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Microstructure and Effect of Ni-P Coating of Sic Particles on Tribological Behavior of Cast Al6061-Sic Composites

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Abstract— **This paper reports on sliding friction and wear behavior of uncoated and Ni-P coated SiC reinforced Al6061composites produced by stir casting method. Electroless plating technique was used to nickel coat SiC particles. The extent of incorporation of reinforcements was varied from 2 to 10 wt% in steps of 2wt%. Developed composites were subjected to microstructure, micro hardness, and friction and wear tests. Sliding wear tests were performed using Pin-on-disc apparatus, as per ASTM G99-95. The loads and sliding velocities were varied from 20N to 100N and 0.314m/s to 1.574m/s respectively. Results reveal that, increased content of SiC particles in matrix alloy increases the coefficient of friction and reduces the wear rates of both uncoated and Ni-P coated SiC reinforced composites. However, when compared with uncoated composites, Ni-P coated SiC reinforced composites exhibited lower coefficient of friction and higher wear resistance at all the loads and sliding velocities studied.**

Keywords— *Casting, Coating, Friction, Metal Matrix Composites, Wear.*

1. INTRODUCTION

Aluminum based composites are the most sought after candidate materials in aerospace, space and automotive industries owing to their superior mechanical and tribological properties [1]. These popular composites are currently manufactured by powder metallurgy, liquid metallurgy, spray forming and diffusion bonding techniques. However, the most simplified approach to develop near net shaped aluminum based composites is by liquid metallurgy route as it is economical and can result in mass production [2]. Further, these cast composites can be subjected to secondary processing such as extrusion and forging to improvise upon the mechanical properties in particular strength coupled with practical ductility. However, since three decades, it has been reported that few challenges like inferior bond, interfacial reaction product need to be addressed in composites developed by liquid metallurgy route. These problems do have a direct deteriorating effect on the mechanical properties of the composites making them unsuitable for industrial components [3]. These challenges have been addressed to by use of metallic coated reinforcement and addition of reactive metals like magnesium by several researchers across the globe [4]. In the light of the above, the present investigation focuses on friction and wear behavior of Ni–P coated SiC reinforced Al6061 composites.

2. EXPERIMENTAL PROCEDURE

Al6061 alloy with the chemical composition given in Table.1 was used as the matrix material. Silicon Carbide (SiC) in powder form having particle size of range 5-30µm was used as reinforcement. Silicon carbide particles were subjected to electroless nickel coating. The detailed coating procedure is as described in our earlier works [5]. The composites were developed using stir cast method as discussed in our earlier works. Both Ni-P coated and uncoated silicon carbide was varied in proportions of 2 to 10wt%.Coated SiC was preheated to 400^{o}C before dispersing in the molten alloy. Dispersion was achieved by use of ceramic coated impeller. The composite melt was poured into preheated metallic moulds maintaining a pouring temperature of 710^{o}C. Cast composites were machined and were subjected to metallographic studies, micro hardness, and friction and wear tests. Dry sliding friction and wear tests were performed using pin-on-disc apparatus as per ASTM G99-95. (Make-DUCOM, Bangalore). Cylindrical pins of 8mm diameter and 20mm height were used as test samples. The specimen end surfaces were flat and polished to maintain a surface finish of 3-5µm. The counter face disc was made of EN-31 steel hardened to 60HR$_c$. The initial surface finish (Ra) of the steel disk was 1µm. A track radius of 30mm has been used for all the experiments. All the tests were conducted in air at room temperature. Test duration of 30 min was adopted for all the tests. The loads and sliding velocities were varied from 20 to 100N and 0.314 to 1.574 m/s respectively. Frictional force was measured using load cell of accuracy 0.1N while the wear loss was measured in the steady state regime by using linear variable differential transducer (LVDT) of accuracy 1 µm at the end of 30 min. The coefficient of friction was calculated using frictional load and normal load data. Wear rates were calculated from the height loss data in terms of volumetric wear loss per unit load and slid distance.

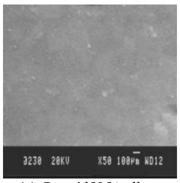
Si	Cu	Mn	Ni	Pb	Ti	Mg	Cr	Al
0.43	0.24	0.13	<0.05	0.024	0.022	0.802	0.18	Bal

Table.1 Composition of Al6061 alloy

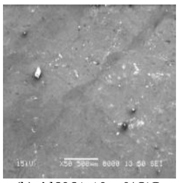
3. RESULTS AND DISCUSSIONS

3.1Microstructure

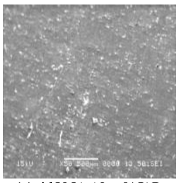
Fig. 1(a-e) shows the SEM of uncoated and Ni-P coated SiC reinforced Al6061 composites. Distribution of SiC particles is fairly homogenous throughout the matrix alloy in case of composites reinforced with Ni-P coated SiC particles. Whereas uncoated SiC reinforced composites shows agglomeration of reinforced phase owing to poor wettability of SiC particles. Further, detachment / decohesion of SiC particles are also observed as evidenced in the Fig.1d. There exists strong interfacial bond between matrix alloy and reinforcement in Ni-P coated SiC reinforced composites as a beneficial result of metallic coating.



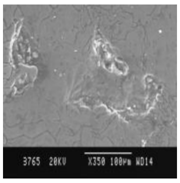
(a) Cast Al6061 alloy



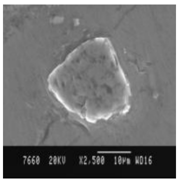
(b) Al6061-10wt%SiC composite (Uncoated)



(c) Al6061-10wt%SiC composite (Ni-P coated)



(d) Uncoated Al6061-SiC composite showing poor bond between matrix and reinforcement



(e)Al6061-Ni-P-SiC composite showing excellent bond between matrix and reinforcement

Fig.1 SEM of uncoated and Ni-P coated SiC reinforced Al6061 composites

3.2Microhardness test

Fig. 2 shows the variation of micro hardness of Al6061 –SiC composites with increased contents of SiC. Increased content of both uncoated and Ni-P coated SiC in the matrix alloy results in enhanced micro hardness of the developed composites. However, Ni-P coated SiC reinforced composites exhibits higher micro hardness for a given content of SiC.

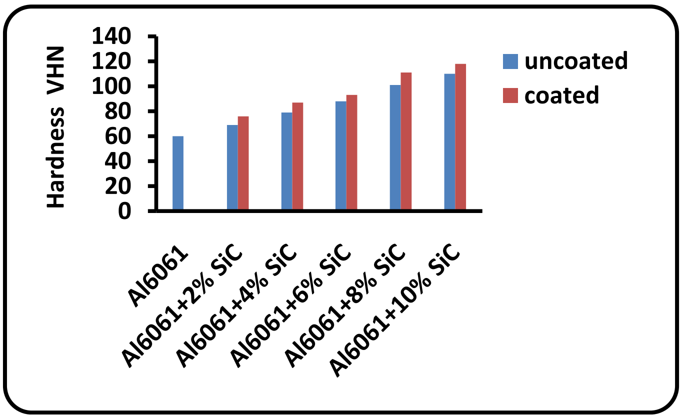


Fig.2 Variation of microhardness of uncoated and Ni-P coated SiC reinforced Al6061composites

Higher hardness values of Ni-P coated silicon carbide composites when compared with uncoated ones can be attributed to reduced casting defects, improved bond strength/load transfer efficiency between matrix alloy and reinforcement coupled with better homogeneity in the distribution of SiC particles in the matrix alloy. A maximum improvement of 96% is observed for Ni-P coated SiC reinforced composites when compared with the matrix alloy for 10wt% SiC.

3.3 Coefficient of friction

3.3.1 Effect of Reinforcement

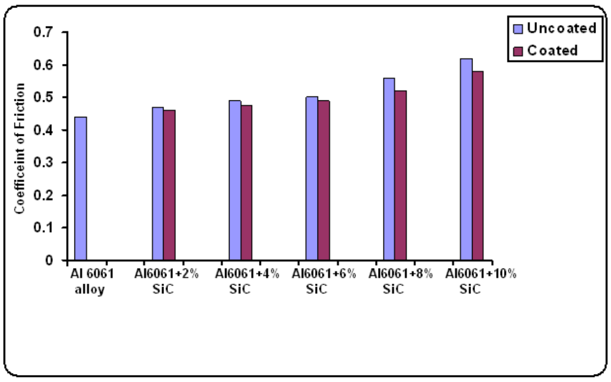
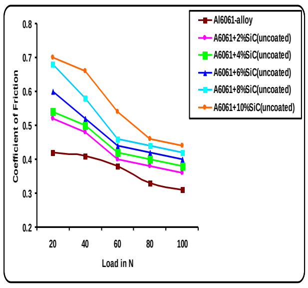


Fig.3 Variation of coefficient of friction of coated and uncoated Al6061-SiC composites

Fig.3 shows the effect of coated and uncoated reinforcement on coefficient of friction of Al6061 alloy. It is observed that coefficient of friction increases with increase in percentage of reinforcement in both uncoated and nickel coated SiC composites.However, when compared with uncoated composites, nickel coated composites exhibited lower coefficient of friction in all the cases studied. A maximum improvement of 32% is observed for Ni-P coated SiC reinforced composites when compared with the matrix alloy for 10wt% SiC.

3.3.2Effect of Load



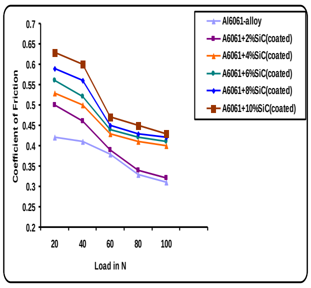


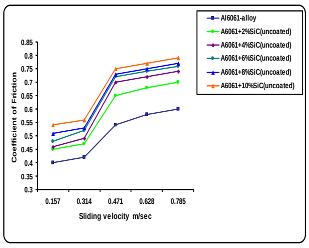
Fig.4 Variation of coefficient of friction of uncoated Al6061-SiC composite with load

Fig.5 Variation of coefficient of friction of coated Al6061-SiC composite with load

Fig.4 and 5 shows the variation of coefficient of friction of Al6061 alloy and uncoated Al6061-SiC composites with increase in load. It is observed that coefficient of friction decreases with increase in load in both alloy and its composites. In all the cases studied Al6061-SiC composites shows higher coefficient of friction when compared with unreinforced alloy. A maximum improvement of 28% is observed for Ni-P coated SiC reinforced composites when compared with the matrix alloy for 10wt% SiC and load 100N.

3.3.3 Effect of sliding velocity

Fig.6 and 7 shows effect of sliding velocity on coefficient of friction of both coated and uncoated SiC reinforced Al6061



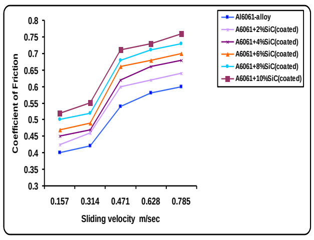


Fig.6 Variation of coefficient of friction of uncoated Al6061-SiC composite with sliding velocity

Fig.7 Variation of coefficient of friction of coated Al6061-SiC composite with sliding velocity

composites. It is observed that coefficient of friction increases with increase in sliding velocity in both uncoated and nickel coated SiC reinforced composites. At all the sliding velocities studied, both uncoated and Ni-P coated composites exhibits higher coefficient of friction when compared with matrix alloy. Further, metallic coated SiC reinforced composites shows marginally lower coefficient of friction when compared with uncoated ones. A maximum improvement of 21% is observed for Ni-P coated SiC reinforced composites when compared with the matrix alloy for 10wt% SiC and sliding velocity 0.785m/sec.

3.4 WEAR STUDIES

3.4.1 Effect of Reinforcement

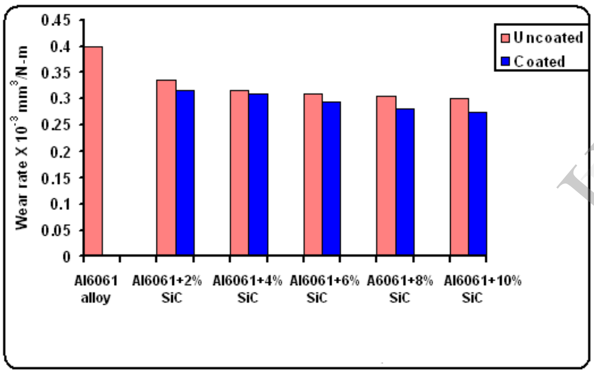
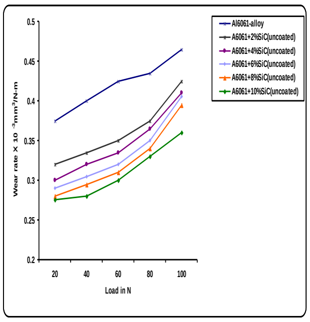


Fig.8 Variation of wear rate of coated and uncoated Al6061-SiC composites

Fig.8. shows the effect of SiC reinforcement on (both uncoated and nickel coated) wear rate of Al6061 alloy. It is observed that wear rate of Al6061 alloy decreases with increase in percentage of reinforcement in both uncoated and nickel coated SiC composites. In all the cases studied nickel coated SiC reinforced composites shows slightly higher wear resistance when compared with uncoated ones owing to improved hardness, uniform distribution of reinforced phase with good bond. A maximum of 27% and 35% decrease is noticed in Al6061-10wt%SiC and Al6061-Ni-P-10wt%SiC composites respectively.

3.4.2 EFFECT OF LOAD



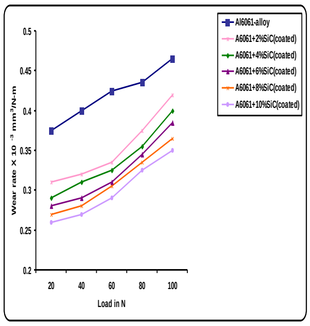
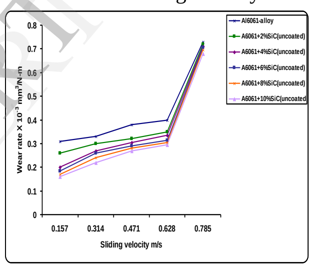


Fig.9 Variation of wear rate of uncoated Al6061-SiC composites with load

Fig.10 Variation of wear rate of coated Al6061-SiC composites with load

The influence of load on wear rate of Al6061-SiC and Al6061-Ni-P-SiC composites are shown in the Fig.9 and Fig.10 respectively. It is observed that the wear rate found increased with increase in applied load in all the composites studied. Nickel coated Sic reinforced composites shows superior wear resistance when compared with unreinforced alloy and uncoated Al6061-SiC composites. At a maximum load of 100N, a reduction of 22% and 65% in the wear rates of uncoated and Ni-P coated SiC reinforced composites respectively is observed when compared with the matrix alloy

3.4.3 Effect of sliding velocity



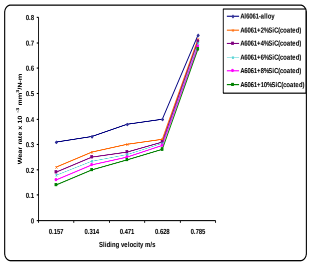


Fig.11 Variation of wear rate of uncoated Al6061-SiC composites with sliding velocity

Fig.12 Variation of wear rate of coated Al6061-SiC composites with sliding velocity

Effect of sliding velocity on wear rate of Al6061-SiC and Al6061-Ni-P-SiC composites are shown in the Fig.11 and Fig.12. It is observed that wear rate increases steadily with increase in sliding velocity up to 0.628m/s. However after this, it shows sudden increase in wear rate in both uncoated and nickel coated SiC reinforced composites. At a maximum sliding velocity of 0.785 m/s, a reduction of 6% and 12% in the wear rates of uncoated and Ni-P coated SiC reinforced composites respectively when compared with the matrix alloy is observed.

4. CONCLUSION

Strong interfacial bond between matrix alloy and reinforcement in Ni-P coated SiC reinforced composites is a beneficial result of metallic coating.Ni-P coated SiC reinforced Al6061 composites exhibited lower coefficient of friction and lower wear rate when compared with uncoated SiC reinforced Al6061 composites under all the loads and sliding velocities studied. Significantly reduced wear rate can be attributed to the destruction of the possible MML layer formed and material softening due to increased temperature with increased sliding velocity during the sliding process.

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