Ruban et al. 2016. *Int. J. Vehicle Structures & Systems*, 8(2), 108-111
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.8.2.09

International Journal of
Vehicle Structures & Systems
Available online at www.maftree.org/eja

Effect of Dry Sliding Wear Behaviour of AA6061/ZrB_2/SiC Hybrid Composite

S. Rajesh Ruban[a], K. Leo Dev Wins[b], J. David Raja Selvam and A. Arun Richard

Karunya School of Mech. Sciences, Karunya University, Coimbatore, India
[a]Corresponding Author, Email: rajeshruban@karunya.edu
[b]Email: leo@karunya.edu

ABSTRACT:

This paper investigates the dry sliding wear behaviour of AA6061/ZrB_2/SiC hybrid composite prepared by the stir casting. A pin-on-disc wear apparatus was used for this study. The effect of ZrB_2 and SiC particulate content and normal load on wear rate was analyzed. The insitu fabricated ZrB_2 and the reinforced SiC particles enhance the wear resistance of the AA6061 composite. The worn surface analysis of the composite as a function of ZrB_2 and SiC particulate content and normal load are also presented.

KEYWORDS:

Metal matrix composite; ZrB2 and SiC; Normal load; Wear rate; Pin-on-disc

CITATION:

S.R. Ruban, K.L.D. Wins, J.D.R. Selvam and A.A. Richard. 2016. Effect of Dry Sliding Wear Behaviour of AA6061/ZrB_2/SiC Hybrid Composite, *Int. J. Vehicle Structures & Systems*, 8(2), 108-111. doi:10.4273/ijvss.8.2.09

1. Introduction

In general, the incorporation of hard ceramic particles into the aluminium matrix improves the wear resistance of aluminium alloys. Due to this metal matrix composites (MMC) are progressively replacing aluminium alloys in many applications where components slide against each other. The sliding action results in wear of components which is influenced by several factors such as the speed, the running hour and the load acting on the component [1-3]. It is essential to estimate the effect of these factors on the wear rate of composites. The wear rate of traditional aluminium alloys reinforced with SiC and Al_2O_3 particles were studied extensively by several researchers [5-8]. But the sliding wear behaviour of insitu formed ZrB_2 and reinforced SiC particles composites have not been explored in sufficient depth. Aluminium Matrix Composites (AMCs) are currently prepared by a number of methods including powder metallurgy, mechanical alloying, squeeze casting, compo casting, stir casting etc [7, 8]. Liquid method of processing is effective owing to its simplicity, ease of adoption, and applicability to large quantity fabrication. Liquid method of processing involves either adding ceramic particles externally to the molten metal or synthesizing in the melt itself. The former is known as stir casting while the latter is called as in-situ fabrication. In-situ fabrication involves a chemical reaction of inorganic salts or metallic powders with the molten metal and ceramic particles are formed inside the melt. The surface of the particle produced in the in-situ process tends to be free of contamination which improves the interfacial bonding strength. Uniform distribution of fine size of particles is achieved without the need for the addition of wetting agent [9].

Abrasive wear resistance of alloy containing ZrB_2 is superior to that of the base aluminium alloy [9-12]. The base alloy wears primarily by micro cutting but the composite wears by micro cutting and delamination caused by crack propagation below the rubbing surface through interfaces of ZrB_2 and SiC and silicon particles with the matrix [14, 15]. Composites reinforced with narrow size range ZrB_2 particle exhibit superior mechanical properties and wear resistance compared to composites with wide size range particles [16, 17].

2. Experimental procedure

AA6061/ZrB_2/SiC hybrid composites were prepared by the stir casting technique. The proportion of ZrB_2 as 0, 2 and 4% by weight is mixed with 5% by weight of SiC particulates. The detailed process parameter for the fabrication of the AMCs is available in previous work done by author [4]. The cast aluminium 6061 alloy as well as the composites reinforced with ZrB_2 and SiC particles was tested for their wear behaviour in the cast conditions. Specimens were prepared from the castings to carry out microstructural characterization [17]. Specimens of size 10x10x30 mm were obtained from the castings having different content of ZrB_2 and SiC. The dry sliding wear tests were conducted on a pin-on-disc wear testing machine (TR-20, DUCOM) as shown in Fig. 1 according to the ASTM G99-04 Standard. Fig. 2 shows the wear testing specimen. The polished surface of the pin was slid on a hardened chromium steel disc. The tests were carried out at different loads (10, 20, 30, 40 and 50 N). The sliding speed and sliding distance was maintained at 1.2 m/s and 1500 m respectively for all the tests. A computer-aided data acquisition system was used to monitor the loss of height. The volumetric loss was computed by multiplying the cross section of the test pin with its loss of height. Worn surface of selected specimens was observed using scanning electron microscope (JEOL-JSM-6390).

Fig.1: Pin-on-disc experimental setup

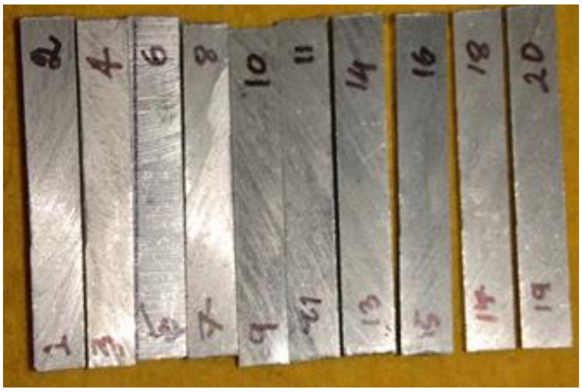

Fig. 2: Wear test specimen

3. Results and discussions

Fig. 3 (a) and (b) shows the wear rate results of base alloy and AMC with 0, 2 & 4% by weight of ZrB2 and constant 5 % by weight of SiC content. It was observed that wear rate decreases with increasing ZrB_2 and SiC content. The wear rate increases as the load increases. It is evident from Fig. 3 (a) that the addition of 2% wt. ZrB_2 and 5% wt. SiC to the base alloy decreases the wear rate by about 1.35 times for all the loads studied. The lower wear rates in composites with higher amount of ZrB2 and SiC particles can be attributed to the high peak hardness and good interfacial bond of the AMCs. In composites with coarse particles, the interfacial strength is high due to large surface bonding which avoids particle pull out and the matrix holds the particle strongly until the particles break down into small particles. This may be due to the breakage of the particles at a relatively faster rate due to the large size of the particles. Microthermal softening of matrix material may also occur at high speeds, which further reduces the bonding strength of ZrB_2 and SiC with matrix material. However, the decrease in wear rate with the increase in amount of ZrB_2 and SiC particulate is not linear, which may be attributed to the complex processes occurring during the wear of the composites. The addition of ZrB_2 and SiC particles improves the hardness of the matrix alloy which reduces the rate of material removal. Due to the difference in thermal expansion between matrix alloy AA6061 and reinforcement tends to append high density of dislocations around ZrB_2 and SiC particles during solidification. The interaction between ZrB_2 and SiC particles and dislocations enhances the wear resistance.

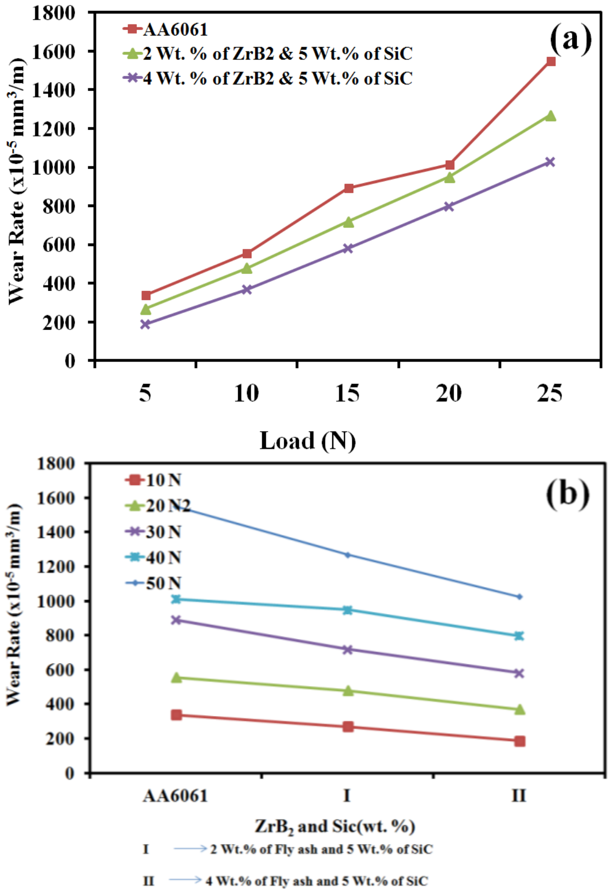

Fig. 3: Wear rate of fabricated AMC as a function of (a) ZrB_2 and SiC content and (b) Normal load

Archard law of wear equation states that the wear rate increases linearly with increasing applied pressure [12]. The applied pressure increases when the normal load increases. Two counter surfaces involve in relative motion during sliding under normal load. Both the surfaces are not perfectly smooth and contain asperities in large number. The shape, height and sharpness of the asperities vary in the same material. During the initial period of sliding those asperities whose height is more than the critical value penetrate deeply into the softer surface of the pin and induce micro ploughing. The fracture, deformation and fragmentation of asperities occur. As the normal load increases, the depth of penetration of hard asperities to the softer pin increases. A higher degree of material transfer between the counter surfaces takes place. The tendency to subsurface deformation and micro cracking increases with the increase in normal load. Particle fragmentation is another reason for the increased wear rate. The rate of fragmentation increases as the normal load increases. The normal load also influences the contact between the counter surfaces [13]. The degree of contact determines the degree of frictional heat generated. The contact becomes intimate with increased normal load and more frictional heat is accumulated at the interface resulting in softening of the pin surface. It becomes easier for the asperities on the counter surface to penetrate into the surface of the softened pin causing increased wear rate.

Scanning electron microscopy (SEM) of wear particles collected from continuous tests showed large particle agglomerates. These agglomerates consist of sub-micron and micron-sized particles in a variety of shapes. Fig. 4 (A) and (B) are SEM micrographs of wear particles agglomerates generated during wear test. It can be seen that the grooves are deeper in the base alloy as compared to the composites tested under similar conditions (50 N) due to the absence of hard ZrB_2 and SiC particles in the former. Also the wear surfaces in the steady state wear regime in the base alloy seem to be quite smooth as compared to the composites. This can also be attributed to the absence of ZrB_2 and SiC particles which otherwise causes the micro ploughing of surface in contact during wear making the surface rough.

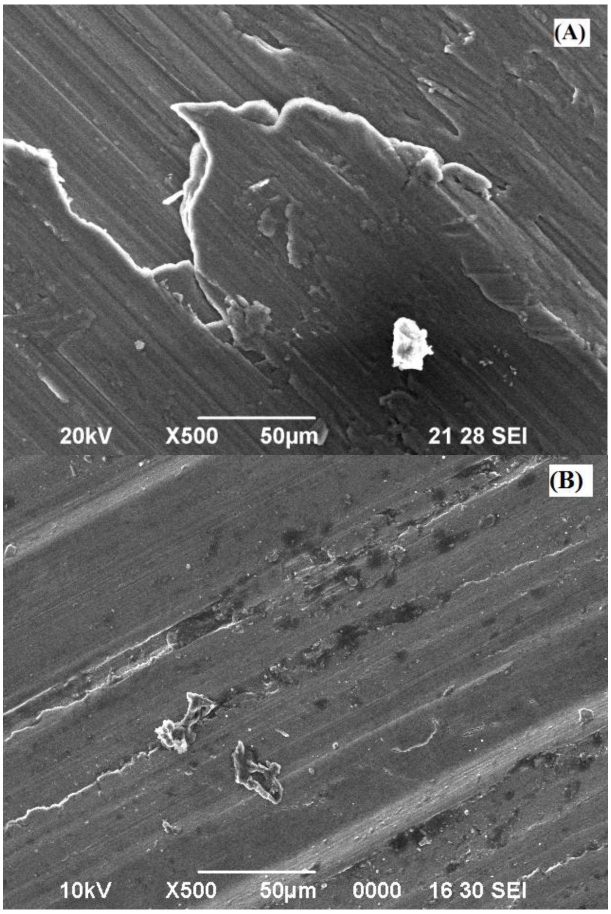

Fig. 4: SEM of the wear surface of the fabricated composite containing content of ZrB_2 and SiC: (A) 0 % wt. (B) 4 % wt. ZrB_2 and 5% wt. of SiC

Fig. 5(A) and (B) reveal the SEM micrographs of the worn surface of the fabricated composite at normal loads of 10 N and 50 N respectively. In Fig. 5(A), the degree of development of cracks on the worn surface is minimum at normal load of 10 N. Relatively smoother and continuous wear grooves as well as some damaged surfaces are observed. The worn surface exhibits micro ploughing of counter surface on the pin. Flaky shaped wear debris is formed as a result of propagation of cracks and fragmentation of asperities. The delamination of the matrix alloy is visible. In Fig. 5 (B), the degree of formation of cracks on the worn surface is more pronounced at normal load of 50 N. The propagation of both longitudinal and transverse cracks is clearly visible. The grooves and cavities are deeper compared to the wear surface at normal load of 10 N. The cavities are formed due to delamination and tearing of surface materials. The deformation of subsurface is also observed. The appearance of the worn surface indicates that it has been subjected to higher frictional heat.

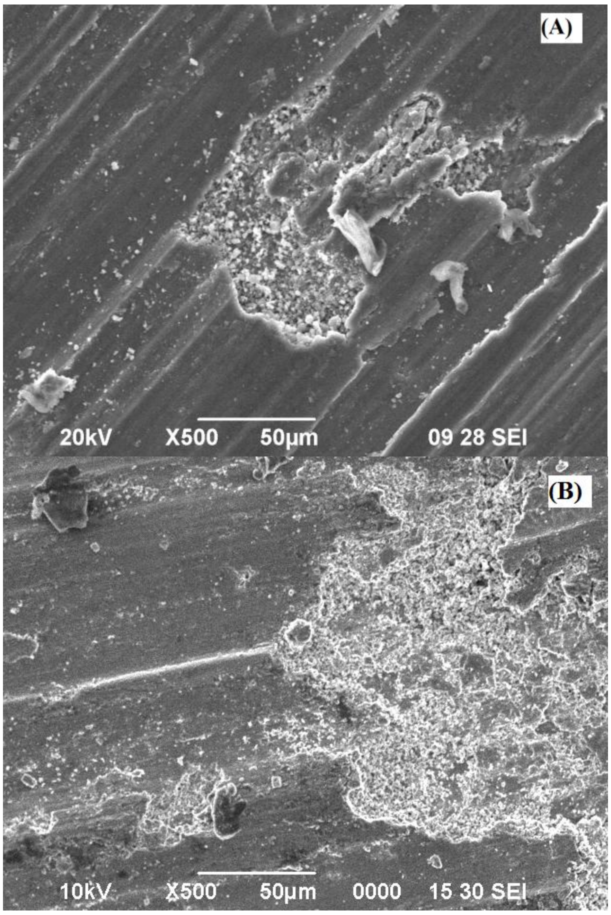

Fig. 7: SEM of the worn surface of AA6061 with 4% wt. ZrB_2 and 5 % wt. SiC AMC tested at normal load: (A) 10 N (B) 50 N

4. Summary

The dry sliding wear behaviour of AA6061/ZrB_2 and SiC compocast fabricated composite was tested using a pin-on-disc wear apparatus. The effect of ZrB_2 and SiC particulate content and normal load on the wear rate of the fabricated AMC was studied. The compocast fabricated ZrB_2 and SiC particles improved the wear resistance of the composite. The dry sliding wear behaviour of the composite was observed to be nonlinear. The wear rate of the composite was observed to bear a proportional relationship with normal load.

REFERENCES:

[1] A. Heinz, A. Haszler, C. Keidel, S. Moldenhauer, R. Benedictus and W.S. Miller. 2000. Recent development in aluminium alloys for aerospace applications, *Materials Science and Engineering: A*, 280(1), 102-107. http://dx.doi.org/10.1016/S0921-5093(99)00674-7.

[2] C. Krishnaraj, G. Sundaram, C. Karthick Kumar and K. Kathirvel. 2015. Analysis of machining and surface finishing of various materials in EDM, *ARPN J. Engg. and Applied Sciences*, 10(14), 6140-6146.

[3] D.B. Miracle. 2005. Metal matrix composites - From science to technological significance, *Composites Science and Technology*, 65(15), 2526-2540. http://dx.doi.org/10.1016/j.compscitech.2005.05.027.

[4] A.P. Sannino and H.J. Rack. 1995. Dry sliding wear of discontinuously reinforced aluminium composites, *Wear*, 189(1), 1-19. http://dx.doi.org/10.1016/0043-1648(95) 06657-8.

[5] S.R. Ruban, L.D. Win, J.D.R. Selvam and S. Kiran. 2015. Fabrication and characterization of insitu formed ZrB2 and SiC particulate reinforced A6061 matrix composites, *Int. J. Applied Engineering Research*, 10(85), 537-542.

[6] C. Krishnaraj and R.V. Vignesh. 2015. Characterization of hybrid black toner using the parameters waste toner and Nano phase carbon, *ARPN J. Engineering and Applied Sciences*, 10(14), 6135-6139.

[7] J.B. Fogagnolo, M.H. Robert, E.M. Ruiz-Navas and J.M. Torralba. 2004. 6061 Al reinforced with zirconium diboride particles processed by conventional powder metallurgy and mechanical alloying, *J. Materials Science,* 39(1), 127-132. http://dx.doi.org/10.1023/B: JMSC.0000007736.03608.e5.

[8] T.P.D. Rajan, R.M. Pillai, B.C. Pai, K.G. Satyanarayana and P.K. Rohatgi. 2007. Fabrication and characterisation of Al-7Si-0.35 Mg/fly ash metal matrix composites processed by different stir casting routes, *Composites Science and Technology*, 67(15), 3369-3377. http://dx.doi.org/10.1016/j.compscitech.2007.03.028.

[9] S.C Tjong and Z.Y. Ma. 2000. Microstructural and mechanical characteristics of insitu metal matrix composites, *Materials Science and Engineering*, 29(3), 49-113. http://dx.doi.org/10.1016/S0927-796X(00)000 24-3.

[10] J.K. Sonber, T.S.R. Ch. Murthy, C. Subramanian, S. Kumar, R.K. Fotedar and A.K. Suri. 2011. Investigations on synthesis of ZrB2 and development of new composites with HfB2 and TiSi2, *Int. J. Refractory Metals and Hard Materials*, 29(1), 21-30. http://dx.doi.org/10.1016/j.ijrmhm.2010.06.007.

[11] S.L. Zhang, Y.T. Zhao, G. Chen, X.N. Cheng and X.Y. Huo. 2008. Fabrication and dry sliding wear behaviour of insitu Al-K2ZrF6-KBF4 composites reinforced by Al3Zr and ZrB2 particles, *J. Alloys & Compounds*, 450(1), 185-192. http://dx.doi.org/10.1016/j.jallcom.2006.10.066.

[12] G. Naveen Kumar, R. Narayanasamy, S. Natarajan, S.P. Kumaresh Babu, K. Sivaprasad and S. Sivasankaran. 2010. Dry sliding wear behaviour of AA 6351-ZrB2 insitu composite at room temperature, *Materials & Design*, 31(3), 1526-1532. http://dx.doi.org/10.1016/j. matdes.2009.09.017.

[13] I. Dinaharan, N. Murugan and S. Parameswaran. 2011. Influence of insitu formed ZrB2 particles on microstructure and mechanical properties of AA6061 metal matrix composites, *Materials Science and Engineering:* A, 528(18), 5733-5740. http://dx.doi.org/ 10.1016/j.msea.2011.04.033.

[14] J. Archard. 1953. Contact and rubbing of flat surfaces, *J. Applied Physics*, 24(8), 981-988.

[15] R.N. Rao and S. Das. 2011. Effect of applied pressure on the tribological behaviour of SiCp reinforced AA2024 alloy, *Tribology Int.*, 44(4), 454-462. http://dx.doi.org/ 10.1016/j.triboint.2010.11.018.

[16] C.S. Ramesh, A.R.A. Khan, N. Ravikumar and P. Savanprabhu. 2005. Prediction of wear coefficient of Al6061-TiO2 composites, *Wear*, 259(1), 602-608. http://dx.doi.org/10.1016/j.wear.2005.02.115.

[17] R.N. Rao, S. Das, D.P. Mondal and G. Dixit. 2009. Dry sliding wear behaviour of cast high strength aluminium alloy (Al-Zn-Mg) and hard particle composites, *Wear*, 267(9), 1688-1695. http://dx.doi.org/10.1016/j.wear. 2009.06.034.

[18] R.N. Rao and S. Das. 2011. Effect of SiC content and sliding speed on the wear behaviour of aluminium matrix composites, *Materials & Design*, 32(2), 1066-1071. http://dx.doi.org/10.1016/j.matdes.2010.06.047.

[19] S. Navaneetha Santhakumar, K.M. Mohanasundaram, N. Godwin Raja Ebenezer and C. Krishnaraj. 2012. Forward Kinematics Analysis of SCORBOT ER V Plus using LabVIEW, *European J. Scientific Research*, 72(4), 549-557.

[20] Pa. Ganeshwaranand and S. Deepa Shri. 2015, A solid waste management in Coimbatore city, *J. Engineering and Applied Sciences,* 14, 1819-6608.

[21] C. Krishnaraj and K.M. Mohanasundram. 2012. Design and implementation study of knowledge based foundry total failure mode effects analysis technique, *European J. Scientific Research*, 71(2), 298-311.

[22] R.A. Prado, L.E. Murr, D.J. Shindo and K.F. Soto. 2001. Tool wear in the friction-stir welding of aluminium alloy 6061+20%Al2O3: A preliminary study, *Scripta Materialia*, 45(1), 75-80. http://dx.doi.org/10.1016/S13 59-6462(01)00994-0.