Effect of Copper Coated SiC Reinforcements on Microstructure, Mechanical Properties and Wear of Aluminium Composites

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Abstract
Experimental investigations are carried out to study the influence of copper coated Silicon carbide (SiC) reinforcements in Aluminum (Al) based Al-SiC composites. Wear behavior and mechanical Properties like, ultimate tensile strength (UTS) and hardness are studied in the present work. Experimental results clearly revealed that, an addition of SiC particles (5, 10 and 15 Wt %) has lead in the improvement of hardness and ultimate tensile strength. Al-SiC composites containing the Copper coated SiC reinforcements showed better improvement in mechanical properties compared to uncoated ones. Characterization of Al-SiC composites are carried out using optical photomicrography and SEM analysis. Wear tests are carried out to study the effects of composition and normal pressure using Pin-On Disc wear testing machine. Results suggested that, wear rate decreases with increasing SiC composition, further an improvement in wear resistance is observed with copper coated SiC reinforcements in the Al-SiC metal matrix composites (MMC’s).

Keywords: Coating: Reinforcement: SiC: Wear.

1.0 INTRODUCTION
In recent years a large quantum of work has been carried out on production of Al-SiC Composites, owing to their mechanical and tribological properties compared to other MMC’s. Al based alloys are reinforced with Al\textsubscript{2}O\textsubscript{3}, B\textsubscript{4}C, TiC and SiC to enhance mechanical properties of Al alloys. Even though various methods are in practice for the production of MMC’s\cite{1-7}. Liquid metal stir casting method proved to be a better method in achieving wettability and homogeneous dispersion of reinforced materials\cite{8,9,12,16}. In this direction earlier research work of krez and so et al made concluding remarks that, wetting agents and wetting angle plays vital role in producing quality composites\cite{10,11}. Improvements in mechanical properties are rather obvious with SiC reinforcements in Al alloys. Some of the researchers also dedicated towards wear of Al-SiC composites\cite{13, 14,...
15, 17-20]. However large quantum of work has been carried out on production of Al-SiC composites, a very little has been reported on effect of wetting agents, stirring speed and stirring time on metallurgical, mechanical and wear behavior of A356-SiC composites. In the present study experiments are carried out to study the metallurgy, mechanical and wear behavior of A356-SiC MMCs with copper coated SiC at optimum stirring speed and time.

2.0 METHODOLOGY

Preparation of composites

Al-SiC composites are prepared by stir casting process. A schematic view of furnace is shown in Figure 1. SiC particles of 75 µm were considered for the preparation of A356-SiC MMC’s as this size results in sound castings [9]. Cu coating is preferred over other elements [9]. Cu coating is done on SiC particles using electroless coating method. A356 was melted in an electric resistance PLC furnace. Commercially available hexachloroethane in the tablet form (~1 wt %) is added as degasser. The temperature of the melt is maintained at ~700±10°C and stirred with a mechanical stirrer at 350 rpm to create the vortex in the melt. Further, among various stirring speeds (250, 350, 450 and 650 rpm for 7 min), it is suggested that 350 rpm is considered as optimum speed as proper distribution of reinforcement particles without having any agglomeration or segregation in the A356-SiC MMCs.

A number of experiments were carried out to optimize the stirring time. It was observed that, stirring the composite beyond 7 min have shown chemical reactions between the SiC reinforcement and the Al melt. All the tools which come in contact with A356 melt were coated with zirconia to avoid contamination with Al melt. The depth of immersion of the stirrer is maintained at ~2/3 the depth of the molten metal. A preheated cast iron mould (250 °C) with diameters in the range of 10 mm and 25 mm is used to obtain the cast bars.

3.0 RESULTS AND DISCUSSION

3.1 Microstructural details

The optical photomicrographs of as cast Al-5SiC, Al-10SiC, and Al-15SiC MMCs with uncoated SiC particles are shown in Figure 2 a, 2c, and 2e. It is observed in the
photomicrographs that, the uncoated SiC particles are grouped around the grain boundaries of Al matrix. Negligible amount of porosity at the interface between SiC particles and Al matrix may be seen. The use of preheated SiC particles have formed a thin oxide layer of SiO₂ on the surface might have restricted the reaction of SiC with Al alloy which would have avoided formation of Al₄C₃ and Si [8]. Mohan et al. [9] have reported and confirmed by XRD results. The optical photomicrographs of Al-SiC MMCs with Cu coated SiC particles are shown in Figure 2b, 2d, and 2f. It is observed that, the bonding between SiC particle and Al matrix seems to be better compared with the Al-SiC MMCs with uncoated SiC particles. It can be attributed to the improved wettability between Cu coated SiC particles with Al matrix. The same can also be depicted from Fig. 3 a and Fig. 3 b which clearly show effect of copper coating on bonding of reinforcement material with the Al matrix, hence improved mechanical and wear resistance of copper coated Al-SiC is seen and is discussed in subsequent sections.

![Fig.2 Optical photographs of A356 –SiC composites (400X)](image)

a) A356-5% uncoated SiC  b) A356-5% copper coated SiC
c) A356-10% uncoated SiC  d) A356-10% copper coated SiC
e) A356-15% uncoated SiC  f) A356-15% copper coated SiC
3.2 Effect on Mechanical properties

Hardness test

Table 1. Hardness of various composites (A356, A356/5SiC, A356/10SiC, and A356/15SiC under coated and non coated conditions)

| Composite      | VHN (Uncoated) | VHN (Cu Coated) |
|----------------|----------------|-----------------|
| Al             | 65             | -               |
| Al/5SiC        | 74             | 76              |
| Al/10SiC       | 80             | 84              |
| Al/15SiC       | 86             | 97              |

Hardness testing of the prepared composites is carried out using Vickers hardness testing Machine. From table 1 it is clear that, improvement in hardness is seen with the addition of SiC reinforcements to Al alloy. It can be also noted that Hardness improves with increasing addition levels of SiC from 5-15 wt %. Further, the composite containing Cu coated SiC particles have improved hardness compared to the composite with uncoated SiC particles. It may be attributed to homogeneous dispersion of SiC reinforcements due to optimum stirring speed and time and also due to better bonding of the SiC particles with the Al matrix due to copper coating, this is confirmed by optical photo micrographs and SEM study.

Tensile test

Tensile tests are conducted using TUFUN -100 computerized universal testing machine. From table 2 it is observed that UTS of A356 Al alloy improves with addition of SiC reinforcements. It is clear from the results that, UTS enhances with Cu coated SiC particles in
comparison with uncoated SiC particles. A similar prediction is made as discussed in the previous section.

Table 2. UTS of various composites (A356, A356/5SiC, A356/10SiC, and A356/15SiC under coated and non coated conditions)

| Composite/Hardness | Uncoated | Ultimate Tensile strength (Cu Coated SiC) |
|--------------------|----------|----------------------------------------|
| Al                 | 180      | -                                      |
| Al/5SiC            | 182      | 188                                    |
| Al/10SiC           | 185      | 191                                    |
| Al/15SiC           | 185      | 197                                    |

3.3 Wear Behavior

Wear tests are carried out using DUCOM TR-20L, Pin On Disc wear Testing machine by varying contact load from 0.50-1.25 N at a constant sliding speed of 1 m/s and at a constant sliding distance of 3000 mtrs. From Fig. 4 & Fig. 5 it is very much clear that wear rate increases with increasing contact load from 0.50-1.27 N in both A356 alloy and A356 metal matrix composites with copper coated and non coated SiC reinforcements.

**Figure 4 Volume loss Vs Contact Load**

It may be attributed to the fact that at higher loads stresses on the contact surfaces increases and the SiC particles get abraded away due to the application of load and the results uphold the conclusions made by Basavarajappa et al (2006) and Mohan et al (2014). It can also be noticed from figures that Wear rate decreases in case of copper coated SiC reinforced MMC’s as compared to non coated ones. This may be attributed to the fact that copper
coating of SiC reinforcement develops sufficient bonding with A356 matrix so as to overcome the applied pressure. Hence, a better wear resistance. It can also be noticed from Fig. 4 & Fig. 5 that improvement in wear resistance is seen with increase in Wt% of SiC and it may be attributed to the fact that hardness of the composite improves with increase in SiC content and hence wear resistance.

Figure 5 Wear Behaviour of A356 and A356- SiC Composites

4.0 CONCLUSIONS

A356 MMC’s reinforced with SiC obviously show improvement in mechanical properties due to reinforcing of a harder SiC into Al metal matrix. Improvement in mechanical properties enhances with increase in SiC reinforcements from 5-15 wt % in A356 matrix. Copper coating of SiC reinforcements at 75 microns has a profound effect on increased wettability and adhesion due to which further improvements in mechanical properties and hence wear resistance can be seen. Further with adaption of optimum stirring speed and time better homogeneous dispersion of SiC reinforcements in A356 matrix can be made which in turn helps in achieving improved mechanical and wear properties.

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