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Fabrication and Performance of Aluminium Based Metal Matrix Composites with SiO_2 and TiO_2 as Reinforced Particles

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Abstract Aluminum alloys are used in automobile and aerospace industries because of their low density and good mechanical properties, better wear resistance as compared to conventional metals and their alloys. In these industries there is continues demand to develop light weight, inexpensive and strong material which has led to the development of aluminum alloy metal matrix composites with ceramics as reinforcement particles. In this present work, aluminum based metal matrix composites have been fabricated using SiO_2 and TiO_2 as reinforcement materials by stir casting process and wear behaviour, hardness and breaking load have been evaluated.

Keywords Composites, Stir Casting, Fabrication, Reinforcement, Wear

1. Introduction

In manufacturing industry there is continues demand to develop light weight, inexpensive and strong material. This demand has led to the development of aluminum alloy metal matrix composites [1]. In these composites hard ceramic particles are reinforced. These materials are having very good mechanical properties. It is very easy to fabricate the composite and these can be moulded to any shape and size easily than conventional materials [2]. Therefore these materials are considered as potential engineering material for various engineering applications such as automotive and aerospace applications [3]. In recent past many researchers have developed different metal matrix composites.

Idrisi and Deva [4] studied the development and testing of Metal matrix composite by reinforcement of SiC particles on Al alloy and investigated the mechanical properties.It was concluded that mechanical properties were increased by increasing the percentage of SiC. Density was also increased by ultrasonic probe assistance at particular reinforcement particle level. Das et al. [5] studied the properties of ceramic reinforcement aluminium matrix composites. There was increase in the density, hardness and toughness with increasing the reinforcement fraction. The compressive strength of ceramic was increased to increase in reinforcement fraction. Mazahery and Shabani [6] studied the Micro structural and abrasive wear properties of SiC reinforced Aluminium-based composite produced by compo casting. The test of Tribological done by using a pin-on-disc wear tester, under dry sliding condition and different loads. It was found that there was increase in wear resistance and hardness of the composite material. Milos et al. [7] studied the aluminium-based composite materials in construction of transport means and concluded that mechanical properties of the composites depends upon the size and weight percentage of graphite and Al_2O_3. Idrisi et al. [8] studied the development and testing of Al 5083 alloy reinforced by Sic particles. The result showed that with increase in weight percentage of SiC, there was increase in tensile strength and compressive strength. Senapati et al. [9] studied the extensive literature review on the usage of fly as a reinforcement agent for different matrix. Fly ash was used in molten metal and cast because it can reduce the overall weight and density due to low density of fly ash.

It is clear from literature review that these materials give good mechanical and wear properties than conventional materials. There is a future scope to fabricate new composite which improve these properties. Therefore in this work aluminum based composites are fabricated with stir casting process by using Silicon dioxide, titanium dioxide and combination of these, as reinforced particles and mechanical properties have been investigated.

2. Experimentation

In this research work, Aluminium alloy was melted in a crucible by heating in a muffle furnance at 800℃ for 3 to 4

hours. The Silicon oxide particles and titanium oxide particles were preheated at 1000℃ and 900℃ respectively for 1 to 3 hours to make their surface oxidized. The furnance temperature was first raised above the liquidus temperature of aluminium near about 750℃. To melt the aluminum alloy completely and was then cooled down just below the liquidus to keep the slurry in semi solid state. Automatic stirring was carried out with the help of radial drilling machine for about 10 minutes at stirring rate of 290 RPM. At this stage, the preheated silicon oxide particles and titanium oxide particles were added manually to the vortex. In the final mixing processes the furnance temperature was controlled within 700±10℃. After stirring process the mixture was pour in the other mould to get desired shape of specimen. The presence of reinforcement throughout the specimen was inspected by cutting the casting at different locations and under microscopic examination. Same process was used for specimens with different compositions of silicon oxide and titanium oxide. Composition of samples is shown in table 1.

Table 1. Composition of Composites

Composition				
Sample No.	Aluminium (gm)	SiO_2 (gm)	TiO_2 (gm)	Remarks
1	600	0	0	Weight of sample 550 gm
2	600	30	0	SiO_2 = 5%
3	600	60	0	SiO_2 = 10%
4	600	0	30	TiO_2= 5%
5	600	0	60	TiO_2= 10%
6	600	30	30	SiO_2 = 5% +TiO_2= 5%
7	600	60	60	SiO_2 = 10% + TiO_2= 10%

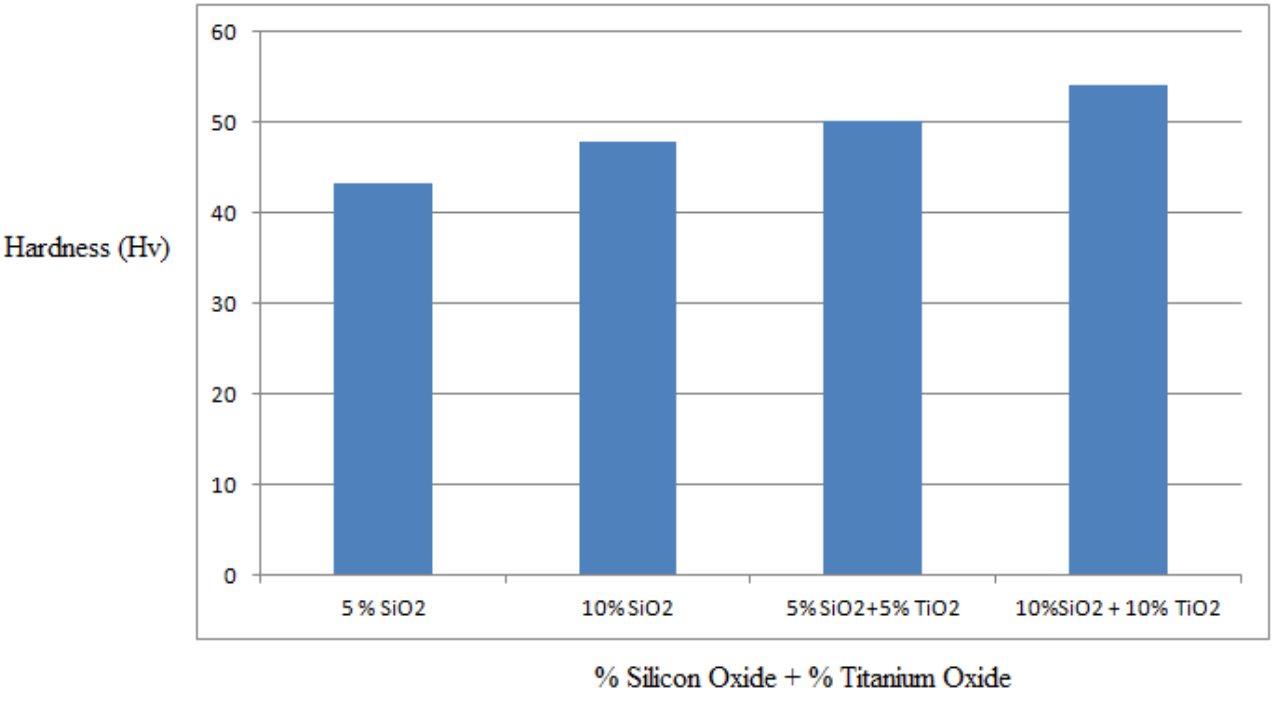

Figure 1. Comparison the hardness with wt. % variation of SiO_2+ TiO_2

3. Results and Discussion

3.1. Comparison of Hardness

Figure 1 shows the comparison of hardness of different composites with different proportions of reinforcement particles.

The figure 1 shows that incorporation of silicon oxide and titanium oxide particles in Aluminium matrix causes reasonable increase in hardness. .Thus, silicon oxide and titanium oxide in Al casting reduces cost, decreases density and increase hardness which are needed in various industries like automotive etc [10].

3.2. Wear Behaviour

3.2.1. Weight Loss of Al + SiO_2 and Al + SiO_2 +TiO_2 during Wear Testing

Weight losses of the different composites are shown in tables 2 and 3.

It is clear from the table 2 and 3 that with increase in the proportion of SiO_2 and SiO_2+TiO_2, wear resistance of the composite increases. Comparative analysis indicates that wear resistance of composite with SiO_2+TiO_2 reinforcement particles is greater than that of composite with SiO_2 particles as reinforcement.

Table 2. Weight Loss of Al + SiO_2 composite

Sample Name	Initial Weight (gm)	Final weight (gm)	Weight Loss (gm)
Al + 5% SiO_2	1.3295	1.3205	0.0090
Al + 10% SiO_2	1.3539	1.3472	0.0067

Table 3. Weight Loss of Al + SiO_2 + TiO_2

Sample Name	Initial Weight (gm)	Final weight (gm)	Weight Loss (gm)
Al + 5% SiO_2 + 5% TiO_2	2.8918	2.8793	0.0125
Al + 10% SiO_2 + 10%TiO_2	1.4714	1.4641	0.0073

3.3. Comparison of Breaking Load

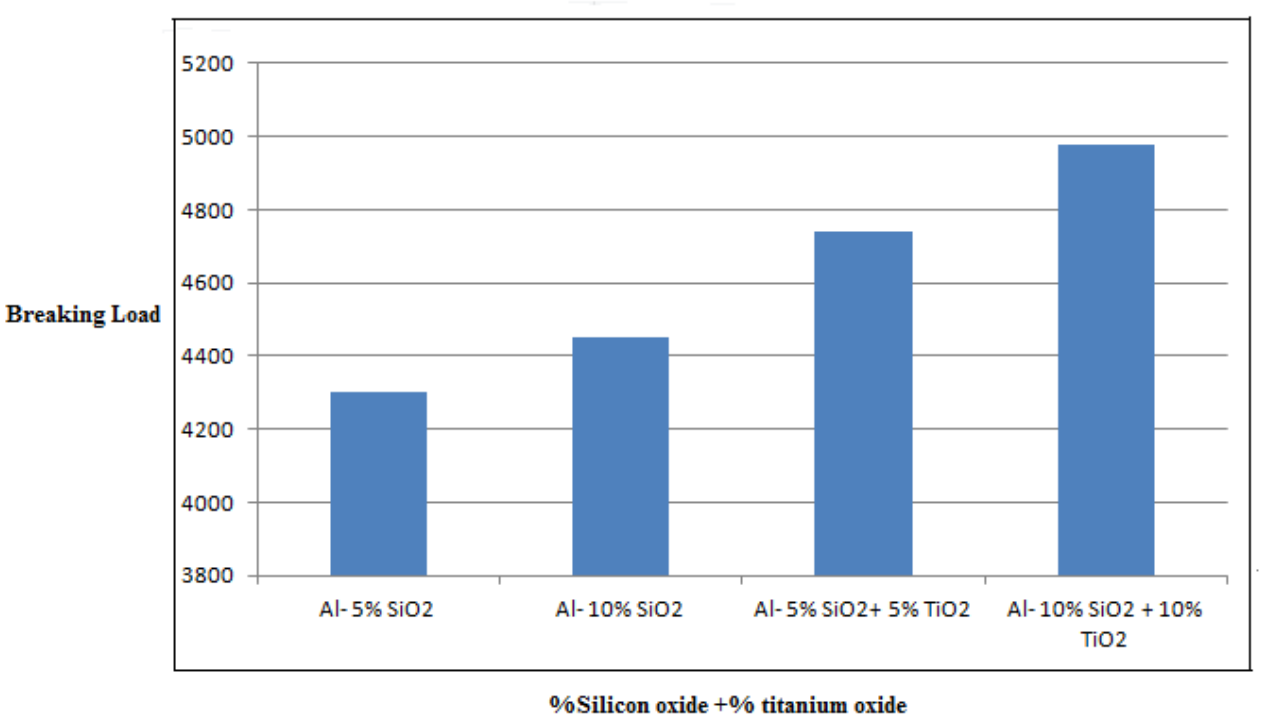

Figure 2. Comparison the Breaking Load with wt. % variation of SiO_2+ TiO_2

The figure 2 shows that incorporation of silicon oxide and titanium oxide particles in Aluminium matrix causes reasonable increase in breaking load thus increase the tensile strength. Thus, silicon oxide and titanium oxide in Al casting reduces cost, decreases density and tensile strength which are needed in various industries like automotive etc [10].

3.4. Results of SEM

Silicon Oxide is Mixed with Aluminium 6061

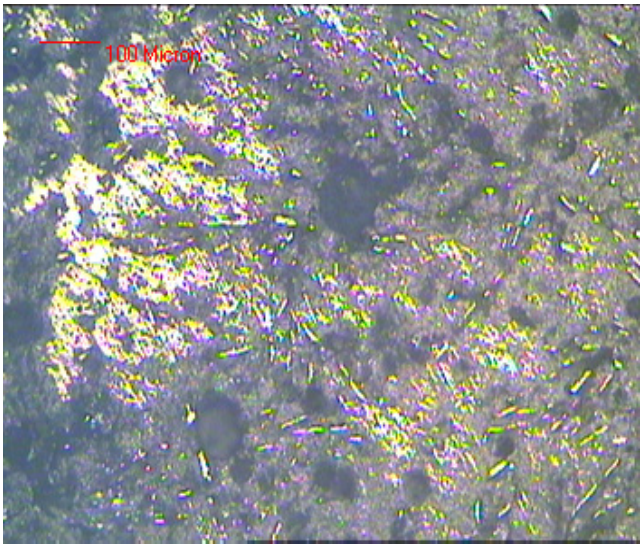

Figure 3. Microscopic view of Al + SiO_2 composite

Titanium Oxide is Mixed with Aluminium 6061

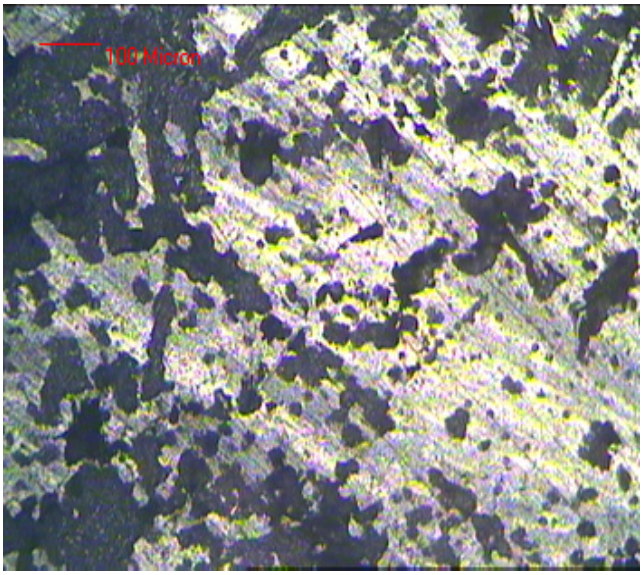

Figure 4. Microscopic view of Al + TiO_2 composite

Silicon Oxide and Titanium Oxide are Mixed with Aluminium 6061

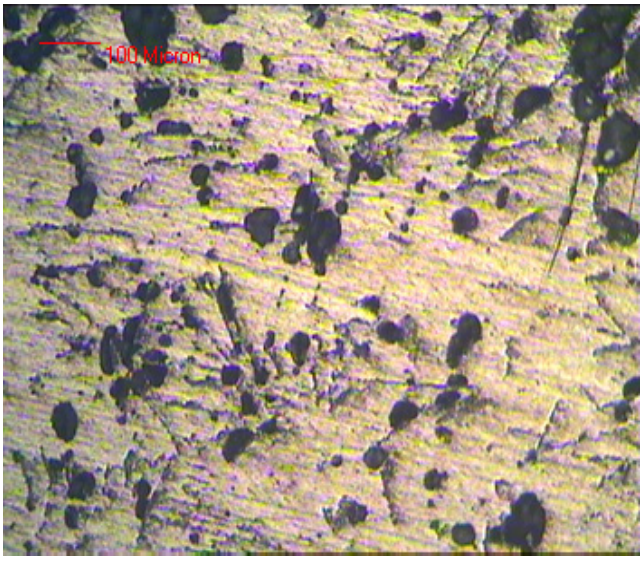

Figure 5. Microscopic view of Al + TiO_2 +SiO_2 composite

Figures 2, 3 and 4 show the microscopic views of the different composite at 1000X magnification. It is clear from the figures that distribution of reinforcement particles in respective aluminum matrix is fairly uniform and homogeneous. Some cracks are also observed in the micrographs.

4. Conclusions

In this research work, different composite materials with different proportions of silicon oxide/titanium oxide reinforcement particles have been successfully fabricated and the following conclusions have been made:

1. The results confirmed that stir formed aluminium 6061 with silicon oxide/titanium oxide reinforced composites is clearly superior to based aluminium 6061 in compression of tensile strength, wear as well as hardness.
2. Addition of SiO_2/TiO_2 in aluminium matrix improves the hardness of the matrix material.
3. The hardness increases after the addition of silicon oxide and titanium oxide particles in the matrix.
4. Wear resistance increases by adding SiO_2/TiO_2 particles.

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