

Wear behavior of AL6063-Alumina Metal Matrix Composite

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Abstract: Aluminium alloys are becoming increasingly important, especially in the automotive and aerospace industries. However, these materials tend to have poor wear resistance during working conditions. Aluminium oxide as reinforcement is potentially very effective in developing hard, wear-resistant composite materials. The aim of present study was to evaluate the wear behaviour of aluminium reinforced Al 6063 aluminium alloy matrix composite with various parameters by using pin-on-disc machine. The wear rate was decreased with increasing the Wt% of Aluminium oxide.

Keywords: Aluminium Alloy, Alumina, Stir casting, Wear test

1. Introduction

Aluminum and its alloys are desirable materials due to high strength stiffness to weight ratio, good formability, good corrosion resistance, and recycling potential for use in automobile industries as components of internal combustion engines, e.g., cylinder blocks, cylinder heads and pistons [6]. Metal matrix composites (MMCs), consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with either of the individual phases. Generally, there are two phases either a fibrous or particulate phase in a metallic matrix. For e.g. Al₂O₃ fiber reinforced in a copper matrix for superconducting magnets and SiC particle reinforced with in the Al matrix composites used in aerospace, automotive and thermal management applications.

Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In traffic engineering, especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and aluminium crank cases with strengthened cylinder surfaces as well as particle strengthened brake disks. These innovative materials open up unlimited possibilities for modern material science and development; the characteristics of MMCs can be designed into the material, custom-made, dependent on the application [4].

1.1 Aluminium as matrix

Aluminium is the most abundant metal in the Earth's crust, and the third most abundant element, after oxygen and silicon. It makes up about 8% by weight of the Earth's solid surface. The chief source of aluminium is bauxite ore. Its Atomic number is 13. Aluminium is a soft, durable, lightweight, ductile and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. Aluminium is nonmagnetic and non-sparking. Aluminium has

about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded. Corrosion resistance can be excellent due to a thin surface layer of aluminium oxide that forms when the metal is exposed to air, effectively preventing further oxidation [3].

1.2 Alumina as Reinforcement

The chemical formula of aluminium oxide is Al₂O₃. It is commonly referred to as alumina, or corundum in its crystalline form, as well as many other names, reflecting its wide spread occurrence in nature and industry. Alumina (Al₂O₃) is the most cost effective and widely used material in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes. With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications. Its most significant use is in the production of Aluminium metal, although it is also used as an abrasive due to its hardness and as a refractory material due to its high melting point [1].

The following are the characteristics of aluminium oxide:

- Hard and wear-resistant
- Resists strong acid and alkali attack at elevated temperatures
- Good thermal conductivity
- Excellent size and shape capability
- High strength and stiffness

2. Raw Materials

2.1 Aluminium alloy

Aluminium alloys are alloys in which Al is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc [2].

Table 1: Chemical Composition of Aluminium 6063 Alloy

Si	Fe	Cu	Mn	Mg	Cr
0.431	0.102%	0.0073%	0.029%	0.50%	0.0026 %
Ti	Ag	B	Be	Bi	Ca
0.013	<0.0001 %	<0.026%	<0.0001 %	<0.001%	0.0037 %
Na	Pb	Sn	Sr	V	Zr
0.0024	0.0086%	0.0026%	<0.0001 %	0.0079%	0.0010 %
Ni	Co	Cd	Zn	Li	Al
0.0036 %	<0.001%	<0.0001 %	0.0049%	<0.0002 %	98.8%

2.2 Alumina

The Alumina particle size ranges between 2 to 4 microns. They are used as reinforcement and are 99.99% chemically pure.

3. Experimental Setup

3.1 Processing of composite materials

Aluminium (6063) alloy matrix composites having 4 % & 8 % Al₂O₃ particles were produced. The alumina particles were initially preheated at a temperature of 250⁰C for 5 minutes to improve wettability with the Al (6063) alloy. The Al (6063) alloy ingots were charged into the crucible furnace and heated to a temperature of 800⁰C (above the liquidus temperature of the alloy). The preheated alumina was added slowly at the processing temperature and stirring of the slurry was performed for 5minutes.The stirring operation was performed at a speed of 600rpm for 10minutes to help the distribution of the alumina particles in the molten Al (6063) alloy. The molten composite was then cast into prepared

moulds. Al (6063) alloy without reinforcement was also prepared to study the effect of reinforcement of wear property.

The processing variables such as Speed of stirrer, Processing temperature, Pouring speed, Mould temperature, reinforcement feed rate, incubation time are have to be considered for developing a good composite.

Table 2: Samples of composite material

Samples	Al 6063	Al ₂ O ₃
1	100 %	0 %
2	96 %	4 %
3	92 %	8 %

3.2 Wear test

The amount of wear generated depends upon the applied load, sliding speed, sliding distance, material properties and environment. For getting reliable and repeatable wear data, contact between the wear disc and the specimen pin is to be 100% and virgin material of specimen pin is to be exposed to the wear disc. EN-31 steel disc has been used with hardness of 60HRC and the pin was prepared with the dimension of 8mm dia and 50 mm length as per ASTM G99-95 standards. The pins were tested against content load of 9.81N and varying velocities as follows 2.5m/s, 3m/s, 3.5m/s, 4m/s[5].

4. Result and Discussion

The wear samples prepared from the processed composite material were tested on pin-on-disc machine for different velocities and constant load of 2 kg.

Fig 1 shows the wear rate of Al 6063 alloy and its composite with 4 % Al₂O₃ + 8 % Al₂O₃ for a sliding velocity 2.5 m/s under load of 2kg. Wear resistance of composite material is higher than matrix material (Al 6063).

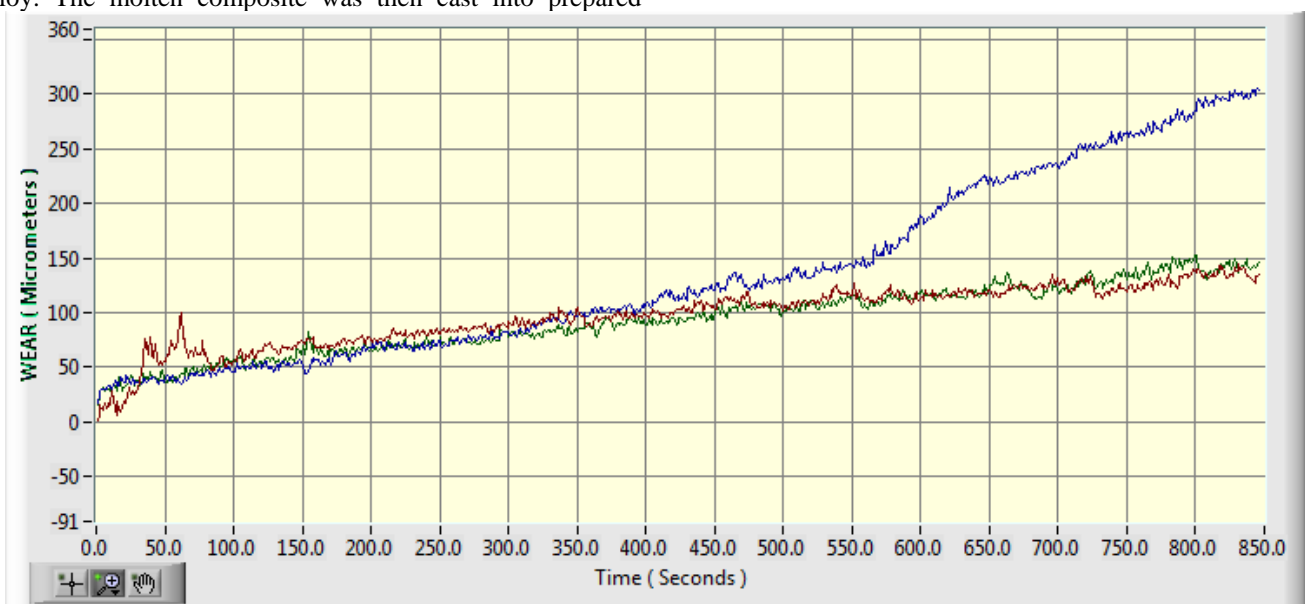


Figure 1: Al6063+0%Al₂O₃, Al6063+4% Al₂O₃, Al6063+8%Al₂O₃ at 2.5m/s sliding velocity

Figure 2 shows the wear rate of Al6063 alloy and its composites for a sliding velocity of 3 m/s. The wear resistances of both composites are almost same.

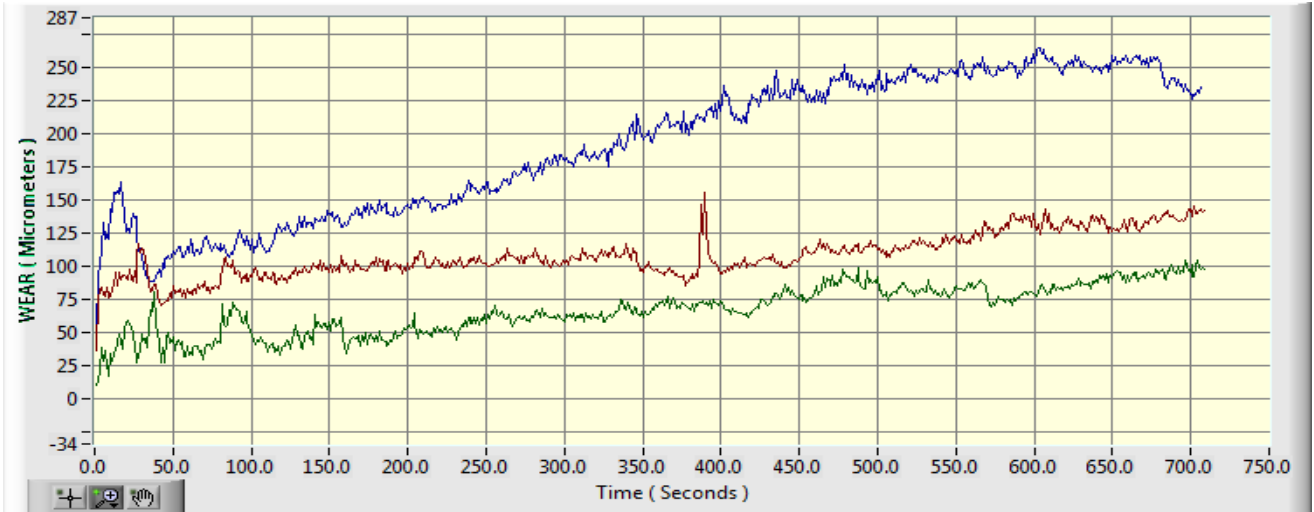


Figure 2: Al6063+0% Al₂O₃, Al6063+4% Al₂O₃, Al6063+8% Al₂O₃ at 3m/s sliding velocity

Figure 3 shows that the wear resistance increases as the reinforcement is added to the alloy.



Figure 3: Al6063+0% Al₂O₃, Al6063+4% Al₂O₃, Al6063+8% Al₂O₃ at 3.5m/s sliding velocity

Figure 3 shows the wear rate of Al6063 alloy and its composites 4 % and 8 % Al₂O₃ for a sliding distance of 4 m/s.

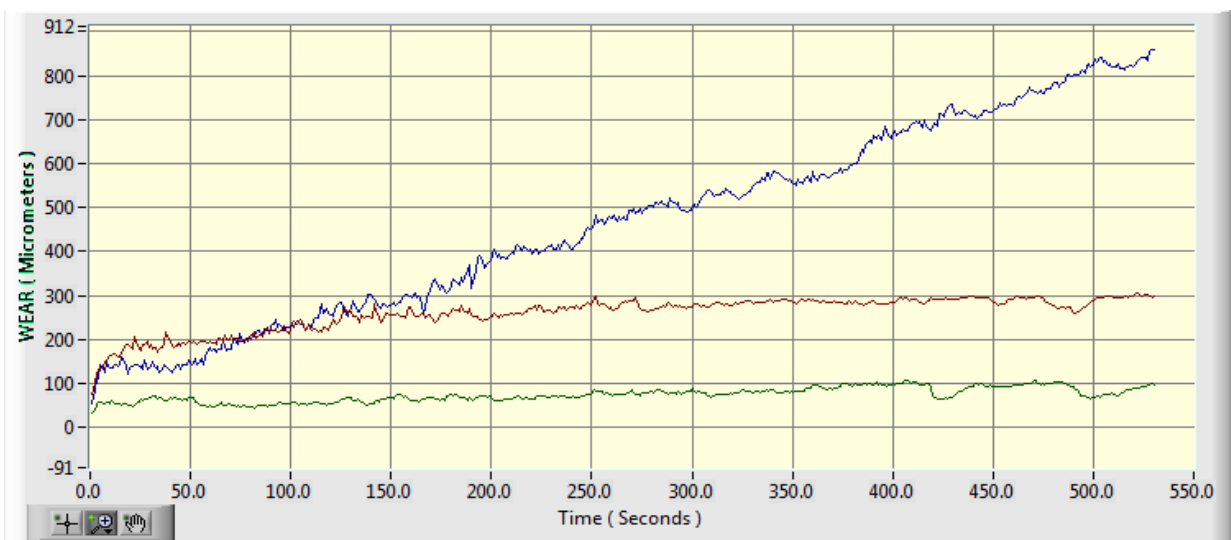


Figure 4: Al6063+0% Al₂O₃, Al6063+4% Al₂O₃, Al6063+8% Al₂O₃ at 4m/s sliding velocity

Finally it is concluded that, wear resistance has been improved for Al 6063 alloy by reinforcing with Al_2O_3 particles. Al 6063 alloy reinforced with 8 % Al_2O_3 particles is showing higher wear resistance for all the velocities tested under the constant load of 2kg.

5. Conclusion

Al 6063 alloy matrix composites reinforced with Alumina particles can be successfully synthesized by the stir casting method.

Wear behavior of Al6063 / Al_2O_3 MMC is tested using Pin-on-disk machine and is that found increasing the percentage of Alumina particles will reduce the wear rate.

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