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Research Article

THE EFFECT OF AGE HARDENING IN THE TRIBOLOGICAL BEHAVIOUR OF ALUMINIUM (LM 25) METAL MATRIX COMPOSITE REINFORCED WITH SIC AND MOS2

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ABSTRACT
This study investigates the tribological behavior of Aluminium (LM 25) Hybrid Metal Matrix Composite (AHMMC) reinforced with SiC (Silicon Carbide) and addition of MoS_2 (Molybdenum disulfide) fabricated by sand casting process. From this study on physical properties and tribological response of Al-SiC composite, addition of 15% SiC to the AHMMC increases its toughness by 25% and that of MoS_2 increases its lubricating properties. This composition exhibits change in variables of co-efficient of friction (COF) with change in normal load giving least sliding wear. The hybrid aluminum matrix composites are heated for different temperatures (350^0C, 400^0C and 450^0C) by aging process to examine the wear properties. From the analysis of scanning electron microscope (SEM), the presence of partial glazed texture and discrete material pull-out indicates dominant adhesion mode of wear. Surface roughness of different temperature aged specimens before and after wear test are also analysed.

Keywords: *Hybrid Metal Matrix Composite (HMMC), SIC (SILICON CARBIDE), MOS_2, Wear Rates, Coefficient Of Friction(COF), Surface Roughness (RA).*

INTRODUCTION
Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. Composites are used not only for their structural properties, but also for electrical, thermal, tribological and environmental applications. Hosking et al. [1] reported that, SiCp were more effective than Al_2O_3 particles for the improvement of wear resistance of Al matrix composites due to the higher hardness, apart from chemical incompatibility. Among modern composite materials, particle reinforced Aluminium Matrix Composites (AMCs) are finding increased application due to their favorable mechanical properties and good wear resistance [2]. Hybrid Metal Matrix Composite (HMMC) has been playing a significant role in engineering applications particularly in light weight materials. Aluminum based metal matrix composite can be an efficient and effective braking material compared to cast iron. But poor wear resistance and high thermal elongation properties of aluminum alloys make them unreliable in the selection of material. The reinforcement of SiCp particulate will enhance the wear behavior and reduce the thermal elongation without any substantial modification of the base material properties.
Aluminum MMCS reinforced with silicon carbide (SICP) particles have up to 20 % improvement in yield strength, a lower coefficient of thermal expansion and a higher modulus of elasticity, and they are more wear resistant than the corresponding non reinforced matrix alloy systems [3]. by varying the matrix, reinforcement and volume fractions, the mmcs can be customized to provide a good coefficient of thermal expansion (CTE) matching for thermal management and thermal conductivity (TC) applications [4]. gurcan and baker [5] and lee et al. [6] also stated better wear resistance of sicp reinforced composites than that of al_2o_3 reinforced composites.

Molybdenum disulfide has very good chemical stability and thermal stability. They can form a highly efficient dry lubricating film. Molybdenum disulfide nanoparticles possess a low friction coefficient, good catalytic activity, and excellent physical properties. They also have a large active surface area, high reactivity, and increased adsorption capacity compared to the bulk material. The area of micro-abrasion is an interesting and relatively recent area in tribo-testing methodologies, where small particles of less than 10 mm are employed between interacting surfaces. It is topical for a number of reasons; its direct relation to the mechanisms of the wear process in bio-tribological applications, ease in conducting tests and the good repeatability of the test results. It has widespread applications in conditions used in the space and offshore industries to bio-engineering for artificial joints and implants. There have been many recent studies on the micro-abrasion performance of materials, ranging from work basic metals to nano structured coatings. However, no significant work is reported on the micro-abrasion resistance of composite materials. Hence, this paper looks at the performance of composite materials with composition of 80% Al, 15% SiCp, 5% MoS_2 in different load condition (2,2.5,3,3.5kgs) and treated in different temperatures (350^0C,400^0C,450^0C) their wear behavior is studied and concluded from the best.
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MATERIALS USED FOR COMPOSITES

As a basis of all experiments a commercial alloy Al LM 25 was obtained in bar form, silicon carbide particulates and graphite are obtained in the powder form. Table 1 shows the chemical composition of the aluminium metal matrix alloy and table 2 shows the details of reinforcement materials.

Table 1 - Chemical composition of the aluminium metal matrix (LM25)

Element	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Al
Content	0.1	0.6	7.5	0.5	0.3	0.1	0.1	0.1	0.05	0.2	90.45

Table 2 - Details of Reinforcements

REINFORCEMENT	**Average grain size [μm]**	**DENSITY (g/cm³)**
SiC_p	45	3.21
MoS_2	42	5.06

The most important have been the non-ferrous lightweight materials for structural use such as aluminum, titanium and magnesium because specific properties of these materials can be enhanced to replace heavier monolithic materials. Aluminum is the most attractive non-ferrous matrix material used particularly in the aerospace and transportation industries where weight of structural components is critical.

FABRICATION

Al/SiC–MoS_2 composites,15% of SiC and 5%MoS_2 by weight were prepared by sand casting technique. A measured amount of silicon carbide particles and graphite was preheated at around 800^0C for 2 hrs to make their surfaces oxidized to achieve better weldability and also to prevent decarburization of SiC and MoS_2 at high temperature. A measured amount of Aluminium alloy (ingots) was melted in the furnace. Pre-heated silicon carbide particles and MoS_2 were added to the aluminium melt. After that, the melt was stirred for 20 min at an average mixing speed of 300-400 rpm to make a vortex in order to disperse the particles uniform in the melt. The SiC particles and MoS_2 are uniformly distributed in the matrix when the processing temperature is around 700^0C to 800^0C as a hold of 10 minutes. After thorough stirring, the

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melt was poured into sand moulds and allowed to cool to obtain cast rods and then machined to 23 mm diameter 12 mm thickness respectively. The cast specimen of 23mm diameter and 12 mm thickness (12 Nos) was used for micro abrasion wear evaluation. Among the 12 specimens, 4 specimens are heated to 350^0C, next 4 specimens are heated to 400^0C and last 4 specimens are heated to 450^0C respectively. Initially all the specimens are heated to 300^0C and maintained it for 2 hours. Then each set of specimens are heated to three different temperatures (350^0C, 400^0C, 450^0C) and maintained it for 1/2 hour each. These specimens are then cooled with oil quenched process.

MATERIALS AND METHODS

Micro-abrasion tests were performed with a commercially available apparatus, the TE-66, micro-abrasion tester (Phoenix tribology Ltd., UK). The configuration has the advantage of accurate control of both normal load (to an accuracy of 70.01N) and sliding speed.

Table 3 - Specifications used in Micro Abrasion test

Parameters	**Size**	**Unit**
Load range	2 to 3.5	N
Diamond ball	15,20,25,32,40	Mm
Metal wheel	50	Mm
Rubber wheel	50	Mm
Abrasive paste	SiC, diamond etc	
Motor	0.15/50-500	kw/rpm

The specimen surfaces were ground and polished by conventional metallographic methods before testing (final grinding and polishing operations were carried out with 4000 grit size abrasive paper). Following the test, the worn specimens were examined by optical microscopy and scanning electron microscopy.

Table 4 - Specimens and Testing Conditions

Specimen sused	Aluminium hybrid metal matrix (80%Al+15%siCp+5%Gr) Specimens
Ball material	Stainless steel (SS-440c, diameter-25mm, supplied by SKF bearings, Hardness—750VHN at 5kg load)
Speed	450 rpm(constant)
Loads	2N,2.5N.3N,3.5N

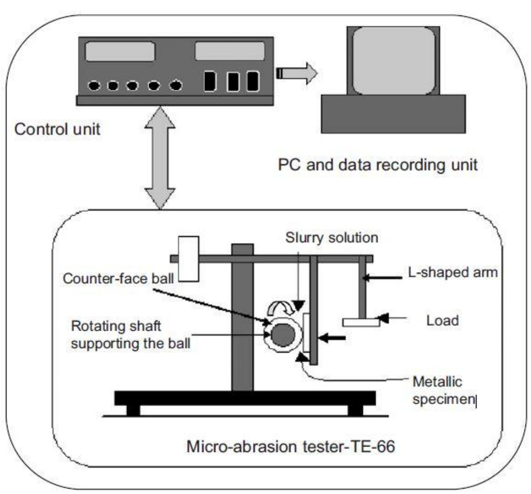

Figure 1. Schematic diagram of microabrasion tester

The experiments are further carried out to different aged specimens. By keeping the speed (450 RPM) constant, the different loads (2N, 2.5N, 3N, 3.5N) are applied to the specimens.

OBSERVATION

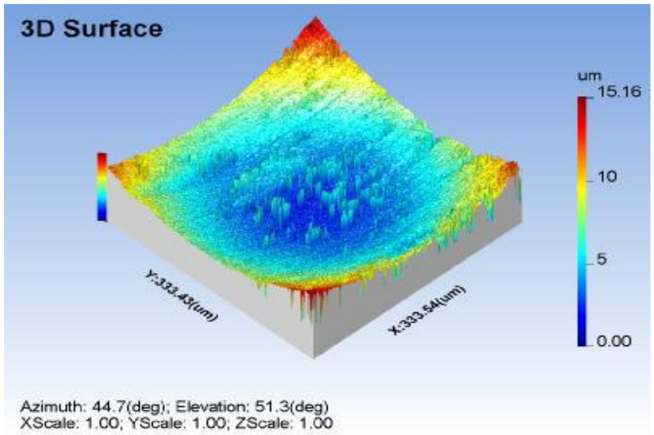

Fig 2 : Typical 3D surface image for spectmen aged at 450 ^{0}C

A. Observation on surface roughness (Ra) values: The following table 5 show the surface roughness Ra values with varying load characteristics and temperatures such as 2kg, 2.5kg, 3kg, 3.5kg.

Table 5 - Surface roughness Ra values

S.No	Temp	Load	Ra values	
			Without load	With load
1	350	2	0.252	1.622
2	350	3.5	0.439	0.623
3	400	2	0.187	0.582
4	400	3.5	0.135	1.02
5	450	2	0.201	0.155
6	450	3.5	0.223	0.232
		MEAN	**0.2395**	**0.705**

B. Observation on wear rates on various loads (2,2.5,3,3.5 kgs) at different temperatures (350,400,450 ^{0}C) : The following table 6 shows the wear rate values of different temperature aged specimens at different applied loads.

Table 6 - Wear rate values

Load (kg)	Wear rates at 350^0 C	Wear rates at 400^0 C	Wear rates at 450^0 C
2	0.0288	0.0222	0.0152
2.5	0.0290	0.0299	0.0188
3	0.0302	0.0324	0.0287
3.5	0.0352	0.0370	0.0310

C. Observation of various loads (2,2.5,3,3.5 kgs) and coefficient of friction At 350^{0}C The following table 7 shows the coefficient of friction values of 350^{0}C aged specimens with respect to different applied loads.

Table 7 - Coefficient of friction values of 350^{0}C

Load (kg)	**CoF1**	**CoF2**	**CoF3**	**CoF4**
2	0.72	0.38	0.82	0.68
2.5	0.43	0.18	0.76	0.70
3	0.78	0.36	0.52	0.95
3.5	0.41	0.99	0.20	0.78

The following table 8 shows the coefficient of friction values of 4000C aged specimens with respect to different applied loads.

Table 8 - Coefficient of friction values of 400^{0}C

Load (kg)	**CoF1**	**CoF2**	**CoF3**	**CoF4**
2	0.92	0.37	0.60	0.19
2.5	0.36	0.74	0.52	0.88
3	0.31	0.48	0.81	0.67
3.5	0.80	0.59	0.35	0.99

Table 9 - Coefficient of friction values of 450^{0}C

Load (kg)	**CoF1**	**CoF2**	**CoF3**	**CoF4**
2	0.76	0.1	0.94	0.26
2.5	0.71	0.18	0.75	0.57
3	0.59	0.73	0.15	0.61
3.5	0.95	0.7	0.64	0.73

RESULTS AND DISCUSSION

A. Wear rates on various loads (2,2.5,3,3.5 kgs) at different temperatures(350^0,400^0,450^0 C)

Table 10 Wear rate values

Sl. No	**Load (kg)**	**Wear rates at 350^0 C**	**Wear rates at 400^0 C**	**Wear rates at 450^0 C**
1	2	0.0288	0.0222	0.0152
2	2.5	0.0290	0.0299	0.0188
3	3	0.0302	0.0324	0.0287
4	3.5	0.0352	0.0370	0.0310

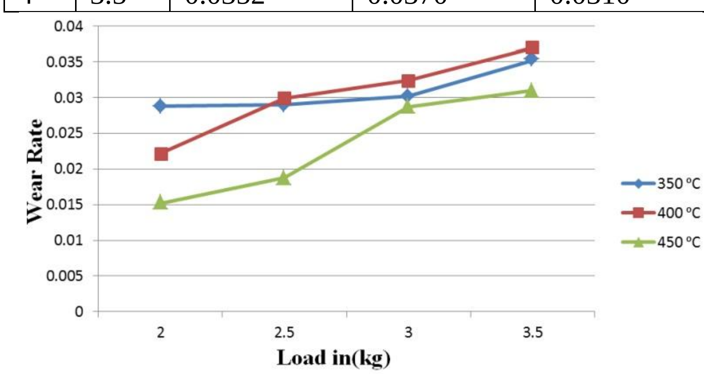

Figure 5. Wear Rate Value Vs Load

From the graph it seen that the wear rate is very less at 450c when compared to 350^{0}C and 400^{0}C.
B. The surface roughness Ra values with varying load characteristics and temperatures such as 2kgs, 2.5kgs, 3kgs, 3.5kgs and 350^{0}C, 400^{0}C. and 450^{0}C.

Table 11 – Before Wear

S.No	Load(kg)	350 ^{0}C	400 ^{0}C	450 ^{0}C
1	2	0.252	0.187	0.201
2	3.5	0.439	0.135	0.223

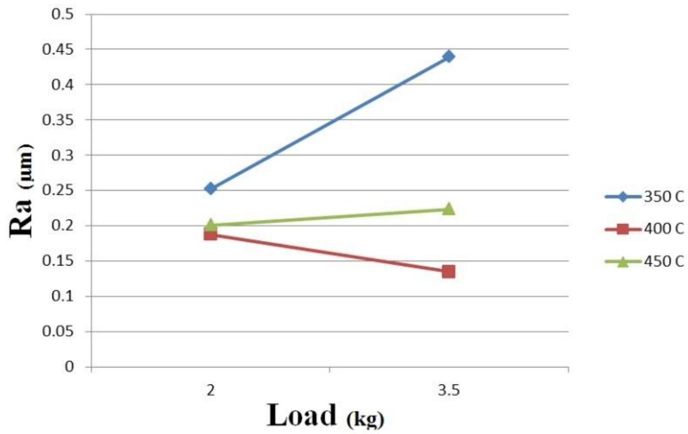

Figure 6. Wear Rate Value Vs Load

Table 12 - After Wear

S.No	Load(kg)	350^{0}C	400^{0}C	450^{0}C
1	2	1.622	0.582	0.155
2	3.5	0.623	1.02	0.232

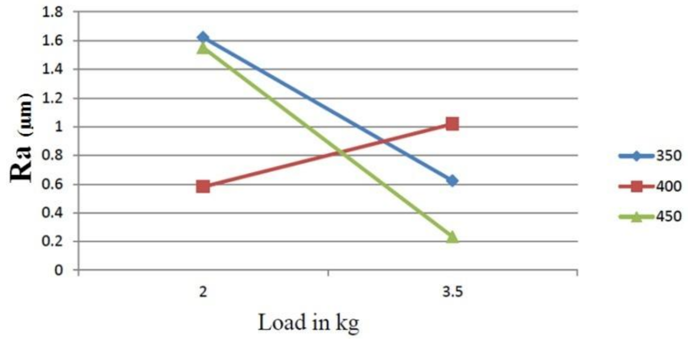

Figure 7. Wear Rate Value Vs Load

Table 13 - Coefficient of friction for Various loads (2,2.5,3,3.5 kgs)

Sl. No	**Load (kg)**	**Mean COF (350^{0}C)**	**Mean COF (400^{0}C)**	**Mean COF (450^{0}C)**
1	2	0.654	0.52	0.662
2	2.5	0.517	0.625	0.652
3	3	0.652	0.5675	0.625
4	3.5	0.595	0.682	0.775

The coefficient of friction is found by using constant sliding velocity and constant speed of 450 rpm and it is increased in 450^0c specimen when compared to the other 2 temperatures. When load increases the COF is found to be increased.

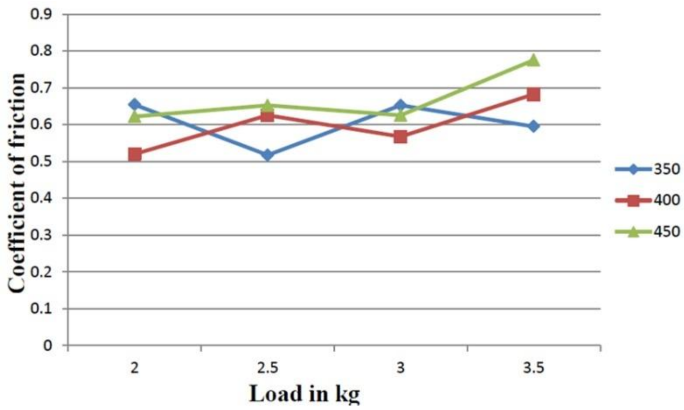

Figure 8. Wear Rate Value Vs Load

CONCLUSION

From the experimental results obtained the following conclusion can be drawn:

1.The surface roughness of the ball significantly affects the wear rates and wear behaviour of the specimens.

2. The wear rates decreases with increasing SiC and MoS2 of the reinforcement, the reason for that is Al (lm25) is having a nature of smooth surface undergoes more wear rate but when it is prepared composite hard SiC and MoS2 particles resist the applied load and forms lesser wear rate.

3. As the load increases the wear rate increases and as the % of reinforcement increases wear rate decreases because SiC and MoS2 particles are crushed and form work harden layer between pin and the counter face.

4. The result also provides that lubricating nature of reinforcement material enhances the wear resistance and this property can be considered as a factor in design of new materials for different application.

5. For the obtained wear property the various wear rates after undergoing aging are (At 350°C the wear rate is 0.0288gm/s,at 400°C the wear rate is 0.0222gm/s, at 450°C the wear rate is 0.0152gm/s).

6.The surface roughness Ra valules is less at the aging temperature increases .So, at 450°C the surface roughness value is less both before and after wear.

REFERENCES

Hosking, F.M., Portillo, F. F., Wonderlin, R. and Mehrabian, R., 1982, " Composites of aluminium alloys: fabrication and wear behavior, ’’ J Mater Sci. 17, 477–98.

N. R. Habbu, September 2000, “Use of Aluminium Silicon Alloys in Automobile Application,” Proceedings of one day Industry Institute Interactive Meet on Al-Si alloys, Development and Application for transport sector, IISC Bangalore.

M. Eslamian, J. Rak, , N. Ashgriz., 2008, “Preparation of Aluminum/Silicon Carbide Metal Matrix Composites Using Centrifugal Atomization Powder Technology, ’’pp.11-20.

T. Huber, H. P. Degischer, G. Lefranc, T. Schmitt., “Thermal Expansion Studies on Aluminum-matrix Composites with Different Reinforcement Architecture of SiC Particles, ’’ Composites Science and Technology 66 2006: pp. 2206 – 2217.

Gurcan, A.B. and Baker, T.N., 1995, “Wear behaviour of AA 6061 aluminium alloy and its composites, ’’ Wear. 188,185– 191.

Lee, 1992, “Wear behaviour of aluminium matrix composite materials, ’’ J Mater Sci. 27, 793–800.

Riahi, A.R. and Alpas, A.T., 2001, "The role of tribo-layers on the sliding wear behaviour of graphitic aluminum matrix composites, '' Wear. 251, 1396–407.
Candan, E., Ahlatci, H. and Cimenog, H., 2001, "Abrasive wear behaviour of Al- SiC composites produced by pressure infiltration technique, '' Wear. 247,133–8.
S C Okumus, S Aslam., 2012, "Thermal Expansion and Thermal Conductivity Behaviors of Al-Si/SiC/graphite Hybrid Metal Matrix Composites (MMCs)," Volume 18, No 4.
Ashutosh. Study of the Age Hardening Behavior of Al- 4.5Cu/ZrSiO4 Composite in Different Quenching Media [Dissertation], Thapar University, Patiala, 2007, p. 26.
S. Ren, X. He, X. Qu, I. Humail, Y. Li. Effect of Mg and Si in the Aluminum on the Thermo-mechanical Properties of Pressureless Infiltrated SiCp/Al Composites Composites Science and Technology.