As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology, 8(08): 01-08, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0808001
Available online at: http://www.ijmtst.com/vol8issue08.html

Wear Studies on Aluminum Matrix Composites Fabricated by Stir Casting Method by using Automotive Applications

M.Shunmuga Priyan | Boby Paul | Jaison Jose | Nevin Mathew Jacob

Department of Mechanical Engineering, Loyola Institute of Technology & Science, Thovalai, Tamil Nadu – 629302
Corresponding Email Address: iampriyan25@gmail.com

To Cite this Article
M.Shunmuga Priyan, Boby Paul, Jaison Jose and Nevin Mathew Jacob. Wear Studies on Aluminum Matrix Composites Fabricated by Stir Casting Method by using Automotive Applications. International Journal for Modern Trends in Science and Technology 2022, 8(08), pp. 01-08. https://doi.org/10.46501/IJMTST0808001

Article Info
Received: 25 June 2022; Accepted: 30 July 2022; Published: 04 August 2022.

ABSTRACT

Metal matrix composites (MMC) are used to improve specific strength, high temperature resistance, and wear resistance. Metal matrix composites are being studied as viable candidate materials, and they are mostly utilized to replace traditional materials in aerospace and automotive applications. By reinforcing AA6061 matrix with boron carbide (B4C) particles, mechanical properties such as hardness, tensile strength, yield strength, and percentage of elongation of AMMCs were improved. AMMCs were made using AA6061 as the matrix material and B4C as the reinforcement material, using the stir casting method. AMMCS with variable percentages of 3, 6, and 9% B4C by different weight percentages were manufactured. The precipitation kinetic was observed to be accelerated by adding the B4C particles in contrast to the matrix metal. In comparison to 3 and 6 percent B4C, 9 percent B4C has the lowest coefficient of friction. Metal matrix composites are under serious study as viable candidate materials, according to the literature, and are primarily utilized to replace traditional materials in aerospace and automotive applications.

KEYWORDS: MMC, Stir Casting Method, Mechanical Properties, Pin-on-Disc, Surface Roughness

1. INTRODUCTION

MMCs are perfect for use in the automobile industry since they are lightweight and resistant to wear and thermal distortion. Because they are significantly more expensive than PMCs, their use is restricted. Aluminum metal matrix composites (MMC) are one of the most attractive material possibilities for the fabrication of lightweight parts for a variety of vehicles due to their low density and high specific mechanical properties. Prashant S D et.al [2019] author reported a comparison among Al 6061 and Al 7075 the nearly Al 7075 has an extra tensile and yield energy of the different alloys. Moreover, the hardness test, consider microstructure and mechanical houses together with pliable quality, and given up quality % prolongation as nicely as % discount through the use of aluminum metallic matrix alloy. Laxmi and Sunilkumar et.al (2017) fabricated the Al 6061-SiC(10%,15%&20%wt) Composite with the aid of using utilizing blend casting path of motion with valid dispersion of debris all around the example. They contemplate the mechanical houses of hardness and brief research of microstructure should be performed on checking electron magnifying lens (SEM) to confirm the scattering of aid in the network.

NiranjanNanjayyanamath et.al (2017) reported approximately the composite cloth they've taken base cloth as aluminum alloy 6061 and reinforcement cloth as fly ash (5%, 10%&15%). The particle length degrees of fly ash have been 5-20, 25-30&50-60µm. They calculated mechanical houses of tensile, compressive, and hardness. They have elevated the fee of support (fly cinder), and after that, the hardness and compressive great may be increments. Ajitkumar Senapati et.al (2016) Investigated on the study of the aluminum alloy 6061 and reinforcement as fly ash (10 and 15%wt). They have considered almost the mechanical behavior of unreinforced combination and metal network composites. They compared the metal lattice composite arranged with 15% of fly ash debris show was better mechanical property to unreinforced amalgam as well as MMC. From the above paper I have concluded that they compared the metal network composite arranged with 15% of fly ash show superior mechanical property to unreinforced amalgam as well as MMC. Madhuri Deshpande et.al [2016] exhibit lower values of hardness as compared with Pure Al7075 hot pressed specimen. Whereas the Ni coated carbon fiber composites show the increase in hardness up to 20Vol% and then it decreases. It is seen from the microstructures that carbon fibers are homogenously distributed in the aluminum matrix for all compositions. S. Rama rao, G. Padmanabhan,et.al (2013) exhibited The hardness of the composites increased and density was decreased with increasing the amount of the boron carbide in the matrix phase. Increasing the amount of boron carbide particles in composites caused the ultimate compression strength to increase. Rajadurai and Senthilvelan et.al (2013) found that the nano-particles were uniformly distributed in the metal matrix for the hybrid ratios up to 1.0 vol% Sic and 0.5 vol % B.C. but for the hybrid ratio of 1.5 vol % Sic and 0.5 vol % B4C the agglomeration tendency increases. Sridhar,et.al (2011) Investigation of Mechanical Properties of Hybrid Composites for Automobile Industry proved that, as load is increased, the change from mild to severe wear takes place much faster in alloy than composites. The wear rate decreases with increasing volume content of the reinforcement the coefficient of friction decreases with increase in particle reinforcement and load. The coefficient of friction and wear rate of the hybrid composite are less when compared with the binary composites. The main objective of the project is an investigation on the low coefficient of friction and surface roughness of Aluminum boron carbide metal matrix composite. The composite has been prepared on different compositions and taken for several physical and mechanical analyses for the wear test and surface roughness of the composite.

2. Experimental Methods

Material Selection

The aluminum 6061 (Fig.1) selected were cut into small strips of 10 cm length. Boron carbide purchased is of granule level powder with 400 meshes. Three different composition samples of aluminum $B_4C$with Weight% 3, 6 and 9% is weighted to be added on 3 batch of aluminum of weight 1kg. For first sample 30 grams of B_4C has been taken (3% of 1 kg aluminum 6061) like that for second sample 60 grams of B_4C and for third sample 90 grams of B_4C were taken the weight of the materials were taken on micro weighing machine. It has good mechanical properties and exhibits good weldability the chemical properties, mechanical properties and physical properties are shown in table no 1 below

Fig. 1 Aluminum Alloy 6061(Raw Material)

Grade	Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
Wt % Al6061	0.63	0.42	0.42	0.12	0.19	0.05	0.02	0.08	Bal

Table.1 Chemical Composition of Al 6061

Stir Casting Method for Fabrication

The fabrication of the metal matrix composites (Fig. 2) are generally based on two technological methods such as solid state processing and liquid state processing method. In solid state processing method, the reinforcements are embedded in the matrix through diffusion phenomenon and are produced at high temperature and pressure. In this process some special care should be taken to avoid the growth of the undesirable phases or compounds species on interfaces.

Some commonly used techniques under this method are diffusion bonding, powder metallurgy etc. The first step is that the furnace has been preheated for removing the moisture in it. Then the metal aluminum 6061 has been placed in the crucible of the apparatus. Furnace was allowed heat up to 1000 °C for melting of the metal (Al 6061). The preheated B_4C by muffle furnace up to 800°C has been added to the stir casting furnace having 6061 aluminum and heated up to 4 hrs. The molten material has been poured into mould and allowed to solidify same process has been done for all the three composition. In liquid state processing, the matrix is in liquid form and the reinforcement either in form of fibers or particles embedded in it. The uniformity in distribution of reinforcement can be made by means of applying some mechanical actions. This is one of the most used and inexpensive method for fabrication of metal matrix composites. Hot forming, liquid infiltration, squeeze casting and stir casting are most common techniques under this method.

Fig. 2 Samples prepared by Stir Casting Process with ($Al+B_4C$) different composition

PIN ON DISC TEST

The pin on disc testing method of characterizing the coefficient of friction frictional force and rate of wear between two materials is done for found out the wear rate of the composite. First of all 3 samples (Fig.3) of each composition were taken. The weight before test has been noted and taken for test. The disc taken for the test was ASTM G99 as shown in Fig. 4. Moreover, the specification of pin-on disc parameters mentioned in the table 2. Mass-loss evaluation and differential analysis of test fluids are typically performed post-test to characterize wear properties. In addition, a contact profilometer can be utilized to evaluate the changes in surface topography due to articulation. Metallurgical evaluation of the post-test wear scarring can also be performed. Testing can also introduce third body debris for accelerated wear evaluations.

Normal Load	0.1 to 20 N
Friction Force Range	0 to 50 N
Contact	Pin on Disc, Ball on Disc
Disc Diameter	75 mm
Track Radius	0 to 35 mm
Rotational Speed	2 to 200 rpm
Sliding Velocity	0.007 to 0.7 m/s
Motor	190 W dc

Fig .3 ASTM G 99 Disc Samples

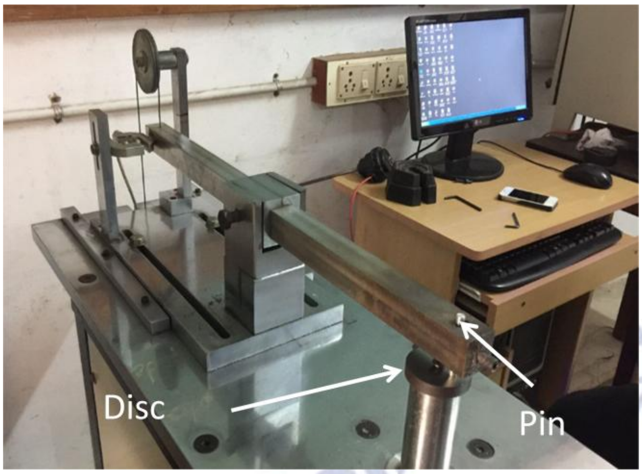


Fig. 4 Experimental setup of Pin-On-Disc apparatus

Table 2: Specification of Pin-on-Disc

For the pin-on-disk wear test, two specimens are required. One, a pin with radius tip (our composite MMC), is positioned perpendicular to the other, usually a flat circular disk (ASTM G99). The test machine causes either the disk specimen or the pin specimen to revolve about the disk center. In either case, the sliding path is a circle on the disk surface. The plane of the disk may be oriented either horizontally or vertically Wear results may differ for different orientations. The pin specimen is pressed against the disk at a specified load usually by means of an arm or lever and attached weights. Wear results are reported as volume loss in cubic millimeters for the pin and the disk separately. When two different materials are tested, it is recommended that each material be tested in both the pin and disk positions. The amount of wear is determined by weighing both specimens before and after the test. Linear measures of wear are converted to wear volume (in cubic millimeters) by using appropriate geometric relations. Linear measures of wear are used frequently in practice since mass loss is often too small to measure precisely. If loss of mass is measured, the mass loss value is converted to volume loss (in cubic milli-meters) using an appropriate value for the specimen density.

NONCONTACT SURFACE ROUGHNESS TESTING

Surface roughness (Ra) is measure by using Non contact Surface roughness tester as shown in Fig.5. The most commonly used parameter for general surface roughness. It calculates average roughness by comparing all peaks and valleys to the mean line and averaging them over the cut-off length. A large cutoff length that the stylus is dragged across the surface; a larger cutoff length that the stylus is dragged across the surface; a larger cut-off length that the stylus is dragged across the surface; a smaller cut-off length that the stylus is dragged across the surface; a smaller cut-off length that the stylus is dragged across the surface; a smaller cut-off length that the stylus is dragged across the surface; a Topography and metallographic observations on the worn surface of the coated layer were carried out to evaluate wear parameters such as wear pattern and surface shape.

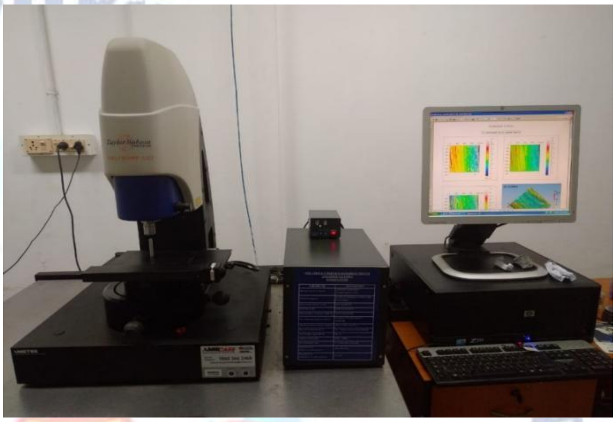


Fig.5 Non-Contact Surface Testing Equipment

VIDEO MEASURING SYSTEM (VMS)

A video measuring system is a high-precision, high-efficiency photoelectric measuring system. A high-resolution CCD color camera with continuous zoom lens, a Cross generator, a precision linear scale, a multipurpose digital readout (DRO), 2D measuring software, and a high-precision working table make up this video measuring system. This video measuring system comes with an RS-232 interface, which allows the user to control and output the graph by connecting to a PC and running the M2D or QIM program. The video measuring equipment principles were as shown in Fig.6.

Fig.6 Non-Contact Surface Testing Equipment

3. Results and Discussion

Weight Loss Analysis

The value of the material's weight before the wear test and the weight of the material after the wear test are used to compute weight loss. The weight loss value of each material is used to analyze the wear performance of pin. Further wear results exhibited in the table 3.

Weight Loss = Weight of the material (before wear test) – Weight of the material (after wear test)

Table 3 Wear Test Results

Samples	Before Pin on disc Test	Load	After Pin on disc	Wear loss
Samples	**Before Pin on disc Test**	**Load**	**After Pin on disc Test**	**Wear loss**
Sample1 (3%)	6.486	1kg	6.484	0.002
Sample 2 (3%)	6.574	2kg	6.572	0.002
Sample 3 (3%)	6.474	3kg	6.471	0.003
Sample 1 (6%)	6.188	1kg	6.187	0.001
Sample 2 (6%)	6.444	2kg	6.443	0.001
Sample 3 (6%)	6.484	3 kg	6.480	0.004
Sample 1 (9%)	6.704	1 kg	6.702	0.002
Sample 2 (9%)	6.988	2kg	6.985	0.003
Sample 3 (9%)	6.806	3 kg	6.802	0.004

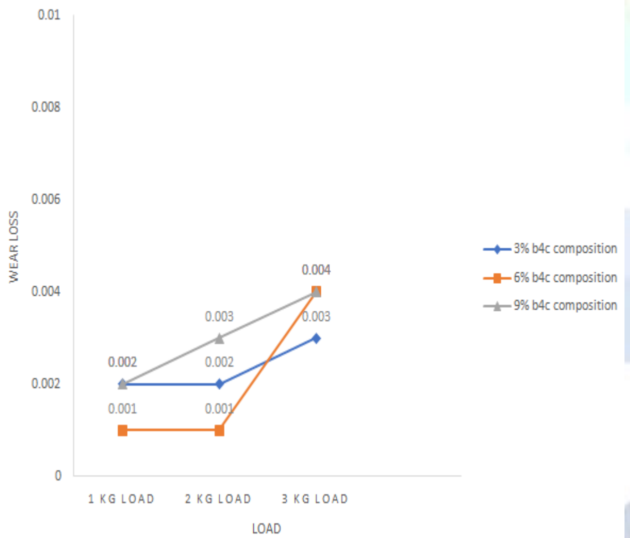


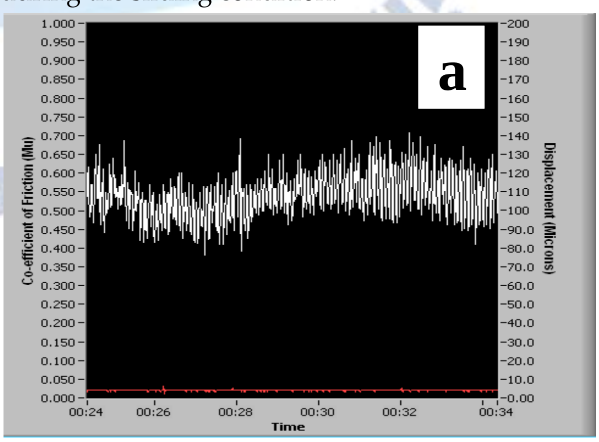
Fig. 7 Graphical Representation of Wear analysis

In this wear analysis we can found out that the wear loss is minimum when load of 1kg is applied and maximum at 3 kg load. The maximum good result is on the 6% of AA601-B_4C composition.

The study wear of materials, we must simulate the process of wear in a controlled manner and study the effect on different samples with the same test conditions at shown in fig 7. One way to perform the wear test is with a ball or pin on disk Tribometer (ASTM G99). With this test, a reference sample is mounted on a rotating stage and a pin or ball (object of study) comes in contact with the Sample surface with a known applied load. Typically the interest of wear would be on the reference sample at the bottom but another alternative testing method is to evaluate the wear of the ball or pin tip. In this case, while the reference sample rotates, the contact pressure gradually wears the ball or the pin

Coefficient of Friction

The low co-efficient friction for applied on different composition composite materials the co-efficient of friction value is measured during machining by using Pin-On-Disc apparatus. In theoretical co-efficient of friction is measured by the value of frictional force and load. But in this research we are using Pin-On-Disc apparatus for measuring co efficient of friction. So, the co-efficient of friction graph is taken by using Tribology Data Acquisition System. The co-efficient of friction of specimen materials are represented in the below shown figures 8. In the above shown online graphical representation of the specimen material, the co- efficient of friction is increases with increase in time up to 4mins at a constant load of 3kg and the sliding speed of disc at 2.1m/s. From the illustration, material is produced high co-efficient of friction due to applied load with dry sliding condition. The surface of the specimen is more plastic deformation in which applied load at ambient condition. Metal to metal contact is more surface area at during the sliding condition.



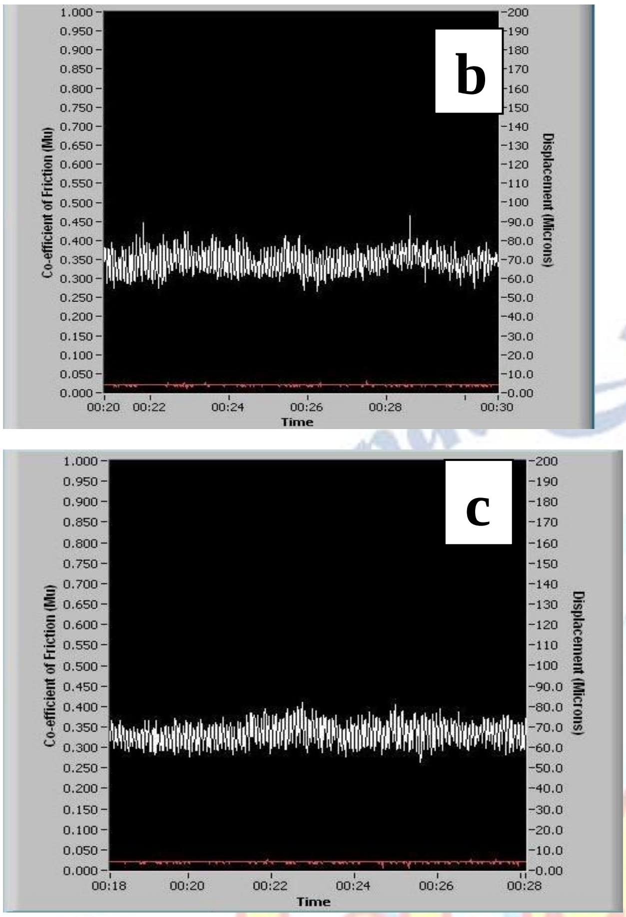
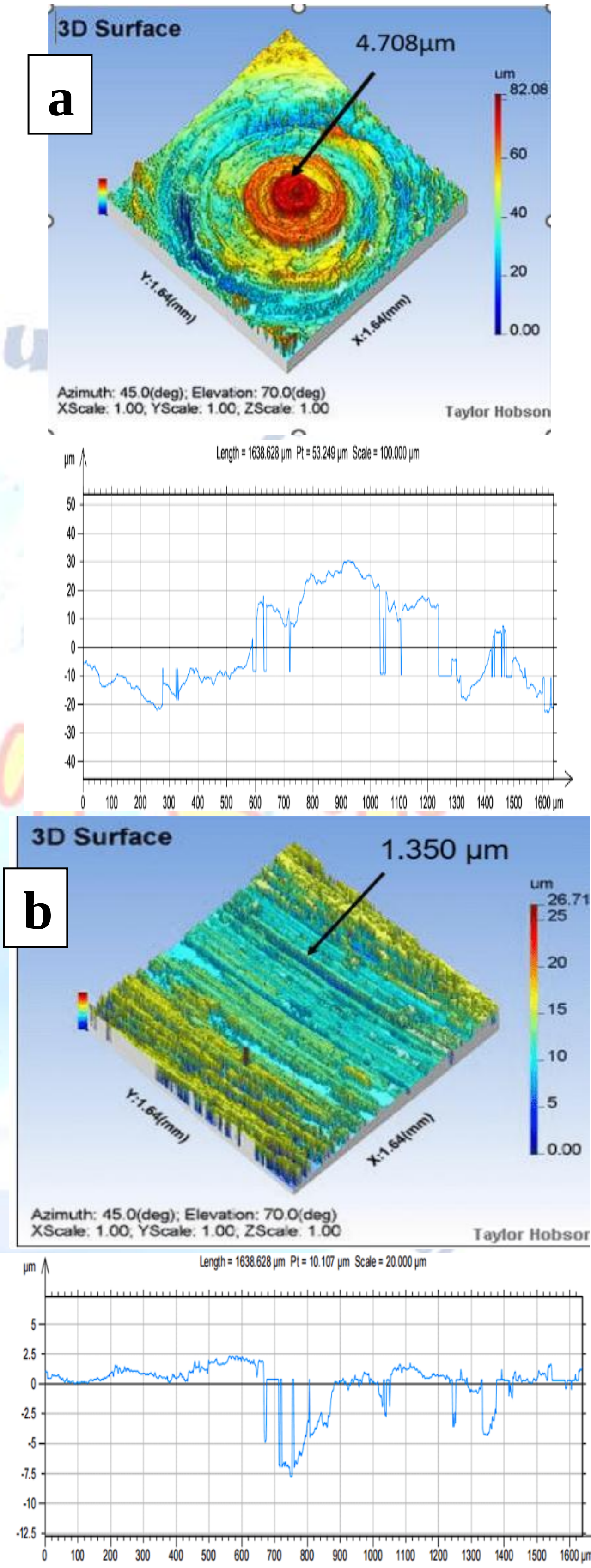


Fig 8: Shows represented as COF at different loads (a) 1 Kg (b) 2 Kg and (c) 3 Kg

SURFACE ROUGHNESS TEST RESULTS

Surface Roughness of the uncoated and coated was found out by using Taylor Hobson surface roughness tester. Normally roughness value was increased on the coated and uncoated specimen due to metallurgical contact on both surfaces and dry sliding condition will occur, produced high roughness value on a materials. Traditional surface finish analysis consists mainly studying the surface texture, consisting of roughness and hardness as shown in fig 9.



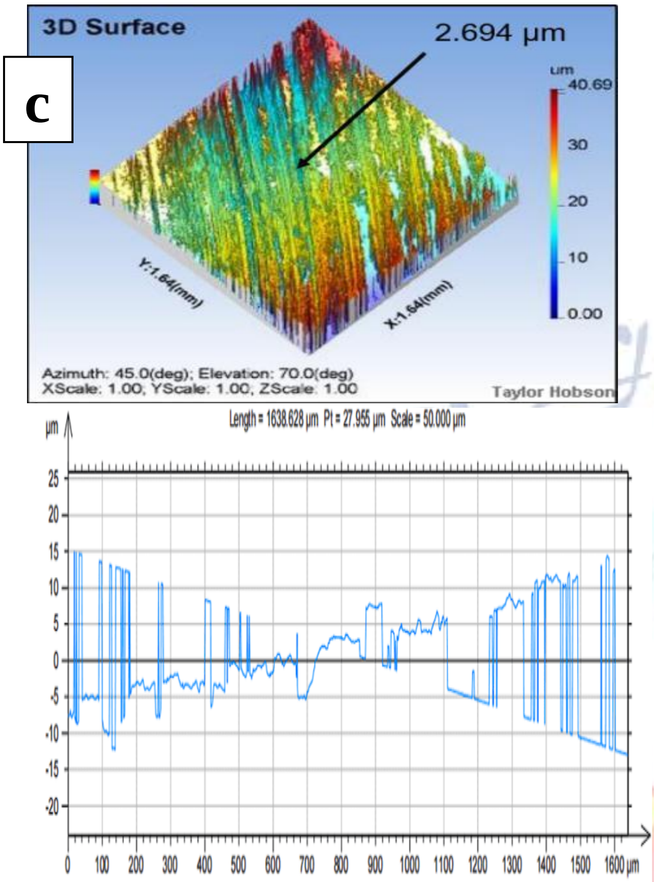
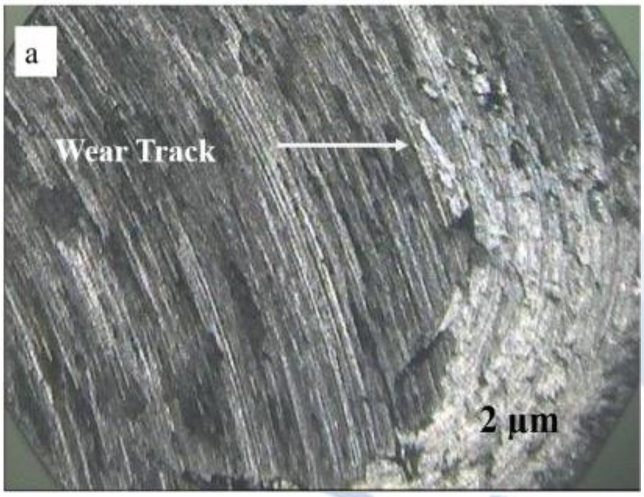


Fig. 9 Roughness Test represented as wear tracking at different load (a) 1 Kg at 3% (b) 2 Kg at 6% and (c) 3 Kg at 9%

VIDEO MEASURING SYSTEM ANALYSIS (VMS)



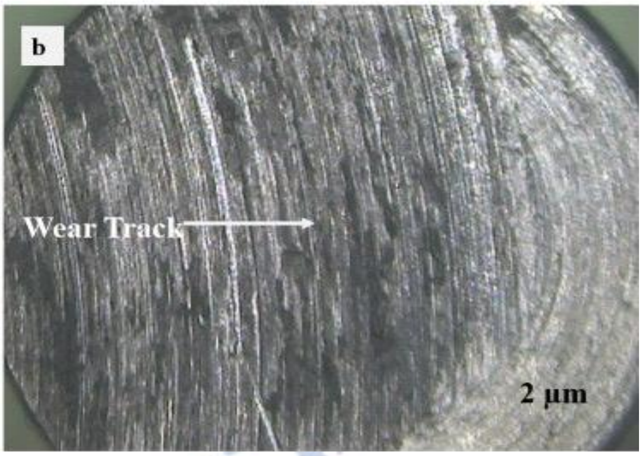


Fig. 10 Shows 3% composition at (a) 1 Kg (b) 2 Kg

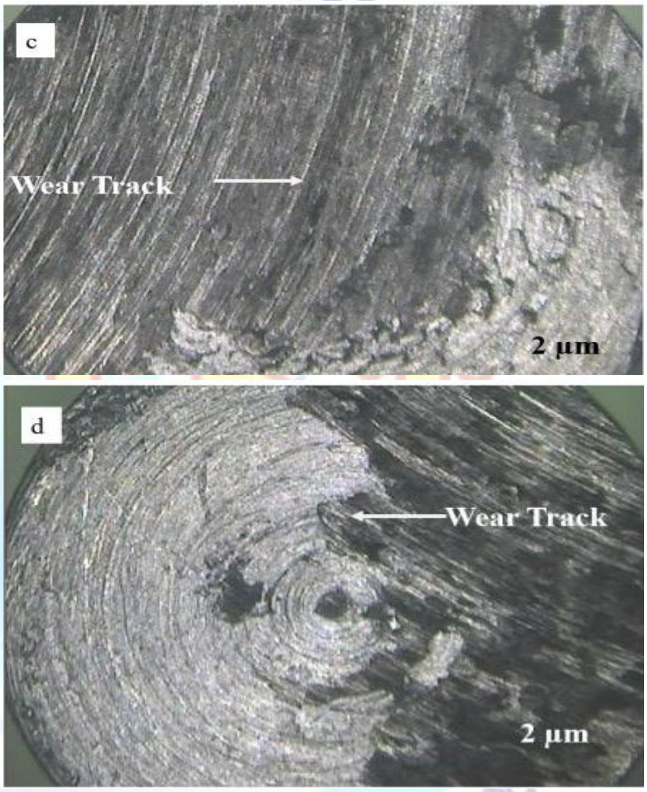


Fig.11. Shows 3% composition at load (c) and (d)3kg

Figure 11 micrograph of the surface morphology represents that after wear testing on base alloy Al 6061 and 3%, 6% and 9% of B_4C composite specimen. It shows that clear morphology of wear track formed at different loading used on the tested specimen. It is clear from the Fig. 11 that the wear tracks and surface grooved formed in the surface due to the surface contact each other. Due to un-melted particles which are act as debris particle motion on material surfaces at loading condition. Depends on the particle debris out form the materials where the surface may be delaminate condition is the condition of that. Wear track is observed in case of Al 6061, indicates the abrasive wear mechanism. Due to high temperate and friction, only oxide wear has taken place. The wear resistance is more in case of (Al6061+ B_4C) composites alloy. The results revealed that the composites with B_4C particulates have better wear resistance property compared to base alloy. Figure 11 shows a surface morphology is having evident for wear tracking when different loading was applied in the composite specimen. The wear track formed based on loading at which minimum loading condition got low grooving surface replied on surface of the composites. It shows of the deep groove has been formed at higher load (Al 6061+9% B_4C) is 3 kg at room temperature. Some time materials has resist plastic deformation during the materials surfaces.

4. Conclusion

The stir casting method was used to successfully create AA 6061, B_4C composites in the percentage combinations of 3 percent, 6 percent, and 9 percent, which were then taken for analysis. With the increase in hardness, the density of the composites decreased. The percentage of boron carbide in the matrix phase increases. The pin on disc wear analysis test reveals that the minimum coefficient of friction is 0.322 microns for a 9 percent composition, and material loss is likewise minimal. The minimum surface roughness, according to the VMS wear track study, is 2μm the noncontact surface roughness value indicates that the minimum surface roughness was 1.350μm and that the composition was 3 percent. So, we can conclude that the best result on low coefficient of friction was found on the AA 6061-B_4C on the 9% composition of MMC and can be used in Automotive applications like Disc brake, pistons and so on. The analysis of composites was successfully completed with best results.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

References

[1] F.A.R. Rozhbiany, S.R. Jalal, Influence of reinforcement and processing on aluminum matrix composites modified by stir casting route, Adv. Compos. Lett. 28 (2019)

[2] G. Xu, Y. Yu, Y. Zhang, T. Li, T. Wang, Effect of B 4 C particle size on the mechanical properties of B 4 C reinforced aluminum matrix layered composite, Sci. Eng. Compos. Mater. 26 (1) (2019)

[3] Shoufa Liu, Yinwei Wang, T. Muthuramalingam, G. Anbuchezhiyan, Effect of B4C and MOS2 reinforcement on micro structure and wear properties of aluminum hybrid composite for automotive applications, Compos. B Eng. 176 (2019)

[4] C. HimaGireesh, K. Durga Prasad, and K. Ramji, ''Experimental Investigation on Mechanical Properties of an Al6061 Hybrid Metal Matrix Composite," J.Compos. Sci., vol. 2, no. 3, p. 49, Aug. 2018

[5] Mr. N. Venkat Kishore and Dr. K. Venkata Rao, ''Mechanical Properties in MMC of Aluminum Alloy (A356/LM25) Matrix and Boron Carbide (B4C) Reinforcement," Int. J. Eng. Res., vol. V5, issue 02, pp. 683–689, 2016

[6] Ibrahim, I.A., Mohamed, F.A., Lavernia, E.J., 1991. Particulate reinforced metal matrix composites – A review. J. Mater. Sci. 26, 1137–1156.

[7] Ilandjezian, R., Gopalakannan, S., 2017. Tensile fracture and compression failure behavior of cenosphere reinforced AA6061 metal matrix composite.

[8] Mura A, Canavese G, Goti E, Rivolo P, Wang H, Ji X, et al. Effect of different types of graphene coatings on friction and wear performance of aluminum alloy. Mech Adv Mater Struct 2020

[9] Türedi E. On the precise measurement capability of the direct microscopic measurement method for wear volume characterization. MATEC Web Conf 2018;188:02007.

[10] V. Kumar, R.D. Gupta, N.K. Batra, Comparison of Mechanical Properties and effect of sliding velocity on wear properties of Al 6061, Mg 4%, Fly ash and Al 6061, Mg 4%, Graphite 4%, Fly ash Hybrid Metal matrix composite, Procedia Mater. Sci. 6 (2014)

[11] S.A. Alidokhta, A. Abdollah-zadeh, H. Assadi, Effect of applied load on the dry sliding wear behaviour and the subsurface deformation on hybrid metal matrix composite, Wear 305 (2013)

[12] A. Wlodarczyk-Fligier, L.A. Dobrzanski, M. Kremzer, M. Adamiak, Manufacturing of aluminium matrix composite materials reinforced by Al2O3 particles Journal of achievements in materials and manufacturing engineering , vol 27- 1 (2008)

[13] V.Bharath,MadevNagaral,V.Auradi,S.A.Kori , Preparation of 6061Al-Al2O3 MMC's by stir casting and evaluation of mechanical and wear properties procedia materials science, vol 6 (2014)

[14] NihanTuncer, BasakTasdelen, Gürsoy Arslan, Effect of passivation and precipitation hardening on processing and mechanical properties of B4C-Al composites, Ceram. Int. 37 (2011)

[15] Kumar, G. V., Rao, C. S. P., & Selvaraj, N. (2011). Mechanical and tribological behavior of particulate reinforced aluminum metal matrix composites–a review. Journal of minerals and materials characterization and engineering, 10(01), 59.

[16] Vencl, A.; Rac, A. New wear resistant Al based materials and their application in automotive industry. // MVM – International Journal for Vehicle Mechanics, Engines and Transportation System. 30, Special Edition, (2004)

[17] Hunt, W. H.; Miracle, D. B. (2001). Automotive Applications of Metal-Matrix Composites, in: Miracle, D. B.; Donaldson, S. L. (Ed.), ASM Handbook, Volume 21: Composites, ASM International

[18] Adebisi, A. A.; Maleque, M. A.; Rahman, M. M. Metal matrix composite brake rotor: historical development and product life cycle analysis. // International Journal of Automotive and Mechanical Engineering (IJAME). Vol. 4, no., (2011).