Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

An investigation on wear properties of SiC/WC strengthened aluminium alloy hybrid composites

J.J. Jayakanth [a], Vamsi Krishna Mamidi [b], R. Pugazhenthi [a,*], G. Anbuchezhiyan [c], A. Ponshanmugakumar [d]

[a] Department of Mechanical Engineering, VISTAS, Chennai, Tamil Nadu, India
[b] Department of Mechanical Engineering, SV College of Engineering, Tirupati, Andhra Pradesh, India
[c] Department of Mechanical Engineering, Valliammai Engineering College, Kancheepuram, Chennai, Tamil Nadu, India
[d] Department of Mechanical Engineering, Sri Sairam Institute of Technology, Chennai, India

ARTICLE INFO

Article history:
Received 28 November 2020
Received in revised form 6 December 2020
Accepted 11 December 2020
Available online xxxx

Keywords:
Aluminium hybrid composite
Si
WC
Squeeze casting
Wear resistant

ABSTRACT

Particulates strengthened aluminium hybrid intermixtures is formed using squeeze casting method by varying weight percentage (2%, 4% and 6%) of SiC and keeping 2% WC constant. Pin on disc of wear test has been used to investigate the wear properties and coefficient of friction of synthesized aluminium hybrid composites under dry sliding conditions by varying its load and sliding speed. The sliding distance had been maintained constant. The structural features of the synthesized composites and its morphological properties were studied by Scanning Electron Microscope (SEM). Wear rate of synthesized mixtures is significantly increased at all affixed loads. SEM images of the worn out surfaces revealed that particulates micro fracture was the predominant mechanism associated with abrasive wear. Micro hardness of Aluminium hybrid been significantly increased due to incorporation of stronger and stiffer reinforced particles and it leads to low wear with high friction coefficient developed hybrid compared with monolithic material.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Materials, Manufacturing and Mechanical Engineering for Sustainable Developments-2020.

1. Introduction

Owing to its lesser density, low cost and desire to formulate the material strengthening using precipitation hardening, aluminium and its alloys have been primarily used for automobile and marine applications. At elevated temperature, when compared with other composites, these materials occupy various significant factors due to its excellent abrasion resistance along with its high strength and stiffness, good thermal conductivity characteristics [1]. Nevertheless, the major disadvantage of using such materials and its alloys, is its low wear resistance. This is due to the fact that these materials sustain considerable plastic deformations. In addition to that during contact of two materials, throughout sliding condition, the formation of protective layer is limited on the wear surfaces and hence material removal is increased. This caused an increased wear rate of aluminium and its alloys [2]. This can be improved by adding ceramic strengthening particulates in the base material to enhance the wear properties of aluminium composites [3]. It is also observed that at high temperature during sliding surfaces it accumulates plastic deformation and hence it forms an interchange of asperities [4]. Additionally the presence of hard and brittle reinforcement, used in aluminium composites, extends over the surface and makes the asperities to interrelate with its counter face, provides more strength to the composites [5,6]. From the literature it has been observed that the inclusion of ceramic reinforcement in aluminium alloy matrix like SiC, Al2O3, B4C, TiB2 and MoS2 can significantly used to reduce such properties [7]. It is also found that the brittle behavior of aluminium composite is increased due to increase in proportion of adding unique particulates in the matrix alloy. In this regard, without compromising the mechanical properties of composites and thereby increasing the percentage reinforcement in aluminium alloy matrix using single reinforcement, two or more reinforcements is necessary to add along with it, to enhance its mechanical and wear properties. This perception forms the basis of hybrid metal matrix composites. The wear properties of Al7075/Al203/Gr hybrid composites using stir casting process has increased by 36% than Al7075 aluminium alloy [8]. The dry

* Corresponding author.
E-mail address: pugal4@gmail.com (R. Pugazhenthi).

https://doi.org/10.1016/j.matpr.2020.12.416
2214-7853/
Selection and peer-review under responsibility of the scientific committee of the International Conference on Materials, Manufacturing and Mechanical Engineering for Sustainable Developments-2020.

sliding wear behavior of Al/SiC/B4C using stir casting method by varying the load range of 20–100 N and sliding velocities from 1 to 5 m/sec has been improved [9,10]. Al6061/SiC/B4C hybrid composites by varying weight percentage of SiC and keeping B4C constant was developed using stir casting method shows better wear properties than monolithic materials [11,12]. The wear behavior of Al/Al2O3/ MoS2 hybrid composites by stir casting method has been characterized and it has been observed that wear properties has been significantly improved [13,14]. It is clearly identified from the literature that only a few studies have been carried out using Al6061/ SiC/ WC as reinforcement. Considering this an effort is made to synthesize such intermixture by varying its weight proportions using squeeze casting method and its wear properties has been characterized.

2. Experimental methodology

In the present survey, Al6061 Aluminium alloy is used as parent material for developing hybrid intermixtures and it finds tremendous applications in automobile and marine industries [15]. The reinforcements SiC (50 μm) and WC (60 μm) of varying particle size is utilized to manufacture such hybrid intermixtures by varying weight proportions (2%, 4%, and 6%) and keeping WC 2 wt% stable. Squeeze casting method is employed to develop such intermixtures [16]. The furnace temperature was kept at 400 °C to remove the surplus gases and moisture present in it, to avoid oxidation. By the presence of magnesium in the parent material a CO2 gas of 3 L/min is allowed to enter in the furnace to prevent burning during casting. The reinforcement is preheated at 250 °C to eradicate the moisture present in it. The alloy was placed in a melt and it was allowed to melt at 750 °C. Stirring speed was maintained at 350 rpm to ensure the metal was completely melted. The reinforcement of varying weight percentage of SiC and WC is added in to the melt. The stirring speed is increased to 450 rpm to obtain uniform dissemination of strengthening particulates in the base material. The mould of 15 mm diameter and 250 mm lengths was preheated before pouring the composite mixture in the die cavity. The temperature of composite mixture was increased to 900 °C and stirring speed was increases to 600 rpm and it was poured in the die cavity. Then the synthesized hybrid composite was allowed to cool at ambient temperature.

3. Out of the experiment

3.1. Microstructure

It is inferred that the strengthening particulates potentially perceptible and certained outlined in the SEM image of synthesized hybrid aluminium composites. The reinforcement particles are homogenously distributed in the Al7075 matrix without signs of cluster as shown in Fig. 1. It is also found that due to pushing of particle phenomena the redundant B4C reinforcement particles are pressed to solid face and considerate in inter dentrite zone and parting the dendrite branches in the materials as particle-free regions. It is also evident that the inclusion of less percentage of reinforcement of B4C accumulates free regions in the microstructure. On contrary, if the percentage of reinforcement increases it leads to porosity and it forms the gas layer on its surface. This hinders the metal alloy liquid flows owing to its particle clustering.

3.2. Wear characteristics

In the present study pin on disc of wear testing machine is used to examine the wear properties of intermixture under dry sliding conditions as per ASTM G99-04. The hybrid intermixture specimen is sampled of 6 mm diameter and 35 mm length. The steel material EN31 of surface roughness 0.3 μm was used as complement of rotating disc [17,18]. The wear track width at the composite contact surface was used to measure the wear parameter using universal measuring microscope. The volume of wear loss was calculated as per ASTM G77-83 [19,20]. The wear-rate of synthesized aluminium hybrid composites at dry sliding conditions of varying applied loads are shown in Figs. 2–4. The wear rate of intermixtures is significantly increased for all the combinations by varying its sliding speed and applied loads. This is due to the fact that the increase in load tends to increase the width of synthesized composites and hence the wear rate also increases due to presence of stiffer and stronger reinforcement in the matrix alloy. This restricts the motion of dislocation movement and hinders the wear rate.

Fig. 2 shows the wear rate of composite material of Al6061 + 2% SiC + 2%WC of various loads impact on the surface, which exhibits that the wear rate also increases due to presence of stiffer and stronger reinforcement in the matrix alloy.

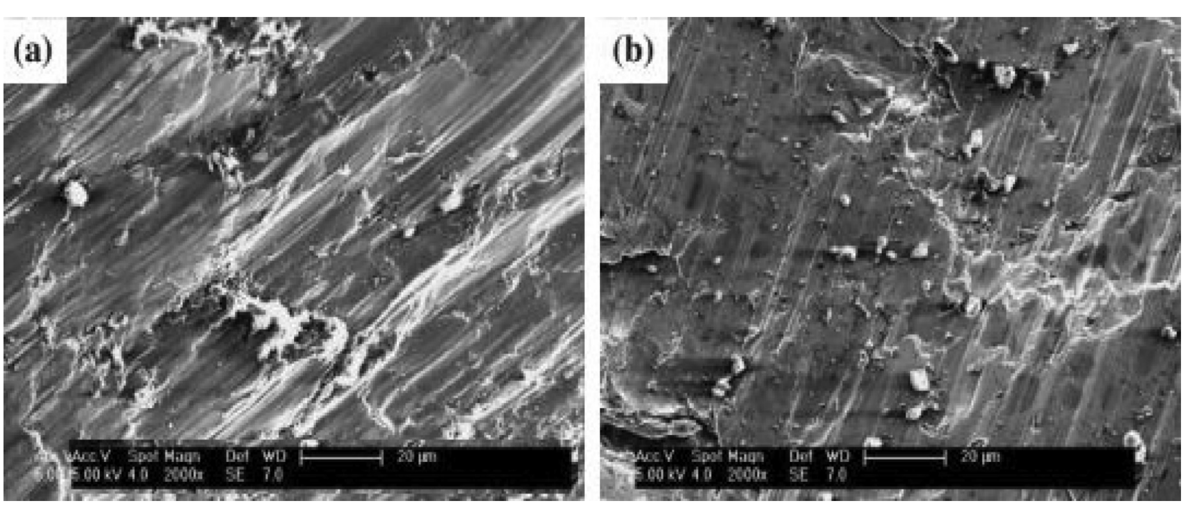

Fig. 1. Fined structure of Al6061 + 6% SiC + 2% WC.

Fig. 3 shows the wear rate of composite material of Al6061 + 4% SiC + 2%WC of various loads impact on the surface, which exhibits that the wear rate also increases due to presence of stiffer and stronger reinforcement in the matrix alloy.

Fig. 4 shows the wear rate of composite material of Al6061 + 6% SiC + 2%WC of various loads impact on the surface, which exhibits that the wear rate also increases due to presence of stiffer and stronger reinforcement in the matrix alloy.

3.2.1. Friction coefficient

The variance of the friction coefficient (μ) of the synthesized hybrid mixtures under three different loads has been shown in Fig. 5. The friction coefficients of SiC and WC particulates are in ranges between 0.14 and 0.47 for the applied loads of 10, 20 and 30 N, respectively. It is observed that the friction coefficient of the hybrid mixtures is significantly increased because of its strengthening effect of matrix and reinforcement, the dislocations in the alloy are ineffective which causes the increment in hardness are the most significant factor to enhance the wear resistant of intermixtures.

SEM micrographs of worn surfaces of synthesized hybrid composites of varying weight percentage under different load are shown in Fig. 6.

The SEM images exhibits the plastic deformation occurs on the surface of the composite material with the grooves which is parallel to the sliding direction under the different loading conditions. The grooves are formed by the wear caused by the pin on disc aspiration, the deep grooves are exhibits the inclusion of SiC and WC which were hard asperities on the steel counter face in the pin on disc test. In the groove it was observed that the material smearing and some local plastic deformation were observed and it indicates that the adhesive wear on the surface. These effects are caused by the additional load were bearded the composites which shows that the inclusion of SiC and WC particles were improved the load bearing capacity of the composite. The formation of transfer layers between the inter mixture particulates which protect the surface from abrasion.

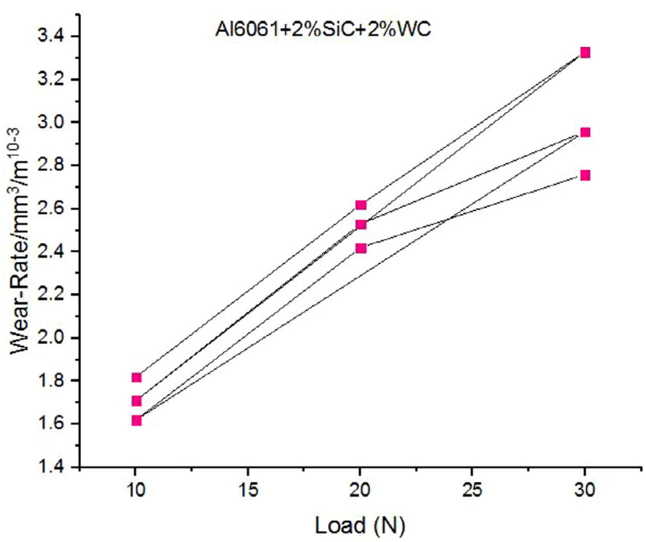

Fig. 2. Wear rate of Al6061 + 2%SiC + 2%WC.

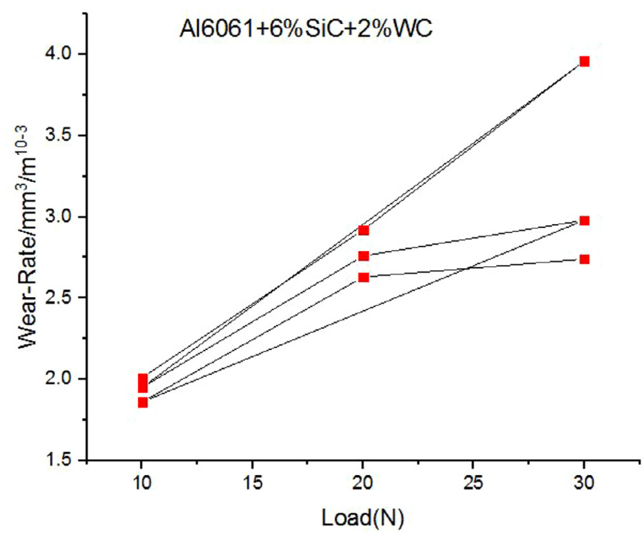

Fig. 4. Wear rate of Al6061 + 4%SiC + 2%WC.

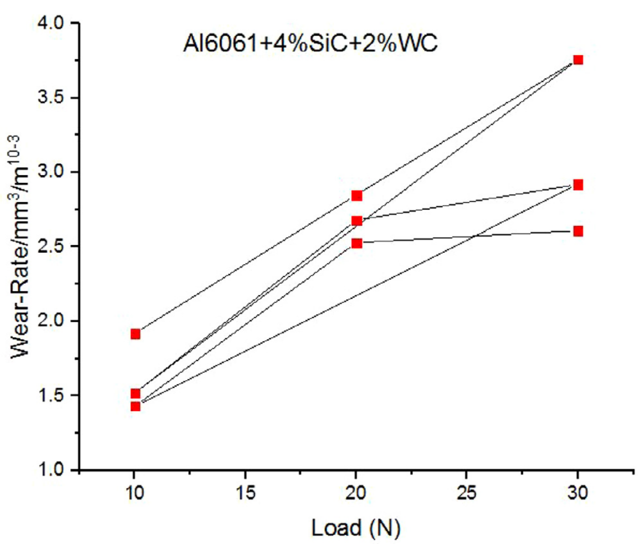

Fig. 3. Wear rate of Al6061 + 4%SiC + 2%WC.

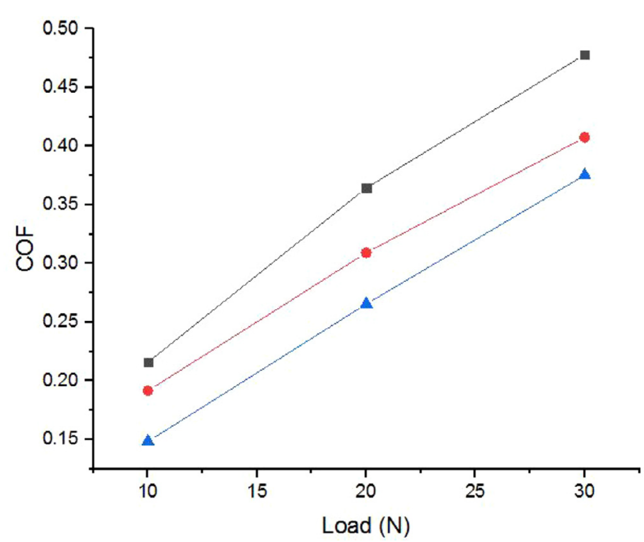

Fig. 5. Coefficient of friction of hybrid intermixtures.

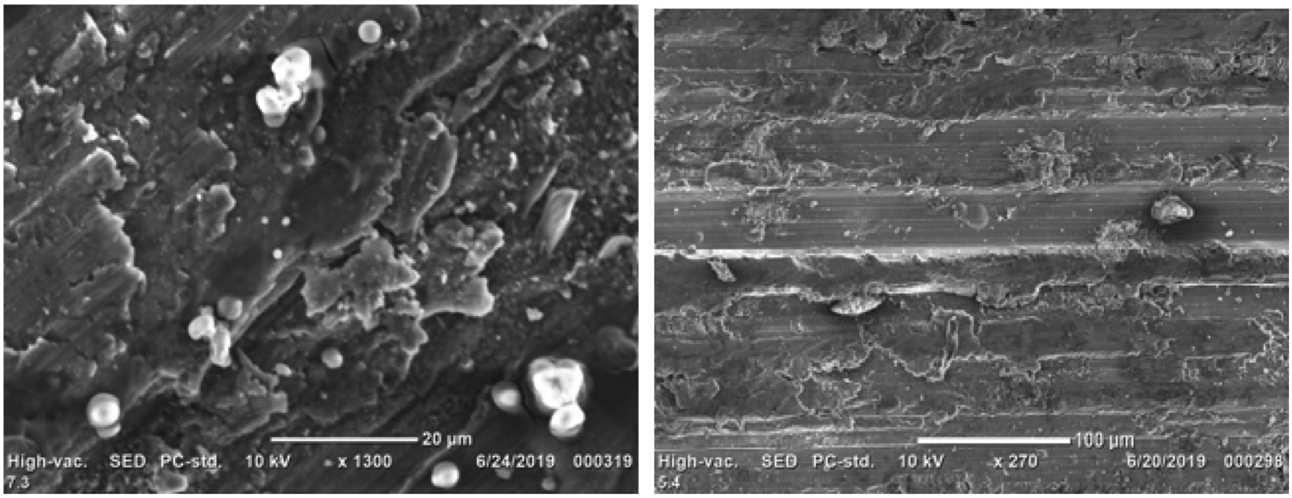

Fig. 6. Worn surface of hybrid intermixtures.

4. Conclusions

Aluminium hybrid composites has been significantly developed using squeeze casting method by varying its weight proportions. The effects of SiC and WC particulates on the microstructure and the wear properties have been investigated. The overall results of the present work are

- The morphological properties of the synthesised aluminium hybrid intermixtures were analysed by SEM analysis. It has been observed that the reinforced particles are uniformly distributed in the matrix alloy without indication of cluster.
- The inclusion of SiC and WC reinforcement in the matrix alloy can significantly increases the co efficient of friction.
- The wear loss analysis of synthesised aluminium hybrid composites has been significantly reduced to a maximum of 23.26% compared with monolithic materials.
- From the worn surface observation, the dominant wear mechanism for all fabricated composites has been observed as abrasive wear due to particulates micro fracture of the composites.

CRediT authorship contribution statement

J.J. Jayakanth: Data curation, Formal analysis. **Vamsi Krishna Mamidi:** Investigation, Methodology. **R. Pugazhenthi:** Conceptualization, Supervision. **G. Anbuchezhiyan**: Project administration, Funding. **A. Ponshanmugakumar:** Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] G. Anbuchezhiyan, B. Mohan, D. Sathyanarayanan, T. Muthuramlingam, Synthesis and characterization of hollow glass microspheres reinforced magnesium alloy matrix syntactic foam, J. Alloys Compd. 719 (2017) 125–132.

[2] V. Uvaraja, N. Natarajan, Tribological characterization of stir-cast hybrid composite Aluminium 6061reinforced with SiC and B_4C particulates, Eur. J. Sci. Res. 76 (2012) 539–552.

[3] D. Patdar, R.S. Rana, Effect of B_4C particle reinforcement on the various properties of aluminium matrix composites: a survey paper, Mater. Today:. Proc. 4 (2017) 2981–2988.

[4] A. Macke, B.F. Schultz, P. Rohatgi, Metal matrix composites offer the automotive industry an opportunity to reduce vehicle weight, improve performance, Adv. Mater. Process. 170 (3) (2012) 19–23.

[5] N. Senthilkumar, T. Tamizharasan, M. Anbarasan, Mechanical characterization and tribological behavior of Al-Gr-B_4C metal matrix composite prepared by stir casting technique, J. Adv. Eng. Res. 1 (1) (2014) 48–59.

[6] B. Venkataraman, G. Sundararajan, Correlation between the characteristics of the mechanically mixed layer and wear behavior of aluminium, Al-7075 alloy and Al-MMCs, Wear 245 (1–2) (2000) 22–38.

[7] K.M. Shorowordi, T. Laoui, A.S.M.A. Haseeb, J.P. Celis, L. Froyen, Microstructure and interface characteristics of B_4C, SiC and Al2O3 reinforced Al matrix composites: a comparative study, J. Mater. Process. Technol. 142 (3) (2003) 738–743.

[8] T. Rajmohan, K. Palanikumar, S. Ranganathan, Evaluation of mechanical and wear properties of hybrid aluminium matrix composites, Trans. Nonferr. Met. Soc. China 23 (9) (2013) 2509–2517.

[9] G. Anbuchezhiyan, B. Mohan, N. Senthil Kumar, R. Pugazhenthi, Synthesis and characterization of silicon nitride reinforced Al-Mg-Zn alloy composites, Met. Mater. Int. (2020), https://doi.org/10.1007/s12540-020-00906-3.

[10] G. Anbuchezhiyan, B. Mohan, S. Kathiresan, R. Pugazhenthi, Influence of microstructure and mechanical properties of TiC reinforced magnesium nano composites, Mater. Today:. Proc. 27 (2020) 1530–1534.

[11] G.A. Dolata, J. Wieczorek, Tribological properties of hybrid composites containing two carbide phases, Arch. Mater. Sci. Eng. 28 (3) (2007) 149–155.

[12] A. Rajasekaran, R. Pugazhenthi, Study of mechanical properties of stir casted Al7075/SiCp composites after thermomechanical treatment, Mater. Today:. Proc. 22 (2020) 766–771.

[13] C. Fenghong, C. Chang, W. Zhenyu, T. Muthuramalingam, G. Anbuchezhiyan, Effects of silicon carbide and tungsten carbide in aluminium metal matrix composites, Silicon (2019), https://doi.org/10.1007/s12633-018-0051-6.

[14] J. Jung, S. Kang, Advances in manufacturing boron carbide–aluminum composites, J. Am. Ceram. Soc. 87 (1) (2004) 47–54.

[15] A. Canakci, F. Arslan, I. Yasar, Pre-treatment process of B_4C particles to improve incorporation into molten AA2014 alloy, J. Mater. Sci. 42 (23) (2007) 9536–9542.

[16] C.K. Dhinakarraj, N. SenthilKumar, M.A. Badri, G. Anbuchezhiyan, Vibration and damping behaviour of Si_3N_4 reinforced magnesium alloy composite for structural applications, J. New Mat. Electrochem. Syst. 23 (3) (2020) 182–189.

[17] F. Toptan, A. Kilicarslan, A. Karaaslan, M. Cigdem, I. Kerti, Processing and microstructural characterization of AA 1070 and AA 6063 matrix B4Cp reinforced composites, Mater. Des. 31 (2010) S87–S91.

[18] P.T. Selvam, R. Pugazhenthi, C. Dhanasekaran, M. Chandrasekaran, S. Sivaganesan, Experimental investigation on the frictional wear behaviour of TiAlN coated brake pads, Mater. Today:. Proc. (2020).

[19] G. Anbuchezhiyan, B. Mohan, R.V. Karthikeyan, Development of magnesium matrix syntactic foams processed through powder metallurgy techniques, Appl. Mech. Mater. 766–767 (2015) 281–286.

[20] N. Poornachandiran, R. Pugazhenthi, S. Vijay Ananth, T.G. Krishnan, M. Vairavel, Investigation of mechanical properties of Al6061 with reinforcement of SiC/B4C metal matrix composites, in: AIP Conference Proceedings, Vol. 2283, No. 1, AIP Publishing LLC, 2020, p. 020113.