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Analysis of Wear Resistance, Cracks and Hardness of Metal Matrix Composites with SiC Additives and Al_2O_3 as Reinforcement

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Abstract

Objective: In modern manufacturing technology, now a day's metal matrix composites are being increasingly identified as new wear resistant material. The main purpose of this article is to investigate the wear down and depth of indentation of the composite material of Al-6061 alloy strengthened with silicon carbide particulate and supported with alumina particulate constructed by stir casting method. **Method/Analysis:** The wear down rate and frictional properties of the composite were learned by using the dry sliding wear test with a pin on disk wear tester. The investigation was carried out with 1750 meters of sliding distance and 1.55m/s of stable sliding velocity over different loads by 10N and 20N for aluminium metal matrix composite. **Findings:** The testing result indicated that the wear resistance increases when there is increase in the load as well as in the sliding distance. Additionally an effort was made by keeping 7% of Al_2O_3 constant along with increase in 10, 15 and 20% of SiC. It was observed that, the strengthened aluminium metal matrix in addition of SiC and Al_2O_3 decreases the range of wear rate. Also found that the coefficient of friction increased by means of raising the load and quantum of reinforcement. **Application/Improvements:** By using scanning electron microscope the wear surfaces were examined and it was observed that the micro and transverse cracks, mild and severe wear occurred in the composite worn surfaces and wear structure of the composite.

Keywords: Al-6061Alloy, Hardness, Hybrid Composite, Stir Casting, SEM, Wear & Crack

1. Introduction

In last two decades, a broader effort and attention has been given towards the improvement of Aluminium Metal Matrix Composites (AMMC). AMMC are one of the advanced engineering materials that has been developed for load critical practices in aeronautics and in recent times in an automotive manufacturing industries on account of their outstanding amalgamation of high specific strength, lightweight, better corrosion and wear resistance[1-3]. Wear behavior may be detected in many automotive subassemblies like brake, gears, valves, cams, bearings, clutches and other applications involving sliding or rolling contact[4]. In addition aluminum based composites become breakable with addition of reinforcement ceramic particles such as Silicon Carbide (SiC) and Alumina (Al_2O_3). The reinforcement particles having effect on the wear and mechanical properties were identified as SiC and Al_2O_3[5-8]. Stir casting process (SCP) presents best bonding particle of metal matrix because of stirring performance of particles into the melts. The latest research investigation states that the good wetting and standardized mixing can be accomplished by choosing proper procedure constraints such as stirring speed, time, temperature of molten metal, preheating temperature of mould and consistent amalgamate of particles[9-11]. Among the production processes, the conventional stir casting is an attractive processing method for making hybrid metal matrix composites as it is relatively inexpensive and offers a wide selection of materials and processing conditions[12-14]. In order to enhance the stiffness, strength, wear, fatigue, corrosion and eminent temperature resistance

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normally in the majority of cases hard ceramic particulates like alumina, zirconia and silicon carbide introduced into aluminum based matrix[15,16]. Between these reinforcements silicon carbide is well-matched with Al and shape a sufficient tie with metal matrix and without raising the inter-metallic stage.

Furthermore, it has similar advantages like good machinability, workability, excellent thermal conductivity and low cost[17-20]. Fabricated Al matrix compound armored with boron carbide and silicon carbide particles through the similar route and under the identical conditions so as to evaluate the result of reinforcement group on the tensile properties of the composites. The composite with 2% by weight Al_2O_3 obsessed a hardness values and tensile strength 123Hv and of 505 MPa over that of unreinforced metal matrix alloy was found and also boosted wear resistance in case of composite[21,22]. Fabricated Al-2024/Al_2O_3 powders composite were studied with its mechanical properties and the result exposed that the tensile strength and hardness value of the prepared compound enhances with enhance in the weight percentage of the reinforcement[23-27]. The silicon carbide hardness value is higher than TiB_2 composite specimen. The expected TiB_2 hardness value is increase in contrast. This reduction in hardness value for TiB_2 content specifies a decrease in the indentation work[28,29]. From the above study, a challenge was made to investigate the effectiveness of the composite material. To calculate the effectiveness and the characteristics of the composite material, which had been strengthened by two different materials like SiC and alumina prepared by the stir casting method we had used the pin on disk wear tester and the Rockwell hardness testing machine. The microstructures of the specimen were studied for the particle sharing and the worn surfaces of the prepared sample by Scanning Electron Microscope (SEM).

2. Experimental Method

Stir casting process has been in use for several years for preparing asymmetrical particle of strengthened metal matrix composites[30]. In this process exact property enrichment such as improving the material's toughness or flexibility in a specific area in the material microstructure using a rotary tool with a pin and a shoulder to a single piece of material could be prepared. The Al-6061 composite reinforced through 10, 15 and 20 wt. % of silicon carbide with 7 wt. % of alumina. For this experiment, One kilo gram of Al-6061 alloy was heated at a temperature of 700°C using graphite crucible. Preheated stirrer was inserted in the melt as the melting temperature reached about 30°C higher than the pouring temperature. The experimental setup for the preparation of sample is shown in figure 1.

As we started the agitation of the melt, particles of SiC which had been preheated at 200°C were fed in 10, 15 and 20 wt% and also by adding Al_2O_3 at 7wt%. Using a spiral shaped stirrer attached to a motor, for about 5 minutes time the above mixture was stirred at 350 rpm and at a temperature of 800°C. During the stirring process we could observe the splitting of the melted aluminium alloy into droplets on account of the existence of Al_2O_3 as well as due to the shearing movement of the impeller. After making sure that we had got proper mixing and slurry by continuously stirring, the same was poured into preheated steel moulds from which specimens were prepared for testing of the composites thus derived for its hardness and wearing.

3. Results and Discussion

3.1 Hardness Test

Rockwell hardness testing machine was used to measure the hardness value of the prepared sample as per ASTM standards. The effects of alumina and silicon carbide on the hardness values of the prepared sample attained from hardness test are given in the following figure 2. The

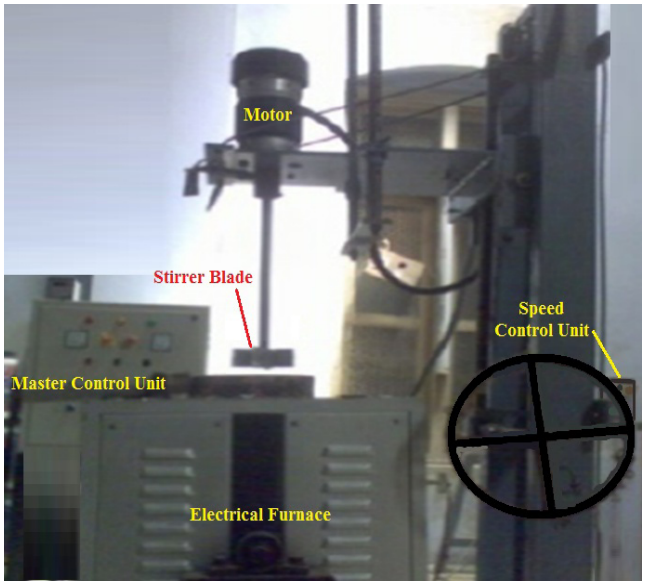


Figure 1. Experimental setup of stir casting process.

following graphical version has shown the results of 10, 15 and 20 wt. % of SiC along with 7wt. % of alumina and also the hardness value for each wt. percentage of SiC. From the outcome it was found that the hardness value of Al-6061/SiC/Al_2O_3 increases from 40 to 52 along with specified SiC.

3.2 SEM Test

By using SEM (HITACHI-3000N), the morphologies of the prepared samples were investigated along with different amplifications and the worn surfaces of hybrid composites as shown in figure 3 were found indicating the levels of abrasion and delamination wear mechanisms existing in these composites. Surface damage with cracks

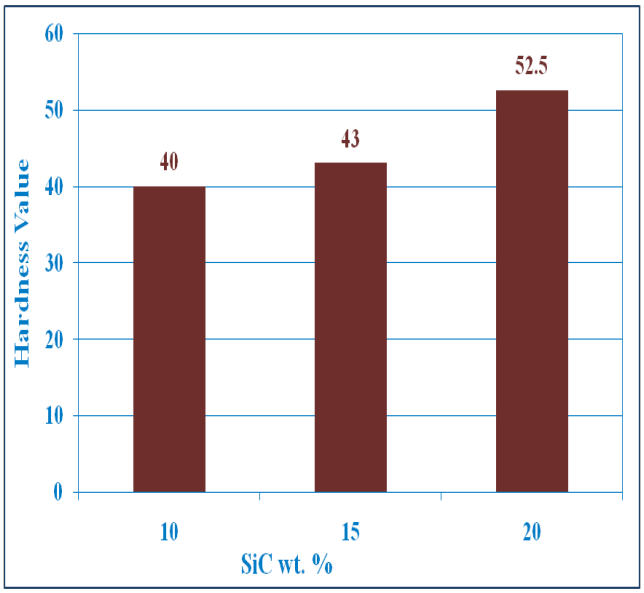
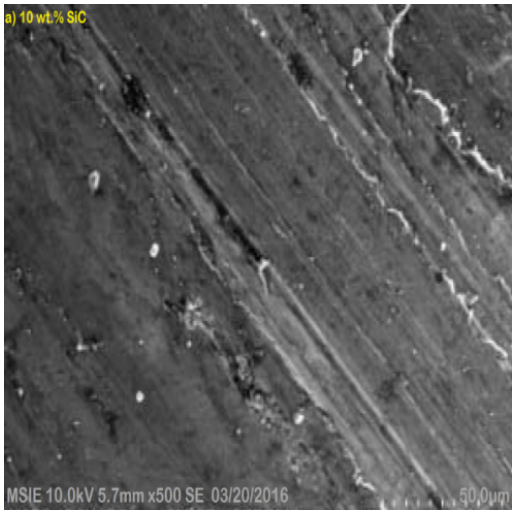
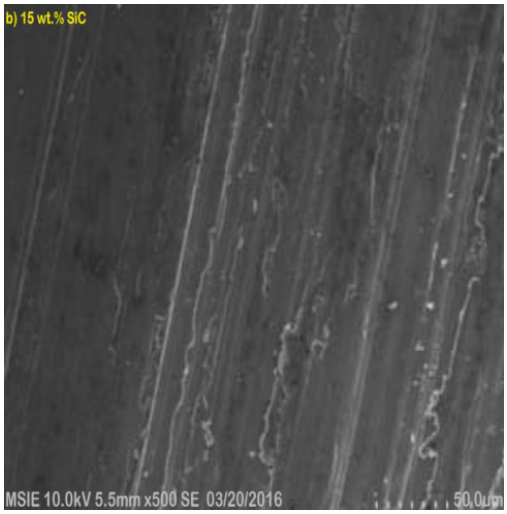


Figure 2. Hardness values of hybrid composites.





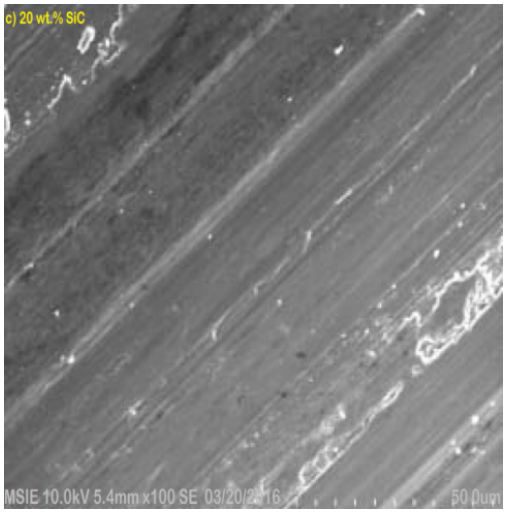


Figure 3. SEM Images of worn surfaces for hybrid composites.

and small cavities with distinct grooves were seen as shown in figure 3(a) in addition to decohesion and detachment of the material on the worn surface of Al-6061/10wt. % SiC/7wt. % Al_2O_3 hybrid composite.

A skinny rich tribo film was seen to be formed from the smeared graphite particles which helps in preventing direct metal contract thereby indicating that the wear rate depends on the available graphite film layer that could well serve as a protective layer which in turn prevents the breaking of hard SiC particles finally resulting in less surface damage and delamination wear in limited regions.

From figure 3(b) and 3(c) which shows worn surfaces of Al-6061 with 15 and 20wt. % of SiC and 7wt. % of Al_2O_3, it can be seen that plastic deformation of matrix can be prevented with the presence of SiC acting as a barrier to

moment of dislocation and creating more wear resistance than base alloy with mild patches and grooves.

3.3 Wear Test

Wear test is an examination to forecast the wear performance and to study the wear mechanism. When three samples with different propositions were studied, it could be seen that there is a significant increase in the wear resistance when reinforcement particles are added i.e. 0.013 to 0.004 with 10N and 0.014 to 0.0055 with 20N by increasing the wt. % of SiC fraction[31]. The observed results are shown in figure 4.

Figure 5 shows the graphical illustration of specific wear rate, which is defined as the volume of material worn per unit applied usual weight as a role of wt. % SiC for various applied loads. This is possibly by reason of the work hardening practiced with alloy and composites at maximum loads during the wear testing which develop the load bearing capacity and consequently report better wear resistance. The decrease on specific wear rate occurs from 1.49 to 0.5 for 10N and 2.6 to 0.75 for 20N when the amount of wt. % of SiC reinforcement increases from 10 to 20 for all applied normal loads. The strengthening amount increases while the specific wear rate is decreases in higher loads, but the difference is a smaller amount as compared to lower loads.

The effect on friction coefficient of Al-6061/wt. % SiC /wt. % Al_2O_3 metal matrix composite is given in figure 6. The above graph exposed that, the occurrence of SiC in

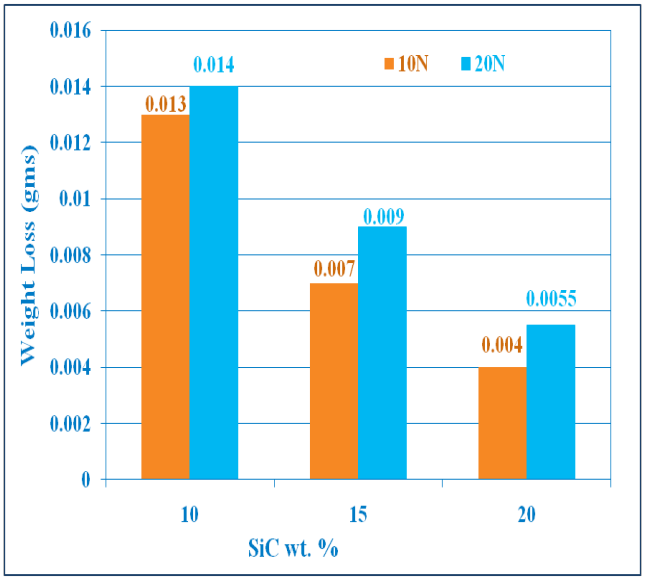


Figure 4. Wear rates for Al-6061/SiC/Al_2O_3 hybrid composites.

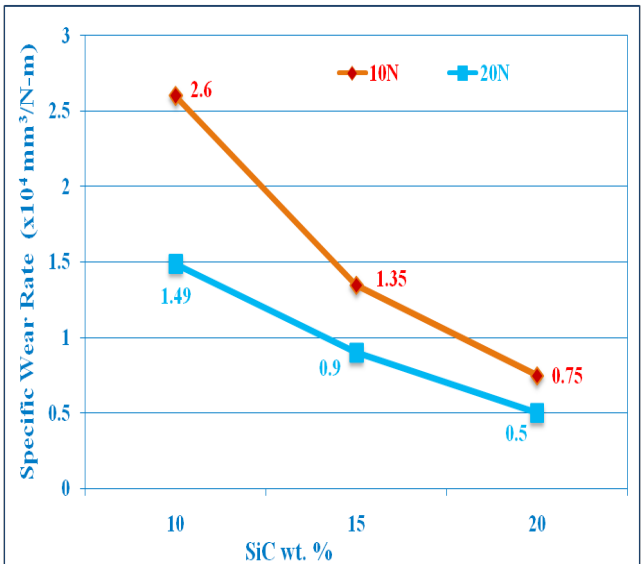


Figure 5. Specific wear rates for Al-6061/SiC/Al_2O_3 hybrid composites.

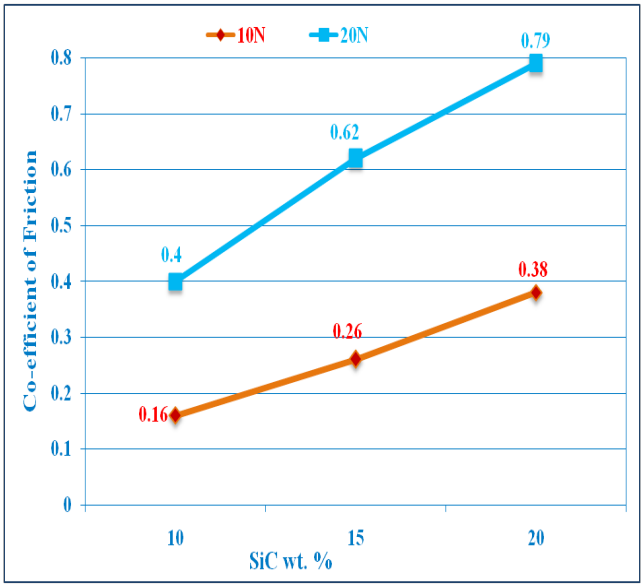


Figure 6. Coefficient of friction for Al-6061/SiC/Al_2O_3 hybrid composites.

the prepared sample increases the coefficient of friction and also it enhances from 0.16 to 0.38 for 10N and 0.4 to 0.79 for 20N with enhance during 10 to 20 wt. % of SiC content.

4. Conclusions

The required composite for testing was prepared using stir casting method. Based on the analysis and testing the following conclusions were made.

- The hardness test of the metal matrix composites exposed that Al-6061/20wt. % of SiC has higher hardness value than Al-6061/10wt. % of SiC.
- The hardness value increases from 40 to 52.5 in hybrid composites by means of increasing the wt. % of SiC from 10 to 20% and also the value was higher when compared to base alloy in every composition.
- Through SEM, it was found that there were micro and transverse cracks, mild and severe wear on the worn surfaces and wear structure of composite.
- It was observed that, as compared with base alloy we could increase the wear resistance with the availability of SiC performing as a fence to the movement of displacement.
- The wear rate is occupied by various factors in the load of 10N and 20N, sliding speed of 500 rpm and sliding distance of 1750 meters. It was also seen that the wear rate increases in direct proportion to increase in the sliding distance.
- When it was pursued through applied load and sliding speed for Al-6061/20wt. % SiC, we could see that the SiC particulate and alumina enlarges the composite wear resistance by forming a protective layer among pin and counter face.

Future research may be viable for the above categories of composites, since it is a mammoth region in engineering and technical.

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