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Tribological behavior of Al based self-lubricating composites

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ABSTRACT – Al based self-lubricating hybrid composites containing SiC as the hard phase and MoS_2 as the solid lubricant were synthesized by using stir casting route. Dry sliding wear and friction characteristics of the composites have been examined at sliding speed of 1 m/s on a pin-on-disc tribometer under different normal loads of 9.8N, 14.7N, 19.6N, 24.5N. Both friction and wear rates were found to reduce with addition of MoS_2, however, bonding between the matrix and reinforcements was not good. Hence, Mg was added to improve the wettability and this resulted in improved mechanical as well as tribological performance.

1. INTRODUCTION

Metal Matrix Composites (MMC's) have very light weight, high strength, and stiffness and exhibit greater resistance to corrosion, oxidation and wear, which is desired for aerospace and automobile applications etc. Composite materials reinforced with ceramic particles/fibres (e.g. SiC, Alumina) are being extensively used in the applications where tribological properties (wear rate, coefficient of friction, lubrication) are important considerations. Aluminium is the most popular matrix for metal matrix composites because of its low density, low cost, its capability to be strengthened by precipitation, good corrosion resistance, and high thermal and electrical conductivity, improved tribological properties [1,2,3].

The objective of the present study is to synthesize self-lubricating aluminum based hybrid composites containing SiC as the hard phase and MoS_2 as the solid lubricant through stir casting and characterize their friction and wear under dry sliding condition.

2. METHODOLOGY

The raw materials used for synthesis of composites are 99% pure Aluminum (Al) supplied by Hindalco India Pvt. Ltd., Silicon carbide (SiC) powder of 99% purity with average size particle of 25µm and 99% pure MoS_2 powder of 25 µm size supplied by Molychem Pvt. Ltd, Mumbai.

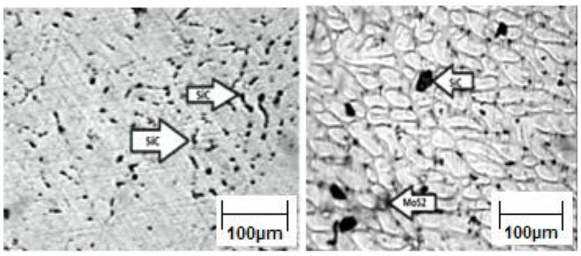
The melting was carried out in a clay-graphite crucible placed inside the electric resistance furnace. In 550 g of Al melt, 10% by weight SiC powder was added to prepare Al/SiC by stir casting technique. In another casting 4% MoS_2 by weight is mixed to study the effect of solid lubricant on the composite. To enhance the wettability of second phase,4% Magnesium (Mg) is added as a bonding element. Microstructure and mechanical properties such as hardness, tensile strength of the cast composites were determined using standard procedures.

The dry sliding wear tests were performed on the pin-on-disc machine to evaluate the sliding wear characteristics of the cast composites under four different load of 9.8 N, 14.7 N, 19.6 N and 24.5 N at fixed sliding speed of 1m /s. The worn surfaces of the composites were examined under Scanning Electron Microscope (SEM).

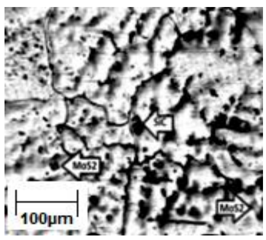
3. RESULTS AND DISCUSSION

Figures 1(a to c) show microstructures of Al10SiC, Al10SiC4MoS_2 and Al10SiC4$MoS_2$4Mg composites, respectively, at a magnification of 100X. SiC particles are black in color while MoS_2 particles are lighter in color as marked by arrows in Figures 1(a) and (b). The distribution of added particles appears to be homogeneous.

The ultimate tensile strength (UTS), hardness and densities of the composites and pure Al are shown in Table 1. The UTS of Al/SiC composite is greater than pure aluminum and it decreased with addition of only MoS_2, due to softer nature of MoS_2 while incorporation of molybdenum disulphide causes an increase in elongation. Magnesium reinforced composite has the highest UTS, hardness and densities where it may be attributed to the better bonding between matrix and reinforcement resulting from addition of Mg. A good bonding between the matrix and the reinforcement particulates with the addition of Mg has also been reported by Veeresh Kumar et al. [4].



(a) Al/SiC (b) Al/SiC/MoS_2



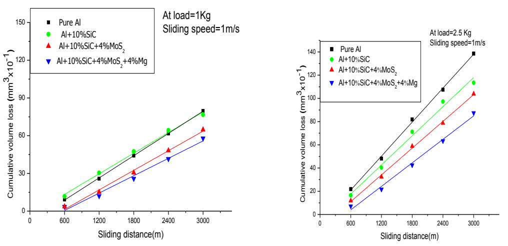
(c) Al/SiC/MoS_2/Mg

Figure 1 Optical micrographs of composites.

Table 1 Mechanical properties of Aluminum and composites.

Material	UTS (MPa)	% Elongation	Hardness BHN	Density(kg/m^3)
Pure Al	58	32	15	2700
A l10SiC	92	20	26.4	2724
Al10SiC4MoS$_2$	73	27	21.4	2771
Al10SiC4MoS$_2$4Mg	200	17	44	2734

The variation of cumulative volume loss with sliding distance for the load of 9.8 and 24.5N is shown in Figs. 2 (a) and (b), respectively, the data points have been fitted using least square method. The cumulative volume loss increases linearly with increasing sliding distance for all materials. It could be seen that Al/SiC/MoS$_2$/Mg composite shows the minimum cumulative volume loss, consistently at all the loads which may be attributed to its higher hardness in comparison other materials. Figure 3 (a) shows variation of wear rate with normal load for different composites. At a given load wear rate i.e. volume loss per unit sliding distance, has been calculated from the slope of the linear least square fit shown in Fig. 2. The wear rate is found to increase linearly with increasing normal load for pure Al and composites indicative of following Archard's law [5].

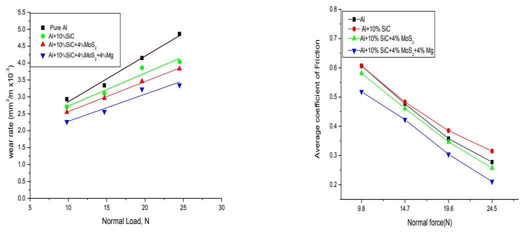


(a) 9.8N (b) 24.5N

Figure 2 Cumulative volume loss Vs sliding distance.

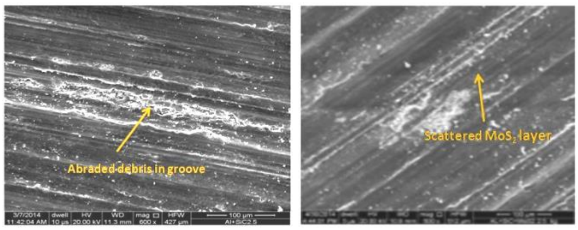
Figure 3(b) shows the variation of average coefficient with normal load. The friction coefficient decreases with increasing normal load. At a particular load the friction coefficient decreases as one moves from pure Al to Al/SiC/MoS$_2$/Mg composite. Al/SiC/MoS$_2$/Mg composites have shown the lowest rate of wear as well as the coefficient of friction than others, It is interesting to note that the friction coefficient of pure Al drops at the highest load where it is almost equal to Al/SiC/MoS$_2$ composite despite the presence of solid lubricant. It may be attributed to the softening of the pure Al due to the frictional heat developed at the higher load and the increased debonding of particles in Al/SiC/MoS$_2$ which is not able to sustain the frictional thrust at higher loads. However, addition of magnesium improves the bonding at the interface and provides increased capacity of holding the second phase particles which, in turn, results in higher hardness and lower coefficient of friction.

SEM micrographs of Al/10SiC, Al/10SiC/4MoS$_2$ and Al/10SiC/4MoS$_2$4Mg are shown in Fig. 4 (a to c), respectively, at a load of 24.5 N. Fig. 4(a) shows the presence of wear debris in wear grooves. The debris gets generated due to pull out of the particles and these pulled out SiC particles act as third body and lead to increased wear [6, 7]. The worn surface of composites containing MoS$_2$ on the surface however, the surface of Al/SiC/MoS$_2$/Mg shows the presence of continuous thin layer of MoS$_2$ whereas it appears to be scattered on the surface Al/SiC/MoS$_2$ (Fig. 4 b). The thin layer of MoS$_2$ on the sliding surface acts as solid lubricant and inhibits metal-metal contact reducing both the wear rate and friction coefficient.

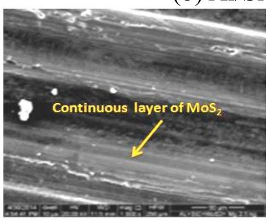


(a) (b)

Figure 3 Variation of (a) wear rate (b) coefficient of friction with normal load.



(a) Al/SiC (b) Al/SiC/MoS$_2$



(c) Al/SiC/MoS$_2$/Mg

Figure 4 SEM micrographs of Worn surfaces at 24.5N.

4. CONCLUSIONS

The present investigation on Al based self-lubricating cast composites shows that it is possible to synthesize self-lubricating Al/SiC/MoS$_2$ through a low cost stir casting process. However, bonding between the particles and matrix is a major concern. Addition of Magnesium to Al/SiC/MoS$_2$ results in better bonding and hence, in increased hardness and improved tribological performance of the composites.

5. REFERENCES

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