

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

Wear Behaviour of Al 6061-SiC-Gr Hybrid Composites

Fakruddinali J Y¹, Noor Ahmed R², K S Badarinarayan², Abrar Ahamed³

PG Scholar, Dept. of Mechanical Engineering, M S Engineering College, Bangalore, Karnataka, India¹

Professor, Dept. of Mechanical Engineering, M S Engineering College, Bangalore, Karnataka, India²

Associate Professor, Dept. of Mechanical Engineering, Vidya Vikas Institute of Engineering & Technology, Mysore,
Karnataka, India³

ABSTRACT: Al6061 matrix hybrid composites reinforced with Silicon carbide and Graphite particles were manufactured by liquid metallurgy route. Tribological properties of both matrix alloy and developed hybrid composites have been evaluated. Dry sliding friction and wear tests were carried out using pin on disk type machine over a load range of 10–40N and sliding velocities of range 0.3–1.2m/s. Results revealed that, Al6061–SiC-Gr hybrid composite exhibited lower wear rate compared to matrix alloy. Wear rates of both matrix alloy and developed composites increased with increase in load and wear rate of the matrix alloy increased with increase in sliding velocity. However, for the hybrid composites the wear rate increased initially upto a sliding velocity of 0.9 m/s and thereafter there was a decrease in wear rate.

KEYWORDS: Hybrid Composites, Reinforcements, Tribological Properties.

I. INTRODUCTION

In recent years, Al based composites are gaining wide spread importance in several high tech engineering applications. Extensive research have been carried out on the mechanical properties of Al based conventional composites involving a single reinforcement. Use of single reinforcement in Al matrix may sometimes lead to deterioration in its physical properties [1]. However, to overcome the drawback of single reinforced composites, the concept of use of two different types of reinforcements is being explored in Al matrix. Of the two reinforcements normally one of the reinforcement will be a hard phase and the other being a soft lubricating phase. Hard reinforcements such as SiC, TiO₂, Al₂O₃, TiB₂ etc will enhance the hardness and abrasive wear resistance of Al while it has a negative effect on the machinability and conductivity of Al [2]. To offset these effects, reinforcements like graphite which is a solid lubricant and possessing good conductivity can be dispersed in Al along with hard reinforcements. However, meagre information is available as regards the processing and characterization of these hybrid Al composites.

There are various approaches to synthesize aluminium based metal matrix composites viz., diffusion bonding, powder metallurgy route, vortex method, squeezes casting, liquid infiltration, Osprey process, disintegrated melt deposition process, laser composite surfacing, in-situ techniques etc. Various researches have adopted the above techniques in developing varieties of metal matrix composites. Further, of the several approaches to synthesize aluminium based composites liquid metallurgy route is the most suitable and economical technique [3].

In the light of the above, the present investigation is aimed at fabrication of Al based hybrid composites using Al 6061 as matrix reinforced with varied proportions of SiC and graphite powders. Subsequently the effect of reinforcing SiC/Gr particles on the matrix alloy is investigated in terms of microstructure and tribological properties.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

II. MATERIALS

Commercially available Al6061 alloy was procured from Fenfee Metallurgicals, Bangalore, in the form of ingots. Chemical composition analysis of matrix alloy was carried out at M/s Raghavendra Spectro Metallurgical Laboratory, Bangalore. The specimens were machined to cylindrical form of diameter 20 mm and thickness of 25 mm. The specimens were tested using Optical Emission Spectrometer (BAIRDAS). The chemical composition of Al6061 alloy used in the present work subjected to chemical composition analysis is given in Table 1. SiC and Gr powders in the ratio of 5:1 and 10:1 respectively were used as reinforcements.

Table. 1: Chemical composition of procured Al6061 alloy

Si	Fe	Cu	Mn	Ni	Pb	Zn	Ti	Sn	Mg	Cr	Al
0.43	0.43	0.24	0.139	<0.05	0.024	0.006	0.022	0.001	0.802	0.184	Balance

III. METHODS

Al6061 based composites have been prepared by liquid metallurgy route, the composite was prepared by well established metallurgy technique. A batch of 4.5 kg of aluminium 6061 matrix alloy was melted using a 6 kW electric furnace. The metal was degassed using commercially available chlorine based tablets (Hexachloroethane). The molten metal was agitated with a mechanical stirrer rotating at a speed of approx. 300 rpm to create a fine vortex. The reinforcements used in the present study are silicon carbide and graphite particles. Preheated reinforcement particle (preheated to 500°C for 30 min) were added slowly into the vortex while continuing the stirring process. The stirring duration was 10 min. The composites melt maintained at a temperature of 700°C was then poured into preheated metallic moulds. The stirrer blades were made of steel and were coated with ceramic material to minimize the iron pickup by the molten metal.

The wear test of both the matrix alloy and the developed hybrid composites were studied on the standard pin on disc wear test rig using wear test samples for different loads. The test specimens for wear test were prepared as per ASTM G99 with pin length of 26mm and diameter of 8mm, while the disc was high carbon high chromium steel having a hardness of Rc 60. Before loading the samples, the counter disc is thoroughly cleaned with acetone. The weight loss of the sample was recorded by weighing the sample before and after test for a sliding duration of 30 min. Wear studies were conducted at various loads ranging from minimum of 10N to a maximum 40N. The surface roughness of the test specimen and the disc were maintained at 1 micron Ra. The sliding velocities were varied from 0.3 m/s to 1.2 m/s. The volumetric wear rate of the cast Aluminum-6061 and its cast hybrid composites specimen is determined using the weight loss method.

IV. RESULTS AND DISCUSSION

Fig.1 shows the microphotographs of both the matrix alloy Al6061, Al 6061-5wt%SiC/1wt%Gr and Al 6061-10wt%/1wt%Gr hybrid composites. The microstructure clearly indicates fairly uniform distribution of reinforcement with minimal porosity in the matrix alloy in all the cast composite systems studied [4]. However, the pores observed in the as cast composite are mostly associated with the reinforcement particles and particle clusters. The latter feature is especially pronounced in the composite with higher weight fraction of the reinforcement in the composites. Further, good bond exist between the matrix and the particle reinforcement.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

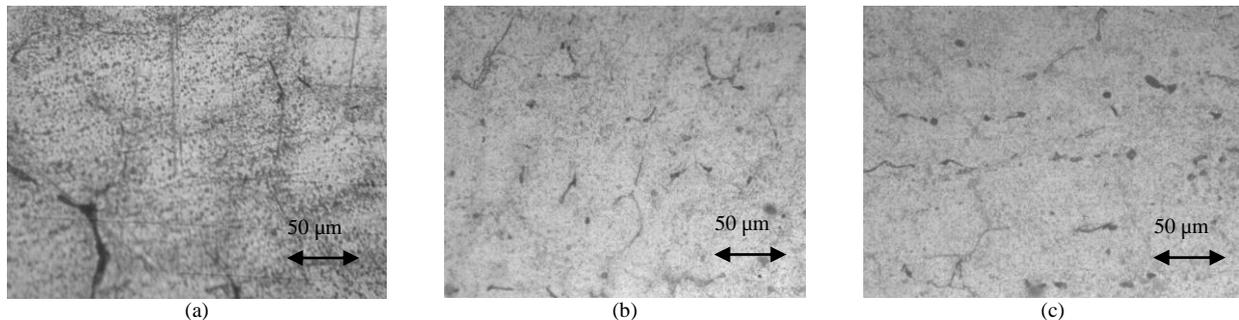


Fig. 1: Optical micrographs of Al 6061 alloy and its hybrid composites (a) Al 6061 alloy, (b) Al 6061-5wt%SiC/1wt%Gr Composite and (c) Al 6061-10wt%SiC/1wt%Gr Composite

Fig. 2 shows the variation of microhardness of cast Al6061, Al 6061-5wt%SiC/1wt%Gr and Al 6061-10wt%/1wt%Gr hybrid composites. It is observed that an increase in weight percentage of SiC in the matrix alloy results in improved hardness of the composite. An increase of about 14.8% and 23.5% have been observed for Al 6061-5wt%SiC-1wt%Gr and Al 6061-19wt%SiC-1wt%Gr hybrid composites respectively when compared with base Al 6061 alloy. The improvement in the hardness can be attributed to the following factors.

- (a) Addition of hard phase into soft and ductile matrix will always result in improvement in the hardness of the matrix alloy [5].
- (b) Increased density of dislocation at the matrix- reinforcement interfaces will lead to lowering of mobility of dislocation which in turn retards the plastic deformation thereby resulting in higher hardness.
- (c) The increased dislocation density can mainly be attributed to the difference in the coefficient of thermal expansion of Al6061 and SiC which is in the ratio of 10:1 [6].

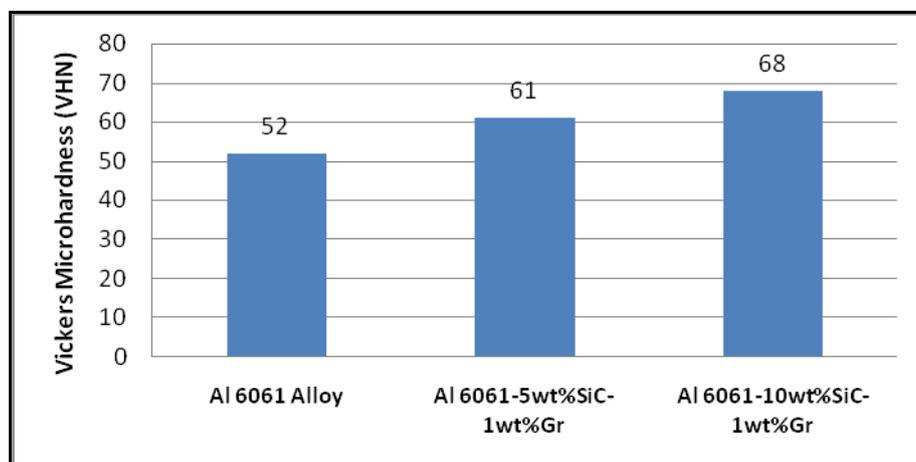


Fig. 2: Variation of microhardness with increase in reinforcement

Fig. 3 shows the comparison of wear rate of Al 6061 alloy, Al 6061-5wt%SiC/1wt%Gr and Al 6061-10wt%/1wt%Gr hybrid composites. It is clearly observed that the dispersion of SiC hard phase in soft aluminium matrix tends to reduce the wear rates of Al6061 alloy. Wear rate of Al6061-SiC-Gr composites decreases with increased content of SiC particles. A decrease of about 24.5% and 57.9% in wear rate is observed for Al6061-5wt%SiC-1wt%Gr and Al6061-10wt%SiC-1wt%Gr hybrid composites respectively when compared with Al6061 matrix alloy. Several investigators have reported that incorporation of hard particles such as SiC and alumina in wrought and cast aluminium alloys improves the sliding wear resistance of these alloys [7-11]. This drastic reduction in wear rate can be attributed to the following reasons.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

- An improved hardness of composites on incorporation of SiC which is a hard phase. An increase in hardness results in improvement of wear and seizer resistance of materials [12].
- Further there is experimental support and practical evidence to suggest that the onset of adhesive process such as scuffing and seizer are restricted by increase in hardness of materials [13].
- Existence of good bond between the matrix and SiC particles. Interfacial bond between matrix and particle reinforcement plays a significant role in wear process. It is reported that wear resistance decreased with increased alumina contents for Cu-Al₂O₃ composites. The detrimental effects of alumina particles on the wear resistance of the composites have been attributed to poor interfacial bond between copper and alumina. Similar observations have been made in case of TiC reinforced composites [13].
- Presence of graphite in the hybrid composites which is good lubricant will further enhance the wear resistance property of the hybrid composites.

Further, decrease in the wear rate of the hybrid composites can also be attributed to higher load bearing capacity and fracture toughness of the SiC particles. On the other hand, from the micrograph it is clear that a good bond exists between matrix alloy and SiC particles. Thus, presence of good bond minimizes the possibility of decohesion or pull out of reinforced phase from the matrix alloy there by limiting the situation of three body abrasive wear, which otherwise would have resulted in higher material removal [2].

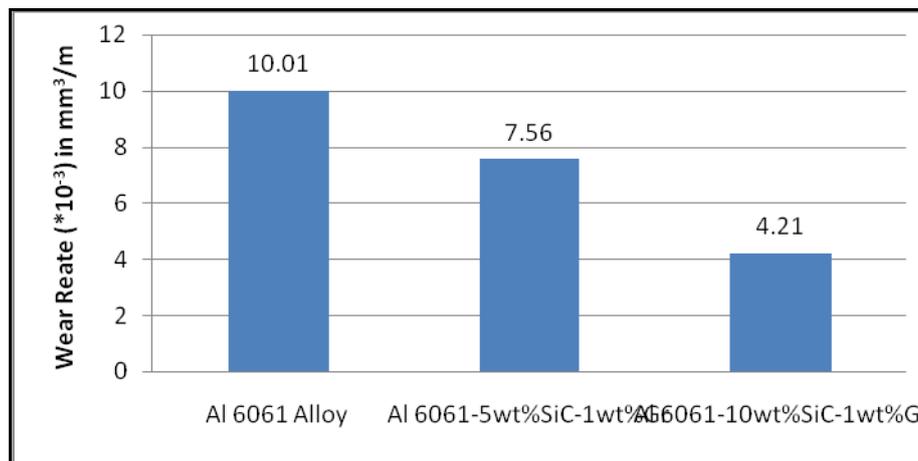


Fig.3: Effect of reinforcement on volumetric wear rate of Al 6061 alloy

Fig. 4 shows the variation of wear rate of Al 6061 alloy, Al 6061-5wt%SiC/1wt%Gr and Al 6061-10wt%/1wt%Gr hybrid composites with increase in load. It is observed that, with increase in load there is increase in wear rate for both the matrix alloy and Al 6061-SiC-Gr hybrid composite. However at all the loads studied, the wear rate of Al 6061-10wt%SiC-1wt%Gr hybrid composite were lower when compared with the matrix alloy. The increase in wear rate can be attributed to the fact that, increase in load will result in onset of delamination leading to higher wear rates of both matrix alloy and its composites as observed by other researchers also [13, 14]. Further, it is reported that [15], at higher loads, since the severity of surface contact is very high, the stresses exceeds the fracture stress of the reinforced particles, leading to fracture of the reinforced phase. Sahin et al [16] has reported that there is an increase in wear rates for both the Al-Si matrix alloy and SiC reinforced composites with increase in load. It is reported that for the matrix alloy, the soft asperities were easily deformed and sheared under the repeated loading conditions while the hard asperities on the counter face or hard particles between the sliding surface plough and cut the soft surfaces, and resulted in giving more damage to the surface.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

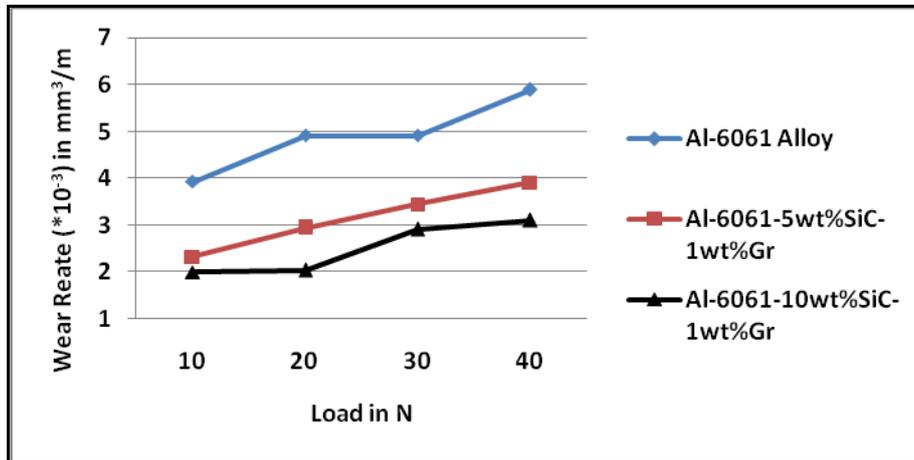


Fig.4: Effect of load on volumetric wear rate of Al 6061 alloy and its hybrid composites

Variation of wear rate of Al 6061 alloy, Al 6061-5wt%SiC/1wt%Gr and Al 6061-10wt%/1wt%Gr hybrid composites with increase in sliding velocity is shown in Fig. 5. It is observed that the wear rate of Al6061 alloy increases with increase in sliding velocity. However, it is observed that, for Al 6061-SiC-Gr composites the wear rate increases linearly upto a sliding velocity of 0.9 m/s and decreases thereafter. At all the sliding velocities studied the Al 6061-SiC-Gr hybrid composites have lower wear rates when compared to Al 6061 matrix alloy. This decrease in wear rate after a sliding velocity of 0.9 m/s can be attributed to the fact that increase in sliding velocity will result in higher relative motions leading to rise in surface temperatures of the sliding members. An increase in surface temperature promotes oxidation of the transformed iron layers from the counter disc on the pin surface. Presence of such iron oxide leads to lubricating effects. As discussed earlier, it can also be quoted that due to the presence of Graphite in the hybrid composites which is a solid lubricant will lead to reduction in wear rates. Further, it can be stated that the extent of grooving on the pin surfaces will be reduced because of the formation of the beneficial tribological film also referred to as MML as a consequence of which the size of the debris tends to be smaller in size at larger sliding velocity. It is the size of the debris that dictates the wear rate of the materials. Smaller the size of wear debris, lower will be the wear rate. Basavarajappa et al. [17] have reported that increase in sliding velocities causes increase in hardness of contact surface due to higher degree of compaction of MML. However, at a particular critical speed, hard top surface layer is removed and leads to increased wear rate.

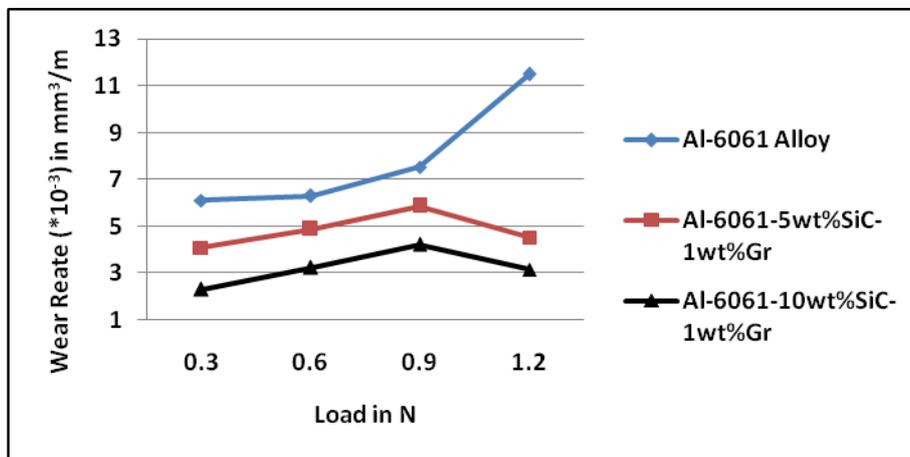


Fig.5: Effect of sliding velocity on volumetric wear rate of Al 6061 alloy and its hybrid composites

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

V. CONCLUSION

- Liquid metallurgy route was used to cast Al 6061 alloy and Al 6061-SiC-Gr hybrid composites.
- SiC and Graphite particles are distributed uniformly within the matrix alloy.
- Hardness of the composites increased with increasing SiC content in the matrix alloy.
- The hybrid composites exhibited superior wear resistance when compared with the base Al 6061 matrix alloy under all the test conditions.
- Increase in applied normal load resulted in increase in wear rates of both the matrix alloy and the hybrid composites.
- Increase in applied sliding velocity resulted in increase in wear rates of Al 6061 matrix alloy; however, for the hybrid composites the wear rate increased up to a sliding velocity of 0.9 m/s and decreased thereafter.

REFERENCES

- [1] Grigoris Kiourtsidis, E., Stefanos Skolianos, M., 2002, "Wear Behaviour of Artificially Aged AA2024/40 μ m SiC_p Composites in Comparison with Conventionally Wear Resistance Ferrous Materials" *Wear*, Vol. 253, pp. 946 – 956.
- [2] C.S. Ramesh, Abrar Ahamed, "Friction and wear behaviour of cast Al 6063 based in situ metal matrix composites", *Wear*, Vol. 271, Issues 9–10, 2011, Pp. 1928-1939.
- [3] C.S. Ramesh, Abrar Ahamed, B.H. Channabasappa, R. Keshavamurthy "Development of Al 6063–TiB₂ in situ composites", *Materials & Design*, Volume 31, Issue 4, April 2010, Pages 2230-2236.
- [4] Tiejun Ma, Hideki Yamaura, Donald A.Koss and Robert C.Voigt, "Dry sliding wear behavior of cast SiC-reinforced Al MMCs", *Materials Science and Engineering A*, V 360 (1-2) (2003) 116-125.
- [5] H.B. Niranjana, K.R. Suresh, Martin Jobraj, M.P. Choudiah, "Tensile and corrosive properties of Al Hematite composite" in Proc. of the First Australasian conference on Composite Materials (ACCM-1), Osaka, Japan, 7-9 October (1998), 546.
- [6] M.K. Surappa, "Aluminum Matrix composites: Challenges and opportunities" *Sadhana* 28 1-2 / February, (2003).
- [7] N. Saka and D.P. Karalekas, "Friction & wear of particle reinforced metal ceramic composition", 'Wear of materials 1985', (Eds: K.C. Ludema), (1985), 784-793, New York, ASME.
- [8] F.M. Hoskins, P.O. Aillo, F.F. Woderlin and R. Mehrabian, "Composites of Aluminium alloys: Fabrication and wear behaviour", *J. Material Science*, (1982), 17, 477-498.
- [9] M.K. Surappa, S.V. Prasad and P.K. Rohatgi, "Wear and abrasion of cast Al-alumina particle composites", *Wear*, 77, (1982), 295-302.
- [10] K. Anand and Kishore, "On the wear of aluminium corandum composites", *Wear*, 85, (1983), 163-169.
- [11] S.V. Prasad and R.K. Rohatgi, "Tribological properties of aluminium alloy composites", *J. of Materials*, 39, (11), (1987), 22-26.
- [12] C.S. Ramesh, S.K. Seshadri, K.J.L. Iyer, "A survey on aspects of wear of metals", *Indian J. of Technol.*, 29, (1991), 179-185.
- [13] C.S. Ramesh, K.J.L. Iyer, "Tribological characteristics of nickel composite coatings", *Wear*, 255, (2003), 893-902.
- [14] O.P. Modi, B.K. Prasad, A.H. Yegneswaran, M.L. Vaidya, "Dry sliding Wear behavior of squeeze cast Aluminum alloy- Silicon carbide composites". *Material Science Engineering* 151 (1992) 235-245.
- [15] G. Levy, R.G. Lingford, L.A. Mitchell, *Wear behaviour and mechanical properties: the similarity of seemingly unrelated approaches*, *Wear*, Vol 21, 1972, pp 167–177.
- [16] Y. Sahin, "Tribological behaviour and wear surface analysis of metal matrix composites", *Journal of material Sci.*, 34(1999) 875-880.
- [17] S. Basavarajappa, G. Chandramohan, A. Mahadevan, M. Thangavelu, R. Subramanian, P. Gopalakrishnan, "Influence of sliding speed on the dry sliding wear behavior and the subsurface deformation on hybrid metal matrix composites". *Wear* 262 (2007) 1007–1012.