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Wear and Mechanical Property Evaluation of Aluminum-silica Composites

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ABSTRACT

In this study, Al alloy LM13-SiO_2 composites were produced by stir casting method using SiO_2 powder as reinforced particles with 150 μ average diameter and Al alloy as the matrix metal. The melt composites were stirred and then cast into a metallic mold. Different samples of 3, 6, 9, and 12 wt.% of SiO_2 were produced. The casted composite specimens were machined as per ASTM test standards. Effects of wt.% of SiO_2 particles on wear, tensile strength, and hardness of Al alloy LM13-SiO_2 composites have been investigated. The microstructures of the composites were studied to know the dispersion of the SiO_2 particles in the matrix. The highest tensile strength was achieved in the specimen containing 12 wt.% of SiO_2, in comparison to the unreinforced Al alloy. It has been observed that addition of SiO_2 particles significantly improves wear resistance, tensile strength, and hardness properties as compared with that of the unreinforced matrix.

Key words: *SiO_2 particles, Al alloy composite, Mechanical and wear properties, Stir casting.*

I. INTRODUCTION

Industrial technology is growing at a very rapid rate, and consequently, there is an increasing demand and need for new materials. Particulate reinforced composites constitute a large portion of these new advanced materials. The choice of the processing method depends on the property requirements, cost factor consideration, and future applications prospects [1].

Metal matrix composite (MMC) is engineered combination of the metal (matrix) and hard particle/ceramic (reinforcement) to get tailored properties. MMCs are either in use or prototyping for the space shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs, and a variety of other applications [2]. MMCs possess significantly improved properties including high specific strength, specific modulus, damping capacity, and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low-cost reinforcements [3-6].

Particulate reinforced aluminum matrix composites are attractive materials due to their strength, ductility, and toughness. Their ability to be produced by conventional methods adds to the advantage. The aluminum matrix can be strengthened by reinforcing with hard ceramic particles such as SiC, Al_2O_3, and SiO_2. Judicious selection of the variables is important to optimize the properties of composites. The shape and size of reinforcement particles and matrix composition have to be carefully chosen [7-8].

A significant improvement in the properties of Al alloys reduced fuel consumption because of light weight, and hence, it has made huge demand from the automobile industry. This growing requirement of materials with high specific mechanical properties with weight savings has fuelled significant research activities in recent times targeted primarily for further development of Al-based composites [9,10]. In this article, Al alloy LM13-SiO_2 MMCs have been prepared by liquid metallurgy method by varying the amount of reinforcements and were characterized.

2. MATERIALS AND METHODS

The following section highlights the material, its properties, and methods of composite preparation and testing. The matrix material for this study is Al alloy LM13. Table 1 gives the chemical composition of Al alloy LM13. Table 2 gives the details of the physical and mechanical properties of Al alloy LM13 and SiO_2 the reinforcing material selected was SiO_2 of particle size 150 μ.

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2.1. Preparation of Composites

The materials used in this work are aluminum LM13 alloy for the matrix and SiO_2 of 150 μm as particulates with different percentages (in wt.% 3, 6, 9, and 12) based on the variation in volume fraction. The tensile test specimens of SiO_2 particulate reinforced LM13 alloy composites used here is prepared according to ASTM standards. The toughness and formability of aluminum - 12% silicon alloy can be combined with the strength of quartz particles. Cast iron permanent mold is used for processing composite castings. The composition and properties of LM13 are shown in the Tables 1 and 2. LM13 alloy is actually a eutectic alloy having the lowest melting point that can be seen from the Al-Si phase diagram. The main composition of LM13 is about 85.95% of aluminum, 12-13% of silicon. Quartz is a hard mineral and provides excellent hardness on incorporation into the soft lead-alloy, thereby making it better suited for applications where hardness is desirable.

2.2. Testing of Composites

The cast composites were machined, and the specimen for the measurement of hardness, mechanical as well as for wear was prepared as per the ASTM standards. Micro Vickers hardness tester was used to measure the hardness. The mechanical properties were evaluated in BISS, Bengaluru, Karnataka, India. Wear properties were evaluated using pin-on-disc wear testing machine.

Table 1: Chemical composition of Al alloy LM13 by wt.%.

Elements	Zn	Mg	Si	Ni	Fe	Mn	Al
Wt.%	0.5	1.4	12	1.5	1.0	0.5	Balance

Table 2: Physical and mechanical properties of Al alloy LM13 and ZrO_2.

Properties	Al alloy LM13	SiO_2
UTS (MPa)	220	25
Density (g/cc)	2.7	2.65
Melting temperature (°C)	695	1830

Table 3: Tensile strength.

Wt.% of silica	Tensile strength (MPa)
3	170.888
6	182.359
9	190.461
12	216.418

Table 4: Hardness values.

Wt.% of silica	Hardness (VHN)
3	143
6	168
9	193
12	161

VHN=Vickers hardness number

3. RESULTS

3.1. Microstructure

The microstructure of Al-Si (LM13) alloy, in as-cast condition, shows the dendrites of aluminum and eutectic silicon in the interdendritic regions and around the dendrites. The micrograph of LM13 with 3-12 wt.% silica composite, in as-cast condition, shows a uniform distribution of silica particles in the aluminum matrix. Figure 1 shows the microstructural observation of prepared composites.

3.2. Tensile Strength

The results obtained from tensile test for prepared composite are tabulated in Table 3. The value of tensile strength and % of SiO_2 is shown in Figure 2. The tensile strength increased with increased wt.% of SiO_2. Because the increase in the percent of closed pores with increasing SiO_2 particulate content would create more sites for crack initiation and hence lower

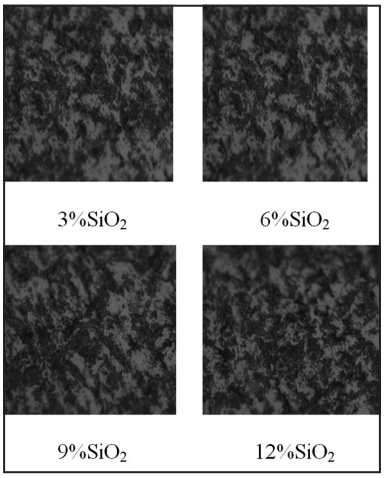

Figure 1: Optical photomicrograph of Al alloy LM13-silica of 150 μm at resolution ×100.

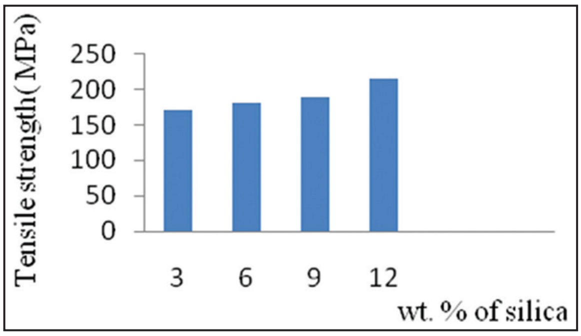

Figure 2: Tensile strength versus wt.% of silica.

down the load bearing capacity of the composite. Besides, if the number of contacts between SiO_2 particulate increases, then the particles is no longer isolated by the ductile aluminum alloy matrix.

3.3. Micro Vickers Hardness

The results obtained from vicker hardness test for prepared composite are tabulated in Table 4. Hardness tests were performed on Al alloy LM13-SiO_2 composites to know the effect of silica in the matrix material. The polished specimens were tested using Vickers microhardness testing system. A load of 50 g for 10 s was applied on specimens. The hardness was determined by recording the diagonal lengths of indentation produced. The test was carried out at three different locations, and the average value was taken as the hardness of the as cast and composite specimens. Figure 3 shows the results of microhardness test on as cast Al LM13 alloy and composite containing different wt.% of silica in it. From the Figure 3, it is evident that the hardness of the composite material is much higher than that of its parent metal. It is also shown that the hardness of the composite material increases with wt.% of silica content. This may be because of addition of silica makes the ductile Al LM13 alloy more brittle. Furthermore, the dispersion of silica particles enhances the hardness, as particles are harder than Al6061 alloy, and render their inherent property of hardness to the soft matrix.

3.4. Wear Results

Wear, the progressive damage and material loss, occurs on the surface of a component as a result of its motion relative to the adjacent working parts. Sliding wear behavior of Al-SiO_2 alloys depends on the microstructure and material related mechanical properties, in addition to load, speed, sliding distance, temperature, environment, and counter face.

3.4.1. Effect of load

The effects of sliding speed on the wear rate of LM13 alloy under constant normal load (1 kgf). From the Figure 4, it is clear that the wear rate of LM13 alloy increases with increase in sliding speeds (400, 500, and 600 rpm). The increase in wear with the increase in sliding speed may be possibly due to the increased contamination of sliding interface by oxide layer called glaze.

3.4.2. Effect of sliding speed

The effect of load on volumetric wear of LM13 alloy under constant sliding speed (500 rpm) and at constant sliding distances (1000 m). From Figure 5, it is clear that the weight loss of LM13 alloy increases with increase in load in all the cases studied and the wear was higher in the case of untreated pure Al, i.e. addition of intermetallic alloys show less volumetric wear as compared to the absence of grain refiner.

3.4.3. Effect of sliding distance

The effect of sliding distance on weight loss of reinforced LM13 alloy under constant normal load (1 kgf), it is known that with increasing sliding distance, wear also increases due to more intimate contact between the contact surfaces of the specimen and with the rotating disc. However, less wear was observed in case of the reinforced alloy; it is clear that the weight loss increases with increasing sliding distance in all the cases (800, 1000, and 1200 m) is shown in Figure 6. Such increase in wear rate could be possibly because wear loss is directly proportional to the sliding distance.

4. CONCLUSIONS

The significant conclusions of the studies on Al alloy LM13-Silica MMCs are as follows.

1. Stir casting method was successfully adopted in the preparation of Al alloy LM13-silica composites.

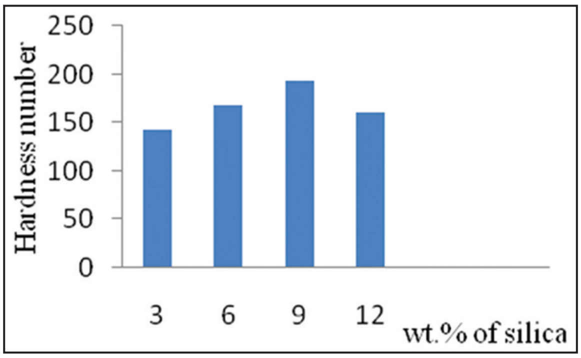

Figure 3: Hardness versus wt.% of silica.

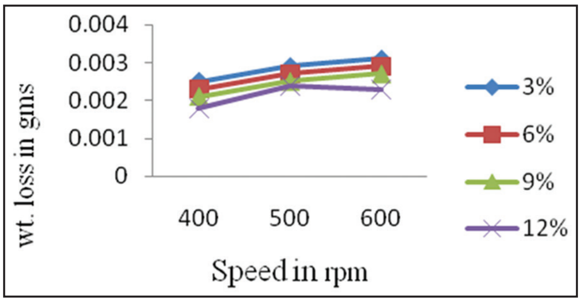

Figure 4: Weight loss versus speed at constant load (1 kgf) and sliding distance (1000 m).

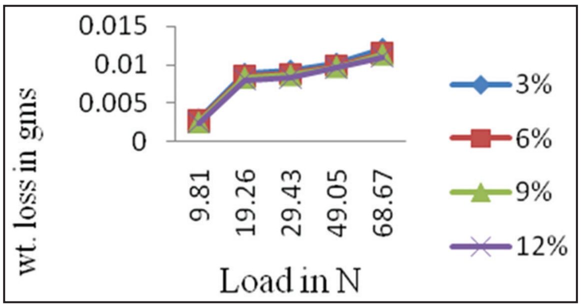

Figure 5: Weight loss versus load at constant sliding distance (1000 m) and speed (500 rpm).

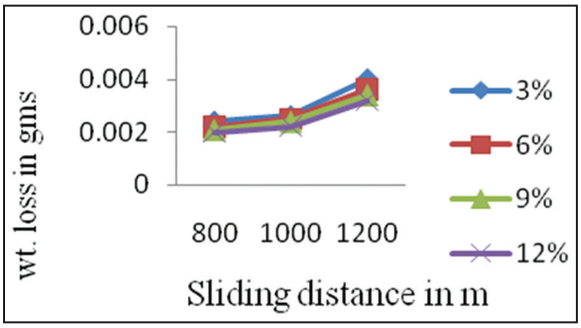

Figure 6: Weight loss versus sliding distance at constant load (1 kgf) and speed (500 rpm).

2. Wear of Al-SiO_2 alloys strongly depend on alloy composition and decreases with increasing alloy content.
3. The wear properties are considerably improved by the addition of intermetallic particles of SiO_2 particulates, and the wear resistance of these reinforce alloys also increases with decrease in the grain size.
4. The microstructural studies revealed the uniform distribution of the particles in the matrix.
5. Tensile strength is increased up to 12 wt.% of silica.
6. Hardness of the composites found increased with increased wt.% of 9 of silica after that decreased.
7. Finally, it can be concluded that Al alloy LM13-silica exhibits superior wear and mechanical properties.

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***Bibliographical Sketch**

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