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Performance of Composite Materials Using a Novel Technique

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ABSTRACT : *This paper reports on tribological behavior of uncoated and Ni-P coated SiC reinforced Al6061-SiC reinforced Al6061 composites produced by stir casting and further by hot extrusion technique using 200T hydraulic press. 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 2 wt%.Developed composites were subjected to microstructure, 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 which may be beneficial in aerospace vehicles for easy heat dissipation.*

KEYWORDS *Microstructure, Coating, Extrusion, Wear,*

[1] INTRODUCTION

Owing to their higher strength combined with lighter weight beyond conventional metals and alloys, metal matrix composites (MMCs) have been extensively applied in automobile and aerospace industries due to their excellent mechanical properties, tribological behavior and low thermal expansion co-efficient .Coatings are increasingly being used to improve the tribological properties of mechanical components such as tools for metal cutting, forming and machine elements such as sliding bearings, seals and valves[1, 2].A particle reinforced MMC is far less tough than its unreinforced matrix since the particles cause a strong acceleration of internal damage build-up and damage is highly localized in front of the crack tip; leading to fracture [3,4]. Present work signifies the innovative method of preparing the composites and evaluating for microstructure and wear tests respectively.

[2] PROCESS DESCRIPTION

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 5-40µm was used as reinforcement. Silicon carbide particles were subjected to electroless nickel coating. The composites were developed using stir cast method. Both Ni-P coated and uncoated silicon carbide was varied in proportions of 2 to 10wt%. Dispersion was achieved by use of ceramic coated impeller. The composite melt was poured into preheated metallic molds maintaining a pouring temperature of 720^{o}C. The cast matrix alloy and the developed Al6061-SiC composites (Both uncoated and Ni-P coated) were machined to the size of 70mm diameter and 200mm length.

Elements	Si	Fe	Cu	Mn	Ni	Ti	Mg	Cr	Zn	Al
Percentage	0.43	0.43	0.24	0.14	<0.05	0.02	0.8	0.18	0.006	Bal

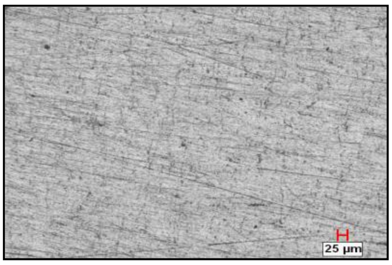
Table 1
Chemical composition of Al6061 alloy

Machined billets were then subjected to hot extrusion in a 200T hydraulic extrusion press, at a billet temperature of 500°C. Extrusion billets were heated in a muffle furnace for 2hrs.The temperature of the die inserts within the container was maintained at 300^{o}C. A graphite based lubricant was applied on the billet, container and die. Extruded Al6061 alloy and Al6061-SiC composites (both uncoated and Ni-P coated). Dry sliding friction and wear tests were performed using pin-on-disc apparatus as per ASTM G99-95 (supplied by 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 60HRC. The initial surface finish (R_a) 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.

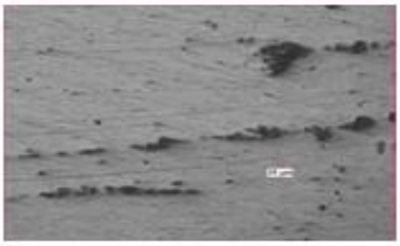
[3] RESULTS AND DISCUSSION

Microstructure

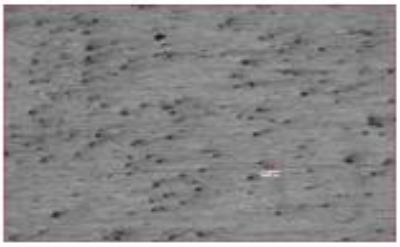
Microphotographs of Extruded Al6061 alloy and Al6061-SiC composites (both coated and uncoated) at varied proportion of reinforcement and at a constant temperature of 540°C are as shown in figure 1.



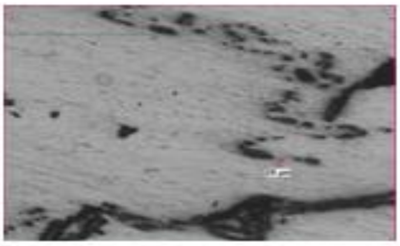
Al6061 alloy



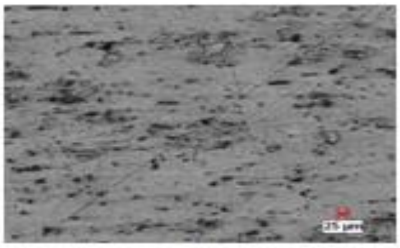
Al6061-4wt%SiC (Uncoated)



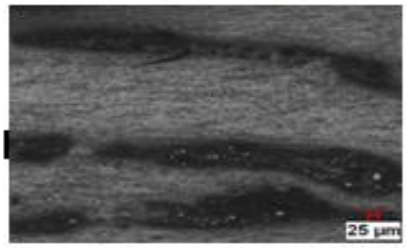
Al6061-4wt%SiC (Ni-P coated)



Al6061-6wt%SiC (Uncoated)



Al6061-6wt%SiC (Ni-P coated)



Al6061-8wt%SiC (Uncoated)

Al6061-8wt%SiC (Ni-P coated)

Fig.1 Optical photographs of hot extruded Al6061 alloy and Al6061-SiC composites (both coated and uncoated) – at Extrusion temperature 540ºC

It is clearly observed that uncoated SiC reinforced Al6061 composites shows agglomeration and non homogeneity in the distribution of SiC particles where as Ni-P coated SiC reinforced Al6061 composites show fairly uniform distribution of reinforced particles throughout the matrix alloy which is beneficial; enhancing various properties.

Wear Analysis

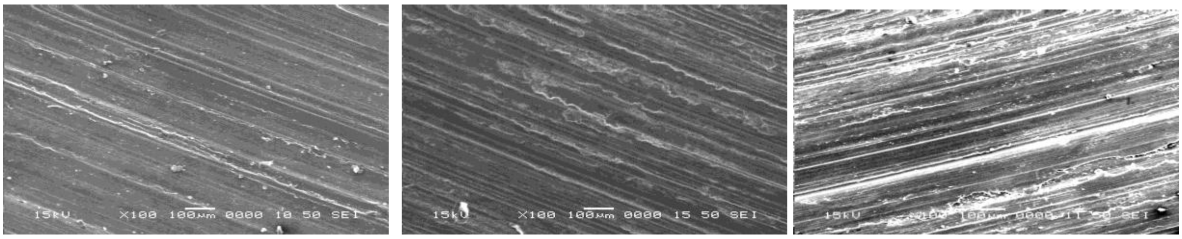


Fig.2 (a) Wear Track of Al6061-SiC (Uncoated) composites

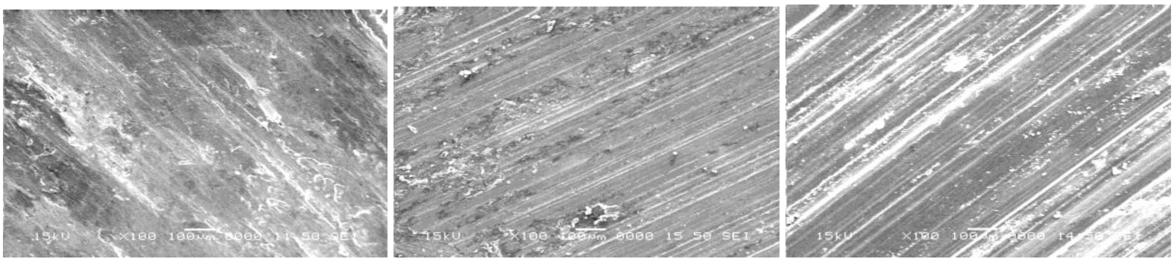


Fig.2 (b) Wear Track of Al6061-SiC (Ni-P coated) composites

Figure 2(a) and 2(b) shows the SEM of worn Al6061 alloy and Al6061-SiC composites (both coated and uncoated) at different speed and sliding velocity. It is observed from the micrographs that, at lower speeds and sliding velocity grooves are wide and the surfaces have been damaged significantly in both matrix alloy and developed composites. However, when compared with the matrix alloy and uncoated SiC reinforced composites, the extent of damage is lower in case of Ni-P coated SiC reinforced Al6061 composites. Further, it is also observed that increase in speed and slid distance has resulted in lower surface damage for both matrix alloy and developed composites. Lower surface damage of Ni-P coated SiC reinforced Al6061 composites clearly indicates high wear resistance of the composites as observed in the above figure. Extensive cracking and shearing are observed for matrix alloy extruded and resulting in higher wear rates of the matrix alloy. In case of extruded Ni-P coated composites the extent of cracking and shearing is observed is very minute. Micro scratching and plastic deformation are observed which indicates of superior wear resistance of composites.

Effect of Reinforcement

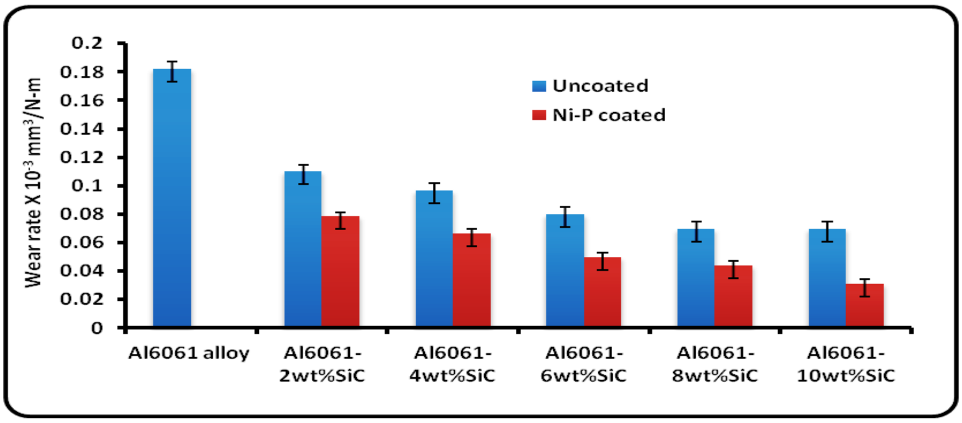


Fig. 3 Variation of wear rate of uncoated and Ni-P coated SiC reinforced Al6061 composites with reinforcement

Figure 3 shows the influence of SiC reinforcement on (both uncoated and nickel coated) wear rates of Al6061 alloy and its composites. It is observed that wear rates of Al6061 alloy decreases with increase in percentage of reinforcement in both uncoated and Ni-P coated SiC reinforced composites. In all the cases studied Ni-P coated SiC reinforced composites do exhibit higher wear resistance when compared with Al6061 matrix alloy and uncoated SiC reinforced composites. A maximum of 55% and 67% decrease in wear rates are noticed in uncoated and Ni-P coated Al6061-10wt%SiC composites respectively when compared with extruded matrix alloy. The improved wear resistance of Ni-P coated SiC reinforced composites can be attributed to higher hardness, yield and tensile strength. In addition to this, uniform distribution of reinforced phase in the matrix alloy in case of Ni-P coated SiC reinforced composite do increase the load bearing capacity and minimizes the matrix contact area. These factors lead to lesser extent of plastic deformation in metallic coated reinforced composites resulting in lower material removal during the sliding process. Further, strong interfacial bond that exist between matrix and reinforcement in case of Ni-P coated SiC reinforced composites also contributes significantly to the improved wear resistance by increasing the load transfer efficiency between matrix and reinforcement. Poor interfacial bond between the hard SiC reinforcement and the soft matrix alloy will lead to three body abrasive wear phenomenon. Another factor favoring the improvement in wear resistance of coated reinforced composites is the presence of low shear strength Ni-P which has a good lubricating property.

Effect of Load

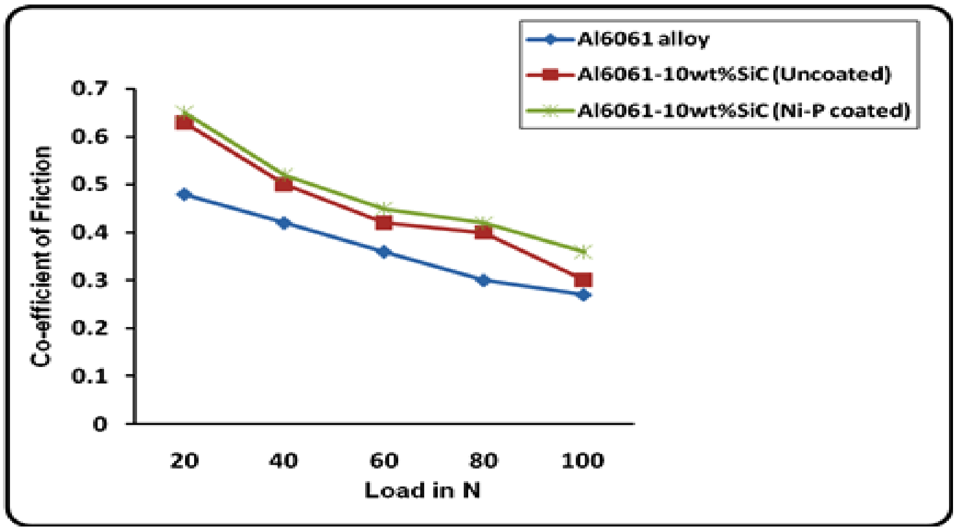


Fig. 4 Variation of co-efficient of friction of Extruded Al6061 alloy and Al6061-SiC composites (both coated and uncoated) with different load and at extrusion.

Figure 4 shows the dependence of co-efficient of friction of hot extruded Al6061 matrix alloy and all its composite systems on load for the given sliding velocity and sliding distance. From above figure it is evident that with increase in load, there is a reduction of co-efficient of friction for both the matrix alloy and the composite systems studied. However at all the loads studied, co-efficient of friction of the composites are higher when compared with matrix alloy. This can be attributed to the fact that increased loads results in higher probability of destruction of the asperity junctions leading to lowering of frictional force.

Effect of sliding velocity: Figure 5 shows the dependence of hot extruded Al6061 matrix alloy and its composite systems on sliding velocity for the given constant sliding distance and load. It is observed that with an increase in sliding velocity there is an increase in co-efficient of friction for all the systems studied. However the extruded matrix alloy possesses lowest co-efficient of friction among all the systems studied. Also it is observed that there is an increase in co-efficient of friction from 0.314 m/s t0.157 m/s of sliding velocity

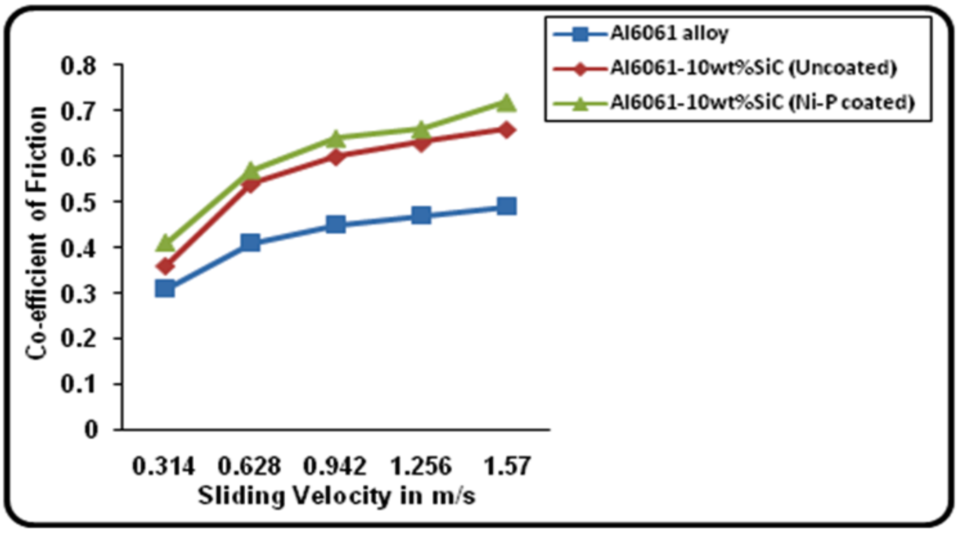


Fig. 5 Variation of co-efficient of friction of Extruded Al6061 alloy and Al6061-SiC composites (both coated and uncoated) with different sliding velocity and at a constant load

[4] CONCLUSION

Ni-P coating of SiC has a significant effect on the wear behavior of extruded composites.
For the extrusion studied, SEM morphology of the worn surfaces reveal that the extent of damage is least for Ni-P coated SiC reinforced extruded composites.
Use of nickel coated silicon carbide has resulted in lowering of co-efficient of friction of composites when compared to that of uncoated silicon carbide composite.

[5] ACKNOWLEDGEMENTS

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