Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 4, Issue 5; October-December, 2017, pp. 257-260
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http://www.krishisanskriti.org/Publication.html

Effect of Nano Boron Carbide Reinforcement on Wear behavior of ADC 12 and Al 7075 Metal Matrix Composites

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Abstract—*The aluminum metal matrix composites are a prime interest of researchers in metal industries; this is due to its light weight of aluminum and added property of the reinforcement. This research focuses on fabricating aluminum 7075 and ADC 12 - Boron carbide composite with varying percentages of B_4C. Both the composites were incorporated with 400 mesh size B_4C nanoparticles and a comparison of wear properties was done. The experiment performed by Pin-on-Disc method with different applied loads, sliding velocities, and sliding distances. This analysis can be used to replace the monolithic aluminum parts having high wear with the Aluminum Metal Matrix Composites with better wear properties.*

Keywords*: Al-7075 alloy; ADC12; B_4C; Dry sliding wear*

1. INTRODUCTION

Aluminum being a lighter in weight, high strength-to-weight ratio, good formability, good corrosion resistance, and recycling potential make it the ideal candidate to replace heavier materials (steel or copper) is being widely used in the automobile industry, but due to its lesser wear resistant properties and low seizure, aluminum cannot be used directly. [1]

Due to these properties, AMMC's are widely being used in aerospace applications, satellites, jet engines, missiles. The most important commercial application to date is the MMC diesel engine piston made by Toyota. This composite piston offers better wear resistance and high-temperature strength than the cast iron piston it replaced. It is estimated that300,000 such pistons are produced and sold in Japan annually. This development is very important because it demonstrates that MMCs are at least not prohibitively expensive for a very cost sensitive application. [2]

At the same time, if we talk about economy of AMC's the cost of particulate reinforcement type AMC's have costs comparable to monolithic materials but with better properties. While, the AMC's with continuous type of reinforcements may have a higher manufacturing costs. [2]

Aluminum Metal Matrix Composites (AMMCs) gained importance due to their enhanced tribological properties that replaces their monolithic counterparts primarily in automotive, aerospace and energy applications. Their resistance to wear added with strength and modulus characteristics made them crucial for many engineering situations, where sliding contact can be expected. Besides the work on abrasive wear behavior, an extensive review on dry sliding wear characteristics of aluminum alloy based composites was carried out [3-7]. And this review came to a conclusion -

Boron carbide is considered to be a favorable reinforcement because of its low density (2.52 g/cm^3), very high hardness, high strength and better chemical stability makes it one of the suitable reinforcement and a good substitute to other reinforcements like silicon carbide (SiC) and Aluminum Oxide (Al_2O_3).

It has seen that on addition of SiC and Gr to the Al359 alloy improves the wear properties of the Al359 alloy. The wear of the Al359-SiC composite is considerably decreased with increase in load and speed up to 1.5 m/s at 2000 m sliding distance. [8-9]

Extensive researches has been conducted on Aluminum Matrix composites but there were very limited which compared the Alloys of Aluminum with the Boron carbide reinforcement for their tribological properties [10-12]. This works aims to fabricate AMMC's (Al-7075 and ADC-12) with particulate Boron carbide reinforcement and compare their wear properties.

2. MATERIALS AND METHODS

Aluminum- 7075 and ADC-12 (also known as LM 2) with different percentages of particulate reinforcement were fabricated using stir casting method. These alloys were chosen for the study because of their wide utility in automobile industryAl-7075 has their wide utility in aerospace components, rock climbing equipment and hang glider airframes. While, ADC-12 is widely being used in casting parts of automobiles.

Due to low density of Boron carbide, the stir casting method can produce fine composites as the chances of wettability issues were reduced. The boron carbide used in this experiment was of mesh size- 400. The reinforcement was also pre heated as an attempt to remove any moisture or volatile impurities in the particulate matter.

The samples fabricated had 2% and 3.5% of particulate reinforcement by weight. This composition was chosen for both the materials. The samples were stirred mechanically for 15 minutes using a steel stirrer to obtain a homogenous mixture. The temperature for the reaction was 850 degree Celsius. After obtaining the samples from the Metal Die, the samples were machined and were reduced in form of pins according to the standard (10mm diameter) of Pin-on-disc type tribometer. Before considering pins for the test, the end surfaces of the specimens were polished using abrasive paper of grade 600 followed by 1000 and 1500 to obtain a similar surface finish for every sample. The tests were conducted according to the ASTM G99-95a test standards for 960m sliding distance and a constant sliding velocity- 2m/s with the load of 30N applied.

Fig 1 Pin Samples

3. ABRASIVE WEAR

The cast was machined into cylindrical pins with flat surfaces with 10mm diameter. These pins were tested for the wear using Pin-on-disc type tribimeter under dry sliding motion.The wear of the pins were examined using a Linear Variable Differential Transducer (LVDT) which is attached with lever of the machine. The applied load subjects the pin to make contact with disc. Wear mechanism of pin surface leads to the very small change in the length of the pin, thus displacing the lever for a very small length. This displacement in the lever arm acts as input to LVDT for measuring the respective wear.

The coefficient of friction between the pin samples and the rotating disc was measured using friction sensors. The coefficient of friction was measured after regular intervals and was noted. Average of those values gives the fair estimation of coefficient of friction.

The above image indicates the morphology of the composite pins after the wear test was conducted, the wear tracks and surface delimation is clearly visible in the image the wear track observed indicated the abrasive wear mechanism. Due to high friction and temperature only oxide wear was seen. [13]

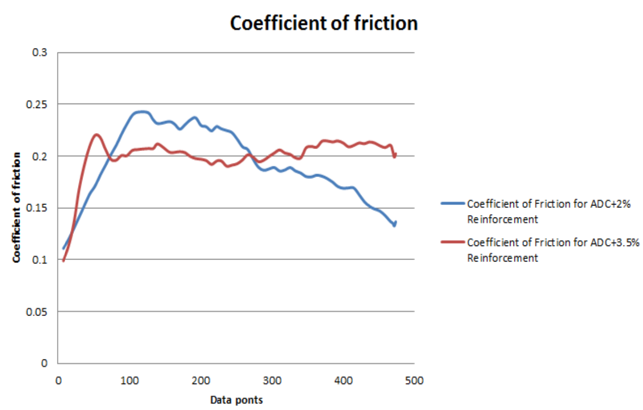

Fig. 2 Coefficient of friction

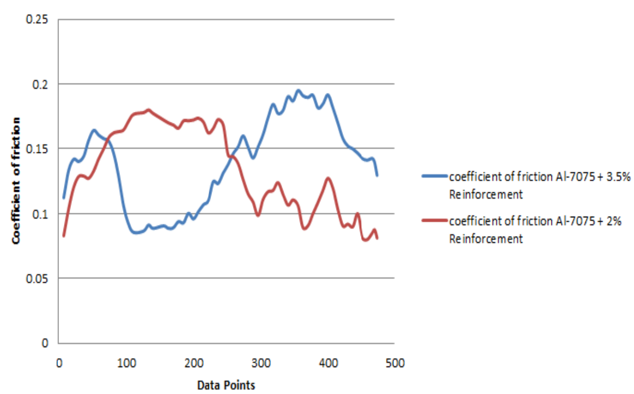

Fig. 3 Coefficient of friction

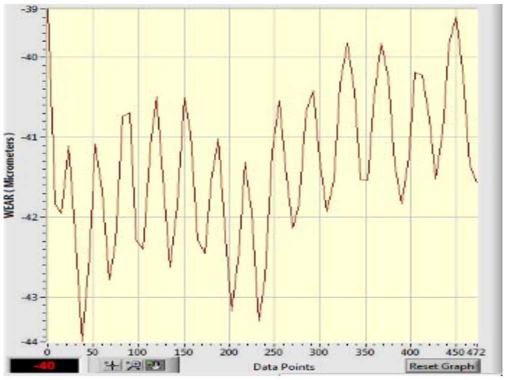

Fig.4 Wear of ADC-12+2%Boron carbide

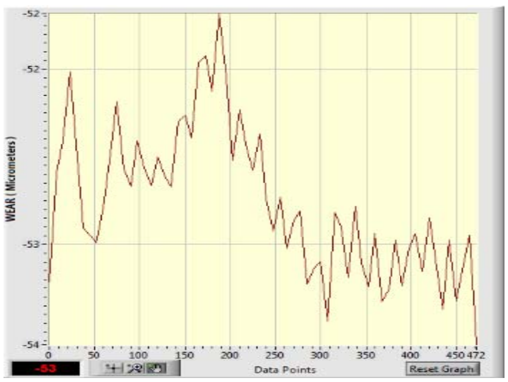

Fig. 5 Wear of ADC+3.5% Boron carbide

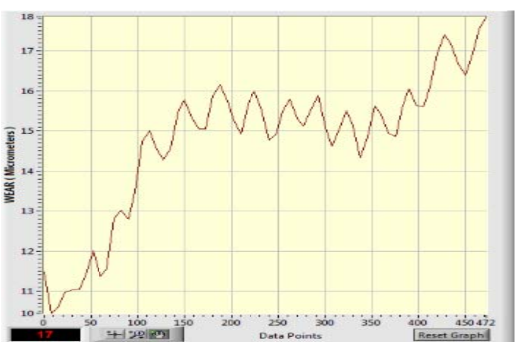

Fig. 6 Wear of Al-7075+2% Boron carbide

Fig. 7: Wear of Al-7075+3.5% Boron Carbide.

4. RESULTS

Designation of the composite formed is mentioned in the below table. The designation is assigned for the purpose of ease. in present work composite has been formed with compositions as- ADC2, ADC3.5, Al2 and Al3.5.

Sample	Material
A2	ADC12+2%B_4C
A3.5	ADC12+3.5%B_4C
Al2	Al-7075+2%B_4C
Al3.5	Al-7075+3.5%B_4C

**A-represents ADC, Al-represents Al7075follwed by the number which represents % of B4C addition.

5. EFFECT ON WEAR

1) A2 showed an increasing trend of wear while one with A3.5showed the overall decrease in the wear. (**Figure 4 and Figure 5**)
2) Al2 showed an increase in wear rate while one with Al3.5 also showed an increase but with a decreasing rate. (**Figure 6 and Figure 7**)

6. COEFFICIENT OF FRICTION

ADC-12+2% showed a first increase and then decrease but it lied between 0.13-0.23. While the one with 3.5% showed an almost similar coefficient throughout (nearly 0.2) as shown in **Figure 2.** The coefficient of friction first found decreases due to the presence of hard boron carbide material in the composite.Al-7075+3.5% showed an overall increasing trend ranging between (0.13-0.18).While the one with 2% showed coefficient ranging between (0.8-0.165).shown in fig3.

7. CONCLUSION

In this work of Processing and evaluation of Al7025-B4C metal matrix composite by stir casting method has led to following conclusions

- The composites of ADC-12(2%B_4C) showed a reducing trend in the coefficient of friction while with increased percentage (3.5%+B_4C) showed a similar friction coefficient throughout the run.(0.2) so, increasing percentage of boron carbide can give better wear properties.
- While that of Al-7075 (2% B_4C) showed an increasing trend in the start followed by a decrease but overall the friction coefficient was seen to be increased with the increase in percentage.

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