of commercial values as they give extraordinary points of interest over traditional solid materials regarding more stiffness and specific strength, enhanced high temperature wear resistance capacities, customizable coefficient of thermal extension (CTE) and resistance to thermal fatigue. The applications of AMCs includes gears and braking system in automobiles, fuel access door covers and ventral fins in automobiles, golf club shafts, bicycle frames, track shoes in military tanks, flywheels, ice hockey sticks, Cryostats, rocket turbine housing, missile nose tips, etc. [4-6]. AMCs with reinforcement in the form of particles are picking up significance because of their isotropic properties when compared with fiber and whisker reinforcements which display anisotropic mechanical properties. These particulates reinforced metal matrix composites (PRMMCs) show high strength, hardness, and wear and corrosion resistance [4,7].

1.1 Composites

A composite material is composed of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material. Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the 'reinforcement' or 'reinforcing material', whereas the continuous phase is termed as the ' matrix'.

Various properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties.

1.2 Aluminium-SiC Metal Matrix Composite

MMCs are made by dispersing a reinforcing material into a metal matrix. They are prepared by powder metallurgy and casting, although several technical challenges exist with casting technology. Achieving a homogeneous distribution of reinforcement within the matrix is one such challenge, and this affects directly on the properties and quality of composite. The aluminium alloy composite materials consist of high strength, high stiffness, more thermal stability, more corrosion and wear resistance, and more fatigue life. Aluminium alloy materials found to be the best alternative with its unique capacity of designing the materials to give required properties. In this work a composite is developed by adding silicon carbide in Aluminium metal by mass ratio 10%. The composite that has been studied has been fabricated by stir casting route. Aluminium metal matrix composite have following advantages:

1) Greater strength
2) Reduced density (weight)
3) Improved stiffness
4) Controlled thermal expansion coefficient
5) Improved high temperature properties
6) Enhanced and tailored electrical performance
7) Thermal/heat management
8) Improved damping capabilities.
9) Improved abrasion and wear resistance

SiC is one of the best widely used ceramic reinforcements in Aluminium metal matrix composites. SiC have high corrosion resistance, high thermal conductivity, low thermal expansion coefficient, high hardness and good refractory properties. The addition of SiC to aluminium improves its strength and other thermal and mechanical properties. SiC improves strength of the alloy and the elevated temperature hardness.

2. METHODOLOGY

There are several fabrication techniques available to manufacture the MMC materials: there is no unique route in this respect. Due to the choice of material and reinforcement and of the types of reinforcement, the fabrication techniques can vary considerably. In this work, Stir Casting method is used for making samples of Metal Matrix composite. Stir-casting techniques shown in Figure 1 is currently the simplest and most commercial method of production of MMCs.

The Al-SiC composite has been fabricated by using stir casting technique. A modified stir casting technique for preparation of the composite is designed, using a plunger for making the reinforcement addition. A mild steel cylinder container is coated with aluminium and used to hold the aluminium melt. A hollow spindle which has its stirrer blades attached to motor and V-belt arrangement for better stirring. The plunger rod is attached to perforated capsule which holds the Silicon carbide particles. Aluminium blocks are melted in the crucible at temperature of 800oC and stirred at 500 rpm. Silicon carbide particles are added through the hollow spindle. The SiC particles is released after the aluminum foil coating melts. The melt is poured into mould and cooled. Then samples of the required dimensions are cut for the wear tests.

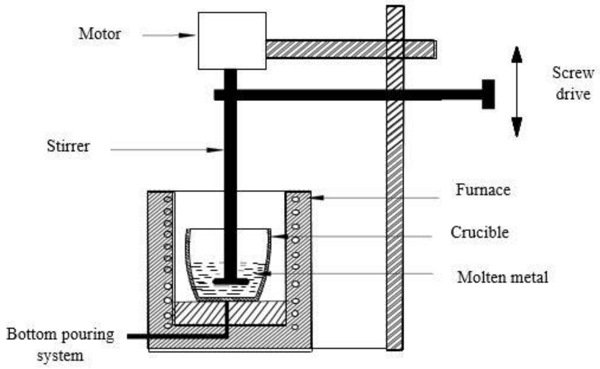

Fig - 1: MMC by casting route through Stir Casting method

2.1 Wear Test:

Wear is the harm caused by a material surface because of the relative movement with other reaching surfaces which for the most part results in useless material misfortunes. Wear can bring about removal of material from either or both the reaching surfaces. Wear is characterized as "the damage to a strong surface, generally involving the progressive loss of material, because of relative movement between two moving surfaces [8].

A pin on disc wear test machine with a Computerized friction and wear monitor is used the for the wear testing.

Fig -2: Pin on disc wear test machine

The test is done by rotating a counter-face test disk against a stationary test specimen pin. The disc, which rotates is made of high carbon, quenched and tempered steel of diameter 120 mm and hardness of 70 HRC. The Al-SiC samples were held stationary in the sample holder and the normal load is applied through a lever mechanism. An electronic weighing balance having an accuracy level of 0.1

mg is used to measure the weight loss of the sample. No lubricant is used as test is carried out in dry conditions. The samples were weighed at regular intervals to measure weight loss. It was under careful examination that the specimens wearing in the test are regularly cleaned with woolen cloth so as to avoid the snaring of wear debris and to achieve uniformity in experiential procedure. The tests were done by varying one among the below mentioned parameters and keeping the other parameters constants:

1) Time
2) Applied load
3) Sliding speed
4) Sliding distance

For finding Specific Wear Rate, the weight loss method was used for calculating specific wear rate during the experiments. Before experiment performing on the pin-on-disc apparatus, initial weight of specimen is measured and after the completion of experiment again final weight of specimen is measured. Then weight loss is calculated by subtracting initial and final weight of specimen. Then Specific Wear Rate (SWR) can be found by the following:

$$K_S = \frac{\Delta m}{L\rho F}$$

Where K_s is Specific Wear Rate (mm^3/N-m), Δm is the mass loss in the test duration (g), ρ is the density of the composite (g/cm^3) and F is the normal load in newton (N), L is the sliding distance in meters (m) and V is the sliding velocity in m/s.

3. RESULTS

The wear behaviour of the composite is investigated at room conditions at four different loads, 70N, 80N, 90N, 100N and with varying sliding speeds like 200, 300, 400, 500, 600, 700 rpms, using a pin-on-disk wear testing machine. The track diameter was held constant at 90mm. Following curves were plotted using the data:

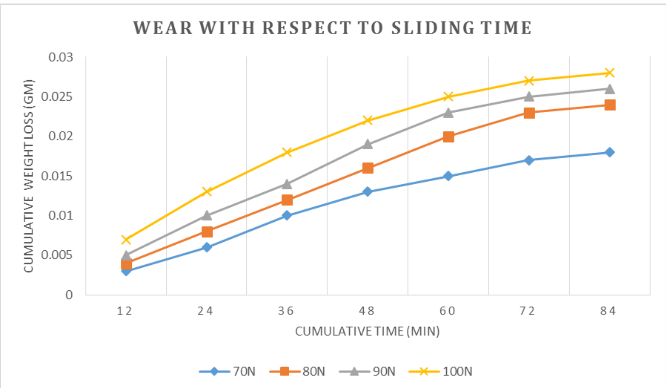

Chart -1: Graph between cumulative weight loss and cumulative sliding time at different applied loads

From the Chart 1-6, following thing is observed:

- ✓ As the sliding time increases weight of the sample decreases constantly which increases the cumulative weight loss. But at higher sliding time wear rate decreases.
- ✓ Initially the surface becomes rough, so the sliding movement occurs in very small areas at the peaks and over time the peaks break and the contact area is increased. So the flattening of the surface occurs, which leads to decrease in the co-efficient of friction and wear at the higher sliding time. Thus sliding over a longer period of time leads to decreases in wear and loss of the metal.
- ✓ As load increases, deeper grooves are created because of increased pressure and temperature. So weight loss is more leading to higher wear at higher loads.

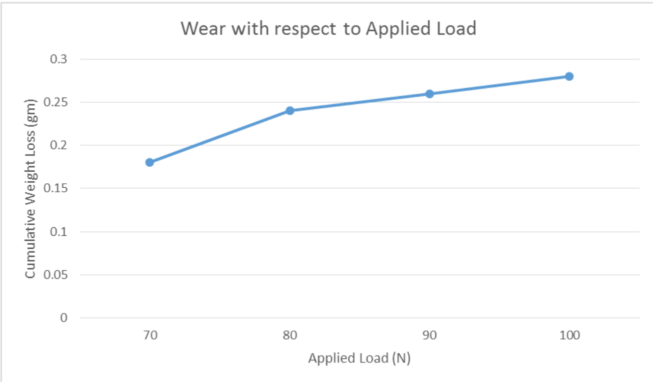

Chart -2: Graph between cumulative weight loss and applied load

- ✓ But as the applied load increases the rate of weight loss decreases, leading to lower wear rate. Because at higher loads the grooves become smooth and in dry condition which can be observed from the optical micrograph of the worn surface. So there is a decrease in co-efficient of friction leading to decrease in wear rate.

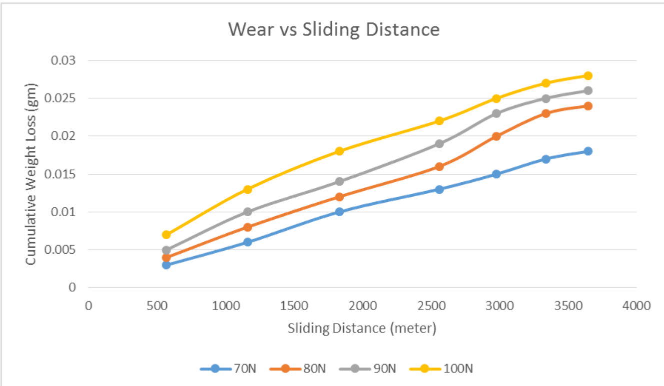

Chart -3: Graph between cumulative weight loss and sliding distance at different applied loads

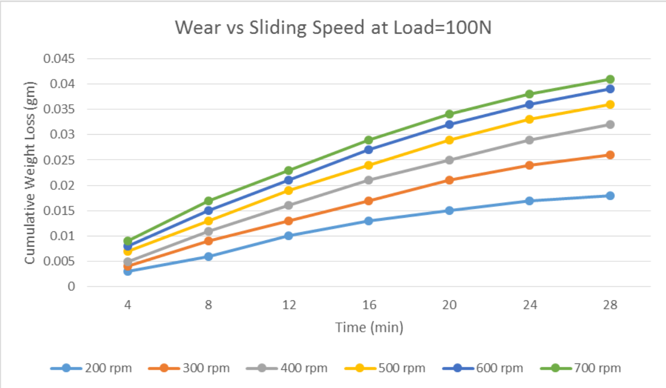

Chart -4: Graph between cumulative weight loss and sliding time at different rpms

- ✓ As the sliding distance and sliding speed increases, the amount of wear increases, but the wear rate decreases at higher sliding distance and sliding speed. Because sliding over long distances and at higher sliding speeds causes hardening of the surface layer composition of the waste debris and reduces the wear rate.

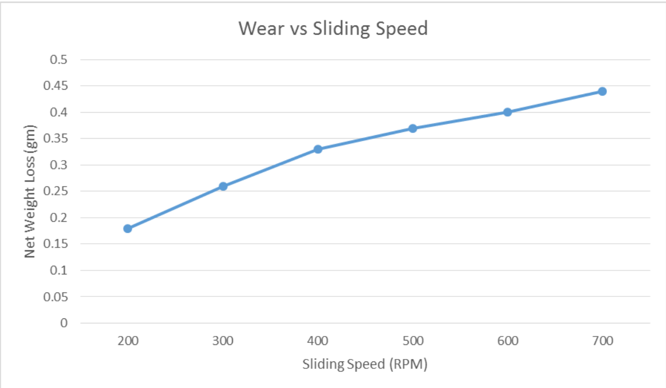

Chart -5: Graph between cumulative weight loss and sliding speed

- ✓ Higher sliding speed leads to decrease in surface roughness. Decreased surface roughness and a small quantity of wear debris decrease the co-efficient of friction. So wear rate decreases at higher sliding speeds.

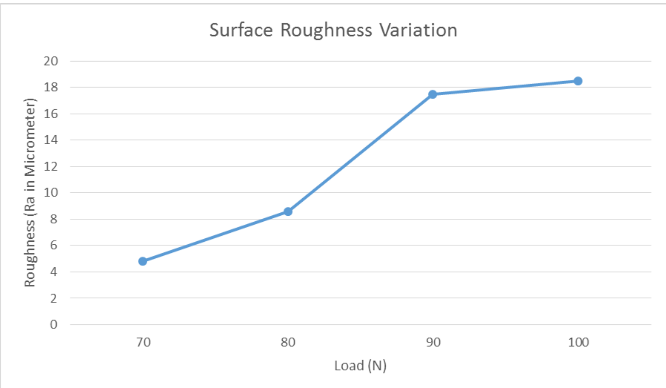

Chart -6: Graph between surface roughness of the worn sample and applied load

- ✓ The surface roughness of the worn surface were measured by using Profilometer and the Ra value was plotted against varying applied load.
- ✓ The increase in load leads to higher surface temperature leads to gradual flattening of the protrusions, resulting in steady state and higher slide speed at high temperature, which reduce the shear force, reduce the surface roughness as well as the co-efficient of friction.

4. CONCLUSIONS

The significant conclusions of the studies carried out on copper-graphite composite are as follows:

- ✓ In the initial stage of sliding time and sliding distance the weight loss suffered by the material almost increases linearly and continuously with increasing sliding time and sliding distance, indicating a completely steady-state behavior.
- ✓ But sliding for long time and sliding over long distances causes hardening of the surface layer compounds of the waste debris and decreases the wear rate.
- ✓ As load increases, deeper grooves are created because of increased pressure and temperature. So wt. loss is more leading to higher wear at higher loads. But as the applied load increases rate of wt. loss decreases leading to lower wear rate. Because at higher loads the grooves become smooth and in dry condition.
- ✓ Al-SiC composites possess improved wear resistance and hardness value.
- ✓ Increase in the sliding time, sliding speed, applied loading, and sliding over very long distances, reduce wear rate. Thus, maintaining an appropriate sliding speed and normal applied load levels can reduce co-efficient of friction, i.e., frictional force, wear and improve the mechanical properties.
- ✓ SiC improves the elevated or high temperature strength and hardness of the alloy.
- ✓ Furthermore, SiC particles in the matrix act as pinning points to hold the wear debris particles on the wear surface, and due to this some of the debris get accumulated around these SiC particles. All these facts result in less wear in the Al-SiC composite.

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