Hindawi
Advances in Materials Science and Engineering
Volume 2022, Article ID 4116843, 10 pages
https://doi.org/10.1155/2022/4116843

Research Article

Investigation on Mechanical and Wear Behaviors of LM6 Aluminium Alloy-Based Hybrid Metal Matrix Composites Using Stir Casting Process

P. Gnaneswaran,[1] **V. Hariharan**,[2] **Samson Jerold Samuel Chelladurai**,[3] **G. Rajeshkumar**,[4] **S. Gnanasekaran**,[5] **S. Sivananthan**,[6] **and Baru Debtera**[7]

[1]*Department of Mechanical Engineering, Park College of Engineering and Technology, Coimbatore, Tamil Nadu, India*
[2]*School of Mechanical Sciences, Department of Mechanical Engineering, Kongu Engineering College, Erode, Tamil Nadu, India*
[3]*Department of Mechanical Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India*
[4]*Department of Mechanical Engineering, PSG Institute of Technology and Applied Research, Neelambur, Tamil Nadu, India*
[5]*Department of Mechanical Engineering, Sri Shakthi Institute of Engineering and Technology, Chinniyampalayam, Coimbatore, Tamil Nadu, India*
[6]*Department of Mechanical Engineering, K. Ramakrishnan College of Engineering, Tiruchirappalli, Tamil Nadu, India*
[7]*Department of Chemical Engineering, College of Biological and Chemical Engineering, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia*

Correspondence should be addressed to P. Gnaneswaran; gnaneswaran1986@gmail.com and Baru Debtera; baru.debtera@aastu.edu.et

Received 18 October 2021; Revised 27 December 2021; Accepted 28 December 2021; Published 10 January 2022

Academic Editor: Dimitrios E. Manolakos

In this investigation, aluminium-silicon-based alloy (LM6) with the addition of (0, 2.5, 5, and 10%) copper-coated short steel fiber and 5% boron carbide (B_4C) element-strengthened composites was fabricated by the stir casting method. Mechanical properties and tribological behaviors of LM6-based hybrid composites were investigated, and microstructures of different castings were examined by an image analyzer. The test was conducted at different loads (10, 20, 30, and 40 N) and different sliding spaces (500, 1000, 1500, and 2000 m), respectively. The results revealed that the sample loaded with 10% of reinforcement recorded the highest tensile strength of 231 MPa. On the other hand, the hardness value increased from 71 to 144 BHN, when 15% of reinforcement was added to the sample. It was also noted that 10% copper-coated steel fiber improved wear resistance up to 50% when compared to LM6. A field emission scanning electron microscope was employed to observe the morphology of the worn surfaces of composites at different sliding distances and load conditions. The hybrid composite revealed that the combination of both short steel fibers and reinforcement of ceramic particles enhanced the mechanical properties, obtaining superior wear resistance.

1. Introduction

Aluminium-based metal matrix composite (AMMC) is widely used in automobiles, sports, aerospace, marine, and other engineering fields. It is because of high strength-to-weight ratio, wear resistance, good corrosion resistance, and better machinability. Aluminium alloy-based ceramic composites fabricated through liquid metallurgy technique offered superior mechanical and tribological properties [1]. Wear is one of the vital parameters for considering aluminium hybrid metal matrix materials. The main drawback of materials is that they exhibit poor tribological properties. Tribological performance of aluminium reinforced with different ceramic particles using a pin on disc tribometer exhibited better wear characteristics [2]. Aluminium alloy reinforced with B_4C composites was prepared by means of liquid metallurgy techniques with various particulate weight fractions. When the density of composites decreased, the tensile power, hardness, compressive power, and fracture toughness increased with the addition of ceramic particles. Aluminium (LM6) matrix reinforced with aluminium oxide and fly ash was fabricated which increased the wear resistance [3–5]. The LM6 aluminium alloy is a eutectic alloy containing 85% of aluminium and 12–15% of silicon. It has the ability to resist corrosion and hot cracking. Aluminium-based metal matrix composites reduce the cost of the material because of their lesser weight, durability, and recyclability. Easy availability of reinforcements and higher production volumes can minimize the cost of metal matrix composites. Addition of ceramic particles like silicon, Al_2O_3, graphite, and lead oxide glass provides better castability and machinability to the composites [6]. Metal matrix composites can be produced by liquid metallurgy techniques to produce complex net shapes. In the stir casting process, discontinuous reinforcements in the matrix result in poor wettability, porosity, and interfacial reactions. The LM6 aluminium-based composites offered better wear resistance and high strength by the addition of adding short steel fiber in various weight fractions [7]. Different weight fractions of B_4C reinforcement (3, 6, 9, and 12 wt. %) with the addition of 3 wt. % graphite (Gr) were added to the matrix material to develop aluminium hybrid composites. The newly developed mixtures were created by the stir casting method. Aluminium hybrid composites were tested under pin on disc for different loads and sliding distances. Addition of graphite materials provided self-lubricating effect, while the ceramic particles increased the strength of the matrix material. Worn surface shows fine grooves with delamination at minimum loads and sliding speed. Al-B_4C-Gr composites with 9% B_4C and 3% Gr enhanced better wear resistance compared with other reinforcements [8]. Moreover, the LM6 aluminium is reinforced with the addition of fly ash using the stir casting technique. The mechanical behavior of composites was investigated, and the ultimate tensile strength was increased from 35% to 45%. However, the density and wear loss of composites were decreased. The accumulation of fly ash into LM6 matrix material increased the mechanical features of composites [9].

The metal matrix (AA6061) reinforced with silicon carbide and B_4C was fabricated by the powder metallurgy process. The hardness, strength, and coefficient of friction increased, while the wear rate was reduced with the addition of 10% volume of ceramic particles. B_4C particles of various weight % (2, 4, 6, 8, 10, and 12 wt. %) and average particles size of 25 μm were reinforced to the base metal by the stir casting method. It was observed that the mechanical features of samples improved by the addition of reinforcements [10]. The LM6 alloy with varying weight fractions of B_4C increased the hardness and decreased the density [11], and the LM6 alloy with copper and SiC composition increased the density and hardness [12]. The addition of Al_2O_3 reinforcement particles into the LM6 alloy increased the hardness and compressive strength [13]. Similarly, the addition of Al nickel particles in LM6 alloy offered higher tensile and yield strength compared with pure alloy. Increased wt. % of Al-N increased both microhardness and macrohardness [14].

Gowtham et al. [15] reported the fabrications of LM6 alloy with B4C which were prepared by the stir casting method. The mechanical behaviors were investigated using tests like the tensile test, hardness test, and compression test. The new composite materials of spur gear can be designed and analyzed by FESEM. Finally, the gear model represented an increase in module, and pressure angle decreased the contact stress among the mating gears. Pio et al. [16] investigated the effect of Al-Ti-B and compared it with LM6 alloy by the sand casting method. The performance of the sand casting process was analyzed by considering different moduli of materials. The authors reported the correction between cooling rates with grain refinement. The authors found that LM6 aluminium alloy produced by lower modulus offered better mechanical properties. Kaur Sandhu [17] investigated the LM6 reinforced with SiC and Al_2O_3. The mechanical properties were improved because of the scattering of ceramic particles.

Sivaprakash and Sathish [18] investigated the LM6 alloy with the addition of Al_2O_3 and Si_3N_4 composites fabricated by a squeeze casting route. The main advantages of this method were maximum utilization of materials, low porosity, and good surface finish. Faisal and Prabagaran [19] investigated that LM6 alloy composites with the addition of B_4C particles, and the mechanical properties were examined. The graphite particles provided self-lubricating properties, which reduced the consumption of fuel and lubricating oil with additional advantage of energy expenditure in industries and automobile modules. The new composite material of the piston was designed, and an analysis was carried out by FEM. Further, it was compared with the base alloy, and the result revealed that hybrid composites produced better static structural properties. Mandala et al. [20, 21] examined Al-2 Mg alloy matrix with uncoated copper and nickel-coated steel fiber. Copper-coated steel fiber indicated good bonding strength and interface between the matrix and fillers. These composites offered higher strength than the parent metal. The fracture mechanisms of composites like dimple formation, fiber breakage, and pull out were identified. From the above literature survey, it was observed that the mechanical properties of base alloy increased with the addition of filler materials and ceramic particles.

In this work, the hybrid composite is prepared by reinforcing copper-coated short steel fiber and B_4C particles into LM6 alloy using the stir casting method. B_4C particle has been selected because of its higher hardness with excellent resistance to wear and corrosion. The earlier research works carried out by the authors report the mechanical and wear behaviors of single steel fiber-reinforced LM13/LM6 aluminium alloy-based composites [7, 22–26]. So far, the authors studied single steel fiber-reinforced composites. The present work presents the mechanical and wear behaviors of particle (B_4C) and fiber (copper-coated steel fiber)-reinforced hybrid metal matrix composites. The combination of particle and fiber-reinforced composites will provide better properties rather than single particle/fiber-reinforced composites. The mechanical properties such as hardness and tensile properties, microstructures, and tribological properties of the fabricated samples are investigated as per ASTM standards and reported.

2. Materials and Methods

2.1. Material Selection. LM6 aluminium alloy is mainly used in automotive applications because of its higher silica content [27, 28]. Hence, it was chosen as matrix. Boron carbide particles have been chosen because of their higher hardness and excellent resistance to wear and corrosion. To have an advantage of particle and fiber-reinforced composites, steel fibers have been chosen because of their higher tensile strength and hardness with better resistance to wear.

Chemical structure of LM6 aluminium alloy is presented in Table 1. Steel fibers with chemical structures are given in Table 2. 5 wt% of B4C with particle size less than 100 microns is reinforced in LM6 aluminium alloy. 3 mm steel fiber is used as secondary reinforcement, and its wt% is varied as 0, 2.5, 5, and 10. Steel fibers are copper coated using the electrode method [7]. Steel fibers with an average fiber diameter of 190 μm and 500–3500 μm length are reinforced in LM6 aluminium alloy.

3. Experimental Procedure

3.1. Stir Casting Method. LM6 Al alloy hybrid metal matrix mixtures were prepared by liquid metallurgy route—stir casting process, as shown in Figure 1. 800 g of LM6 Al alloy was dissolved in a graphite crucible and warmed up to 750°C. Then, the B_4C and short steel fiber were stirred at 950°C for 2-3 hours with 850 rpm, respectively. Ceramic particles and short fibers are split due to shear force exerted by the impeller while stirring process. The melt is continuously stirred to achieve uniform dispersion of ceramic particles and fibers in the matrix. Consequently, the molten melt is discharged into a preheated cast iron die at 250°C for required 300 mm length with 30 mm diameter (Figure 2). According to ASTM standards, the samples were made and the microstructure, hardness, tensile strength, and wear were investigated.

3.2. Tensile Test. Tensile samples were prepared as per ASTM E8 standard, as shown in Figure 3. The tensile tests were conducted by computerized UTM Model TECSOL and TMC Engineering model, India, with a 10 kN load cell for each sample. The tensile strength was investigated using a crosshead speed of 2.5 mm/min. Figure 4 shows the prepared tensile samples and broken tensile samples tested to explore the tensile strength of mixtures.

3.3. Brinell Hardness Test. The hardness test was performed in Brinell hardness verifier to check the hardness of LM6 Al alloy hybrid metal matrix composites. In this test, a hardened steel ball indenter is forced into the surface of a metal to be tested. The test was performed by using 5 mm ball indenter with a load of 500 kgf and dwell time of 10–15 S.

3.4. Wear Test. Wear specimens were prepared for the required dimensions of 10 mm diameter with 35 mm length as per ASTMG99 standard. The contact surface of the pin against the rotating disc (EN31 stainless steel) wear tester is shown in Figure 5. To study the wear behavior of samples, a load of 10 N–40 N with a sliding distance of 500–2000 m was considered. Weight losses were measured during the experiment through a single pan electronic machine with a precision of 0.0001 g. The sample was cleaned using acetone solution to calculate the wear loss for each sample. The worn surfaces were investigated using FESEM.

4. Results and Discussion

4.1. Microstructure Analysis. Analysis of LM6 Al alloy-based hybrid composites was carried out by an optical microscope at various wt. % of reinforced materials. Various percentages of composite samples were polished by using an emery sheet. There are various types of emery sheets used to polish the materials like 120, 400, 800, 1200, 1500, and 2500 grit sheets. After completion of polishing process, the samples were etched for microstructure analysis.

Dispersion of reinforcements was examined in different samples. Those particles were clearly visible while examining through the metallurgical microscope. LM6 Al alloy strengthened by different weight % of steel fiber with the addition of 5 wt. % of B_4C materials is shown in Figures 6(a) and 6(b). It shows uniform dispersion of reinforcements in AMMCs. Also, a good interface relation among steel fiber and parent material is achieved because of its coating of copper on fibers. Figures 6(c) and 6(d) show the microstructure of steel fiber in LM6 Al alloy, and micropores were obtained. This fiber was also coated with copper. Copper coating on steel fibers avoids the connection among liquid aluminium as well as steel fiber, hence feasible creation of intermetallic compounds. Copper responds to aluminium and creates a logical relation on the boundary. LM6 aluminium alloy-based hybrid metal matrix composites are produced by reinforcing ceramic particle and short steel fibers.

4.2. Mechanical Behavior of Composites

4.2.1. Hardness. Hardness of samples increases with the addition of short steel fiber and constant B_4C addition in matrix. This is due to a reformed grain size of material that increased the hardness of material as shown in Figure 7.

By observing the graph, it was found that without any addition of reinforcements, the hardness number is low. By varying copper-coated steel fiber (CCSF), the hardness of samples increased. The hardness of composites increased up to 146 BHN by reinforcing 10 wt% short steel fiber and 5 wt% boron carbide particles in the matrix.

4.2.2. Ultimate Tensile Strength. The effect of ceramic particles and steel fibers on tensile strength of hybrid composites was determined from the tensile test. Change of ultimate tensile strength with varying steel fibers is shown in Figure 8. This steel fiber is coated with copper. Tensile

Table 1: Chemical composition of LM6 Al alloy (wt. %).

Sample	Si	Fe	Cu	Mn	Mg	Ni	Sn	Pb	Zn	Ti	Al
LM6	11.78	0.40	0.02	0.02	0.03	0.006	0.05	0.06	0.12	0.08	Balance

Table 2: Chemical composition of steel fiber (wt. %).

Sample	C	Si	Mn	Ni	Cr	S	Fe
Steel fiber	0.10	0.41	2.17	6.89	7.68	0.24	Balance

Figure 1: Stir casting setup.

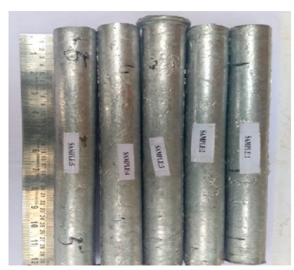


Figure 2: LM6 Al alloy hybrid composites samples.

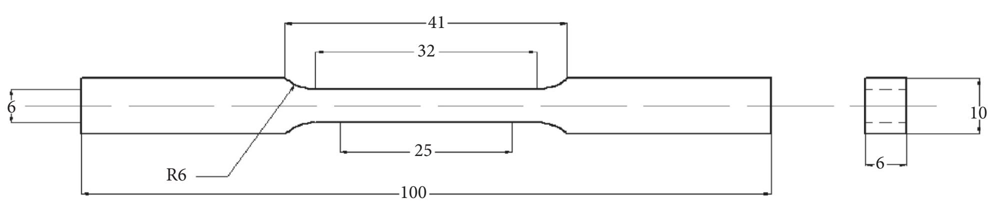


Figure 3: Tensile samples (mm).

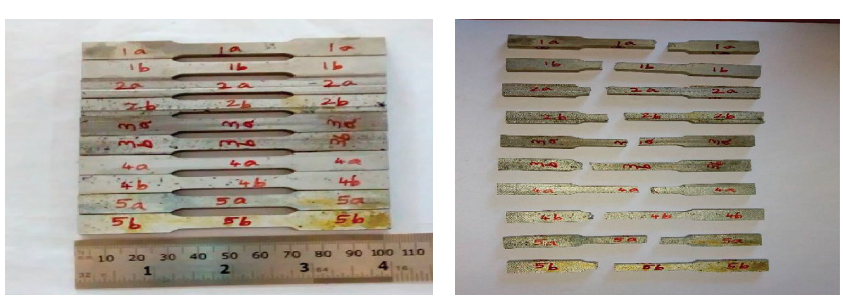


Figure 4: Tensile samples before and after tensile test of LM6 Al alloy hybrid composites.

Figure 5: Wear tester.

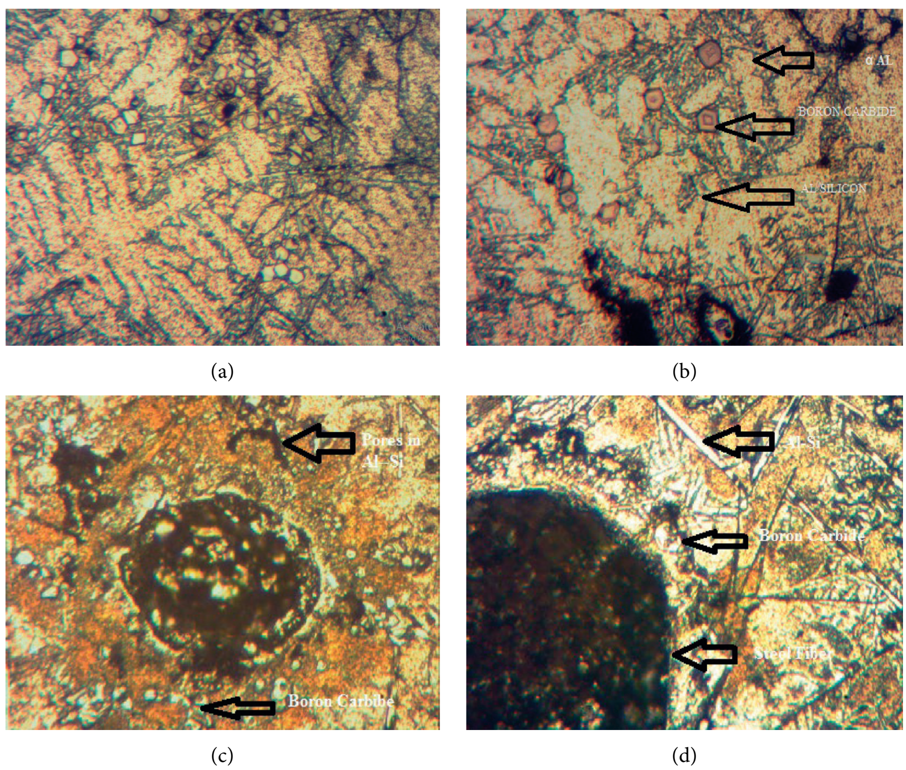


Figure 6: (a, b) Optical micrographs of LM6 Al alloy hybrid composites with 5% of B_4C. (c, d) Optical micrographs of LM6 Al alloy with 5% of CCSF and 5% of B_4C.

strength of models increased along with increment of fiber content up to 5 wt. % CCSF. Addition of steel fibers reduces the ultimate tensile power of samples.

Percentage of elongation is measured for checking the ductility, as shown in Figure 9. It was observed that the position of mixture material reduces with the addition of short steel fibers in the matrix material.

4.2.3. Analysis of Rupture Surface. Rupture surface of LM6 alloy hybrid composites is shown as a crevice that produces ductile fracture. However, broken steel fibers are measured in the fracture layer of hybrid composites, as shown in Figures 10(a)–10(d). It offers good interface bonding among matrix and reinforcement.

4.3. Tribological Behavior of Hybrid Composites

4.3.1. Cumulative Wear Loss. Collective weight loss of LM6 Al alloy hybrid composites for a stable sliding length of 2000 m with various weight conditions 10 N, 20 N, 30 N, and 40 N is shown in Figure 11. Variation of collective weight failure of hybrid mixtures reduced with the increase of fiber wt. % addition with constant wt. % of B_4C. Weight losses increase with a varying load of 10 N to 40 N.

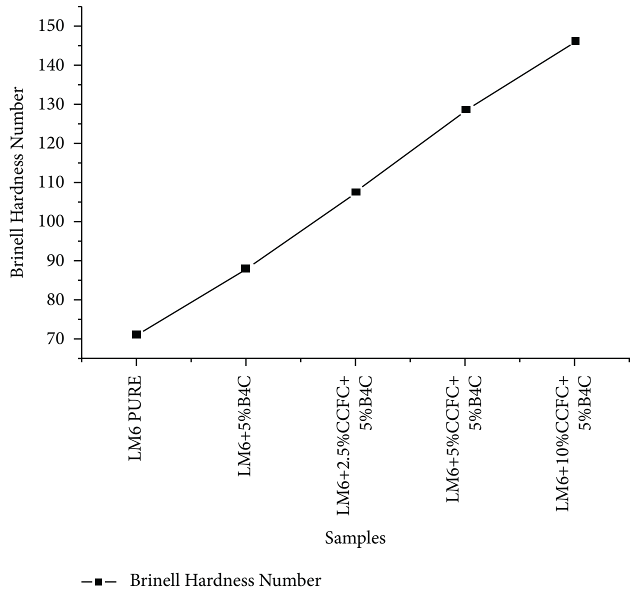


Figure 7: Changes of hardness against wt. % of strengthening.

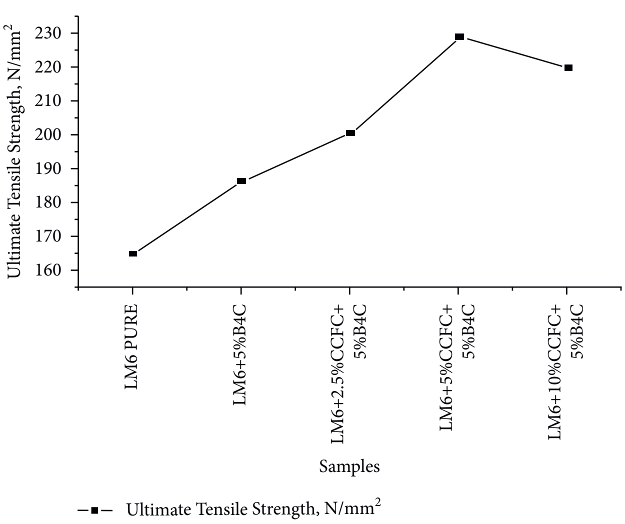


Figure 8: Extreme tensile strength of LM6 Al alloy hybrid composites.

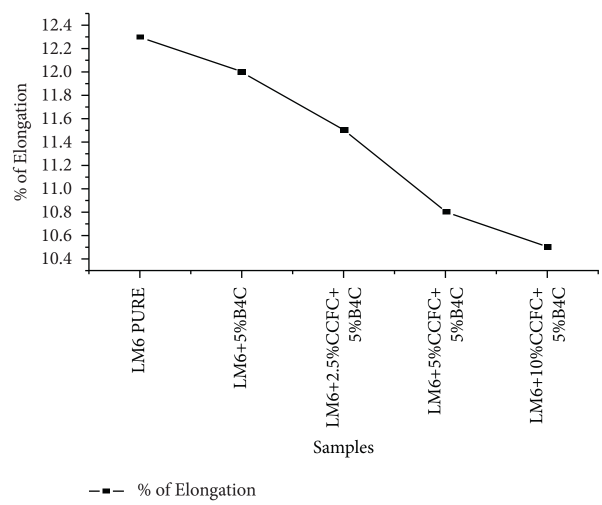


Figure 9: Percentage of elongation of LM6 Al alloy hybrid composites.

4.3.2. Consequence of Sliding Length. Changes in weight loss for LM6 Al alloy and LM6 Al alloy hybrid mixtures are shown in Figure 12. The entire material present shows a constant improvement in wear loss with improved sliding length. However, minimum wear loss is observed with the addition of reinforcement.

4.3.3. Analysis of Worn Layer. Worn layer of LM6 Al alloy hybrid composites was analyzed under a sliding length of 2000 m at 10 N weight as constant as shown in Figures 13(a)–13(d). Lengthy unbroken channel was examined on the layer corresponding to its sliding direction. Figure 13(a) shows unbroken depressions because of local division of many layers, and Figure 13(b) shows comparatively fine grooves because of combination of steel fibers in LM6 Al alloy. The volume of the cut is found to be smaller when higher wt. % of fiber is observed. Figures 13(c) and 13(d) show the damaged layer of 5 wt. % CCSF and 5 wt. % of B_4C reinforcement tested at a load of 30 N.

Figures 13(e)–13(h) show the micrographs of 5 wt. % B_4C and 5 wt. % CCSF for a moving length of 2000 m in various loads varying between 10 N and 40 N. The number of grooves increased with the increasing weight, and confined division was recorded at maximum weight. While increasing the sliding distance, the matrix loses weight, and unbroken

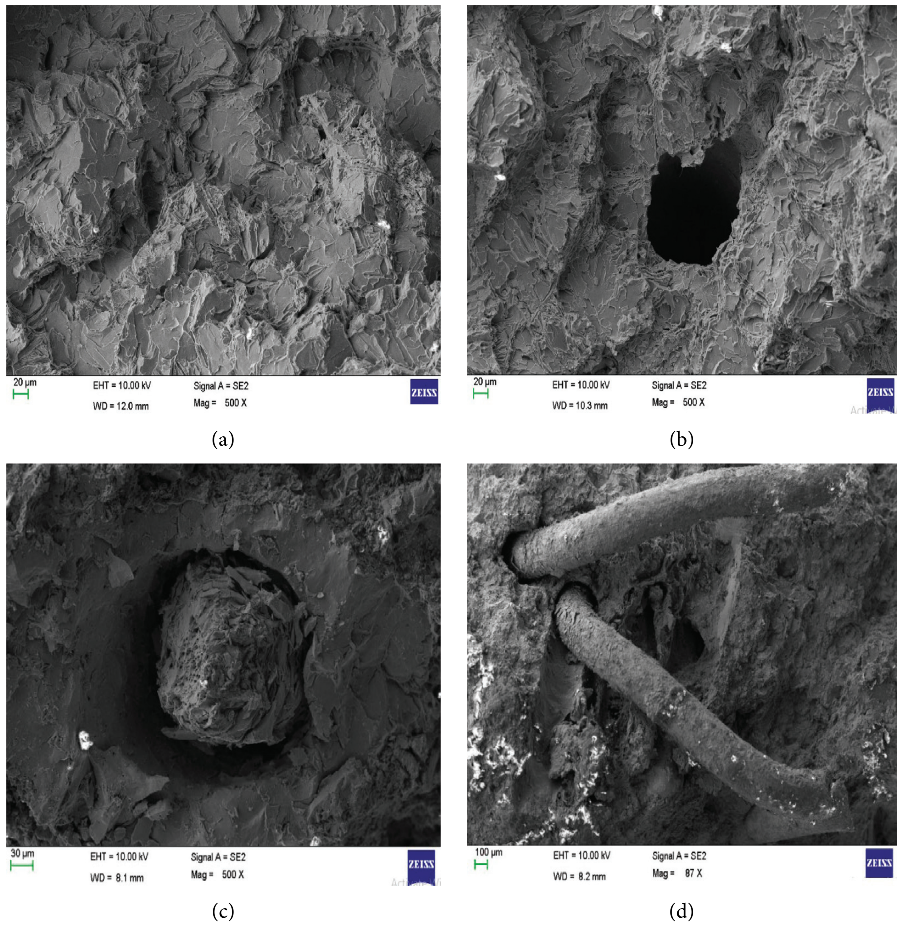


Figure 10: (a) Rupture surface of LM6 Al alloy. (b) Rupture surface with dimples of LM6 Al alloy hybrid composites. (c) LM6 Al alloy hybrid composites with broken wires. (d) LM6 Al alloy hybrid composites with two broken wires.

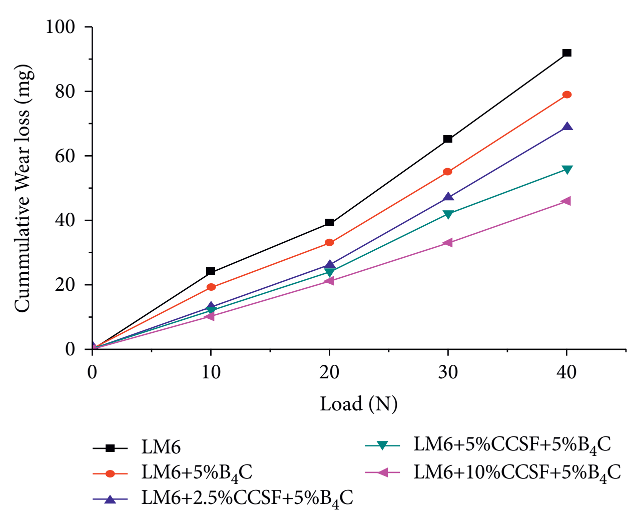


Figure 11: Cumulative wear losses with varying load conditions of LM6 Al alloy and hybrid composites.

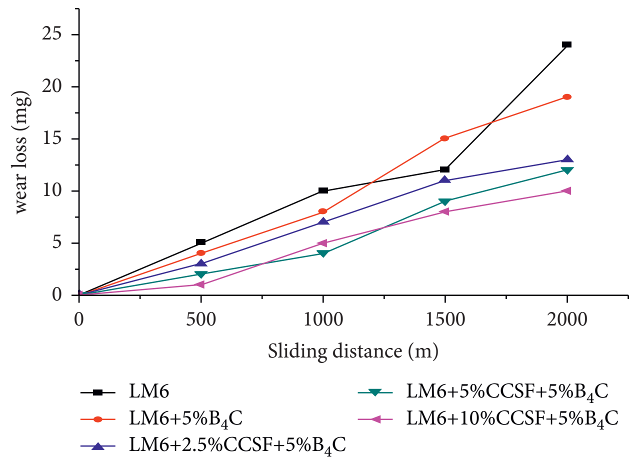
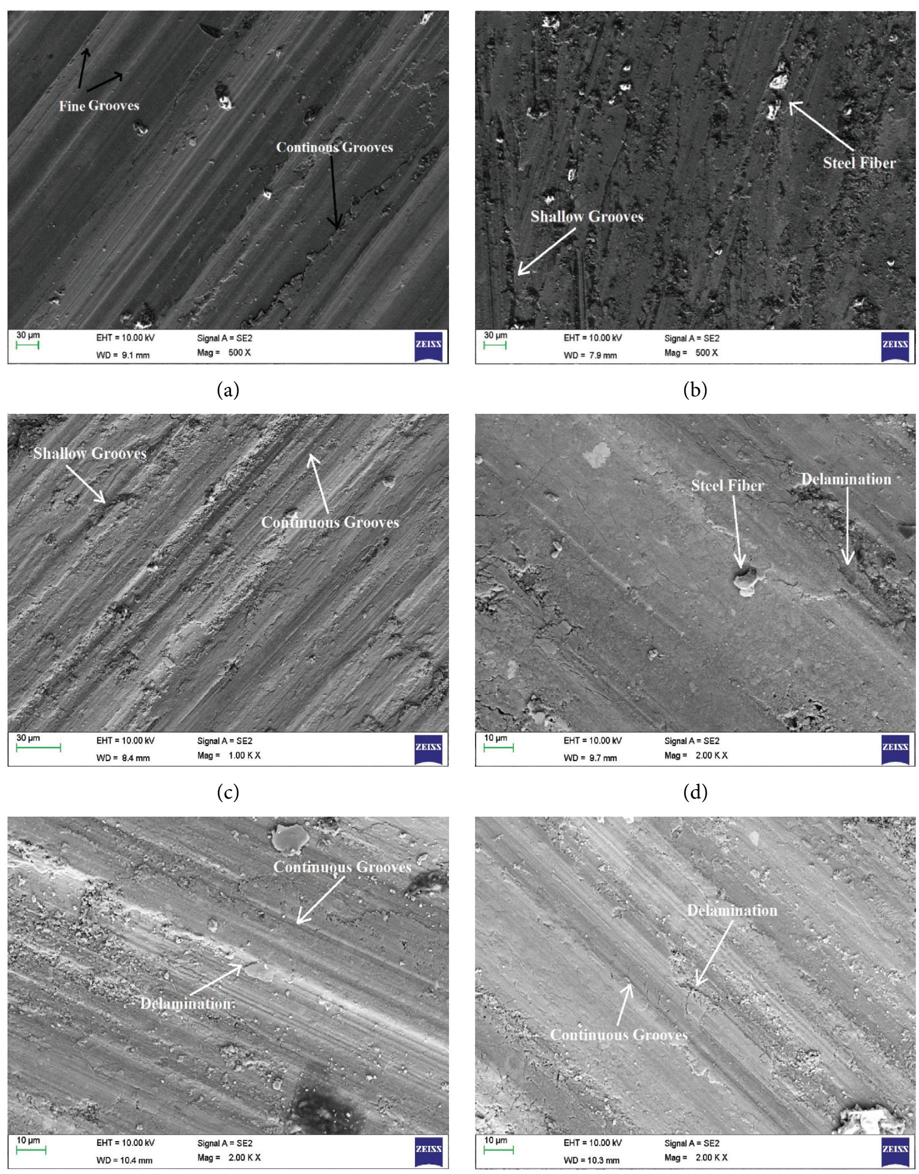
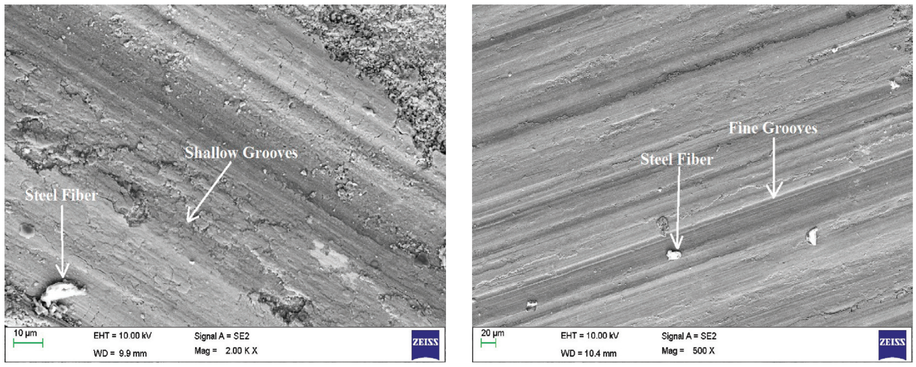


Figure 12: Wear losses with varying sliding distance of LM6 Al alloy and hybrid composites.



(a) (b) (c) (d) (e) (f)

Figure 13: Continued.



(g) (h)

Figure 13: (a–d) FESEM micrographs of damaged surfaces of LM6 Al alloy hybrid mixtures under a load of 10 N. (e–h) FESEM micrographs of damaged surfaces of LM6 Al alloy hybrid composites under various load conditions (10 N, 20 N, 30 N, and 40 N).

particles and fibers are observed. The wear method transforms from medium to serious through varying weights. At a load of 40 N, local delamination and extensive surface ploughing were examined.

5. Conclusion

Experimental investigations were conducted on LM6 Al alloy-based hybrid metal matrix materials that were prepared for various weight fractions of short steel fiber (CCSF) by the stir casting route. The above samples were investigated to check the tensile strength, hardness, and wear resistance, and the following results were obtained:

(1) Microstructure of samples indicated good interfacial connection among matrix stage and support.

(2) Brinell hardness increased with increasing short fiber content and constant amount of B_4C into the base material.

(3) Tensile strength of samples indicated that percentage of fiber reinforcement in LM6 Al alloy hybrid composites increased the tensile strength, and high strength was observed for 5 wt. % of short steel fiber-reinforced composites. If fiber content increases beyond 5 wt. %, then the tensile strength of materials is reduced.

(4) Wear weight loss of samples increased with the addition of weight and sliding distance. However, weight loss is reduced with the addition of weight percentage of reinforcements.

(5) Fracture surface of samples showed broken steel fibers with depression on the layer. Ductile fracture was found for composites.

(6) Worn surfaces of composites revealed fine grooves, continuous grooves, delamination, and steel fibers at different locations in samples.

Data Availability

The data used to support the findings of this study are included within the article.

Disclosure

The publication is only for the academic purpose of Addis Ababa Science and Technology University, Ethiopia

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

[1] A. Baradeswaran, S. C. Vettivel, A. Elaya Perumal, N. Selvakumar, and R. Franklin Issac, "Experimental investigation on mechanical behaviour, modelling and optimization of wear parameters of B4C and graphite reinforced aluminium hybrid composites," *Materials & Design*, vol. 63, pp. 620–632, 2014.

[2] M. Uthayakumar, S. Aravindan, and K. Rajkumar, "Wear performance of Al-SiC-B4C hybrid composites under dry sliding conditions," *Materials & Design*, vol. 47, pp. 456–464, 2013.

[3] S. Rama Rao and G. Padmanabhan, "Fabrication and mechanical properties of aluminium-boron carbide composites," *International Journal of Materials and Biomaterials Applications*, vol. 2, no. 3, pp. 15–18, 2012.

[4] A. Devaraju and K. Pazhanivel, "Evaluation of microstructure, mechanical and wear properties of aluminium reinforced with boron carbide nano composite," *Indian Journal of Science and Technology*, vol. 9, no. 20, 2016.

[5] N. Swapnil and D. Dr. S. A. Sonawane, "Experimental investigation of wear properties of aluminium LM6, Al_2O_3, flyash metal matrix composite," *International Journal for Scientific Research & Development*, vol. 4, no. 6, 2016.

[6] R. Akhil, J. David Rathnaraj, and S. Sathish, "Study on mechanical and microstructure properties of LM6 metal matrix composite with PbO glass reinforcement," *International Journal of Current Engineering and Technology*, vol. 2, no. 2, pp. 174–177, 2013.

[7] S. J. S. Chelladurai, R. Arthanari, N. Nithyanandam, K. Rajendran, and K. K. Radhakrishnan, "Investigation of mechanical properties and dry sliding wear behaviour of squeeze cast LM6 aluminium alloy reinforced with copper coated short steel fibers," *Transactions of the Indian Institute of Metals*, vol. 71, no. 4, pp. 813–822, 2018.

[8] T. Thirumalai, R. Subramanian, S. Dharmalingam, and R. Nachiappan, "Wear behaviour of B_4C reinforced hybrid aluminum-matrix composites," *Materiali in tehnologije/Materials Technology*, vol. 49, no. 1, pp. 9–13, 2015.

[9] N. Suresh, S. Venkateswaran, and S. Seetharamu, "Influence of cenospheres of fly ash on the mechanical properties and wear of permanent moulded eutectic Al–Si alloys," *Materials Science-Poland*, vol. 28, no. 1, 2010.

[10] B. Ravi, B. BaluNaiK, and J. UdayaPrakash, "Characterization of aluminium matrix composites (AA6061/B_4C) fabricated by stir casting technique," *Materials Today Proceedings*, vol. 2, no. 4-5, pp. 2984–2990, 2015.

[11] L. Gómez, D. Busquets-mataix, V. Amigo´, and M. D. Salvador, "Analysis of boron carbide aluminum matrix composites," *Journal of Composite Materials*, vol. 43, no. 9, pp. 987–995, 2009.

[12] W. R. Blumenthal, G. T. Gray, and T. N. Claytor, "Response of aluminium-infiltrated boron carbide cermets to shock wave loading," *Journal of Materials Science*, vol. 29, no. 17, pp. 4567–4576, 1994.

[13] S. Das, R. Behera, and B. Nayak, "Effect of Al_2O_3 on mechanical behaviour of the stir-cast aluminium alloy metal matrix composites," *IPASJ International Journal of Mechanical Engineering (IIJME)*, vol. 3, no. 5, pp. 2321–6441, 2015.

[14] Kumar and Murugan, "Aeronautical applications of metal-matrix composites," *Air Force Research Laboratory, Light Met. Age*, vol. 57, no. 1, 2, pp. 117–121, 1999.

[15] A. V. S. Gowtham, T. Lakshmana Kishore, and M. Komaleswara Rao, "Analysis of spur gear using boron carbide particulate reinforced Lm6 aluminium metal matrix composite," *IJEDR1704102 International Journal of Engineering Development and Research*, vol. 5, no. 4, pp. 2321–9939, 2017.

[16] L. Y. Pio, S. Sulaiman, A. M. Hamouda, and M. M. H. M. Ahmad, "Grain refinement of LM6 Al-Si alloy sand castings to enhance mechanical properties," *Journal of Materials Processing Technology*, vol. 162-163, pp. 435–441, 2005.

[17] K. Kaur Sandhu, "Development and characterization of aluminium LM6 based matrix using 2% sic & 2% Al_2O_3," *International Advanced Research Journal in Science, Engineering and Technology ISO 3297:2007*, vol. 3, no. 11, pp. 2394–1588, 2016.

[18] A. Sivaprakash and S. Sathish, "Investigation of microstructure and mechanical properties of squeeze cast LM6 alloy with varying contents of Al2O3and Si3N4 - a review," *International Journal of Current Engineering and Technology*, vol. 2, no. 2, pp. 207–212, 2013.

[19] M. H. Faisal and S. Prabagaran, "Micro structural and static structural analysis of LM6/B4C and LM6/B_4C/GR hybrid aluminium metal matrix composites," *International Journal of Engineering & Technology*, vol. 7, no. 1.1, pp. 37–42, 2018.

[20] D. Mandala, B. K. Duttab, and S. C. Panigrahib, "Effect of wt% reinforcement on microstructure and mechanical properties of Al–2Mg base short steel fiber composites," *Journal of Materials Processing Technology*, vol. 198, pp. 195–201, 2008.

[21] D. Mandal, B. K. Dutta, and S. C. Panigrahi, "Microstructure and mechanical properties of Al–2Mg alloy base short steel fiber reinforced composites prepared by vortex method," *Journal of Materials Science*, vol. 41, no. 15, pp. 4764–4770, 2008.

[22] S. J. S. Chelladurai, R. Arthanari, A. N. Thangaraj, H. Sekar, and H. Sekar, "Dry sliding wear characterization of squeeze cast LM13/FeCu composite using response surface methodology," *China Foundry*, vol. 14, no. 6, pp. 525–533, 2017.

[23] S. J. S. Chelladurai, R. Arthanari, R. Selvarajan, R. Kanagaraj, P. Angappan, and P. Angappan, "Investigation on microstructure and tensile behaviour of stir cast LM13 aluminium alloy reinforced with copper coated short steel fibers using response surface methodology," *Transactions of the Indian Institute of Metals*, vol. 71, no. 9, pp. 2221–2230, 2018.

[24] S. J. S. Chelladurai, R. Arthanari, R. Selvarajan et al., "Optimisation of dry sliding wear parameters of squeeze cast AA336 aluminium alloy: copper-coated steel wire-reinforced composites by response surface methodology," *International Journal of Metalcasting*, vol. 13, no. 2, pp. 354–366, 2019.

[25] S. J. S. Chelladurai and R. Arthanari, "Prediction of hardness of stir cast LM13 aluminum alloy - copper coated short steel fiber reinforced composites using response surface methodology," *Materialwissenschaft und Werkstofftechnik*, vol. 51, no. 2, pp. 221–229, 2020.

[26] K. S. Selvaraj and P. Govindan, "Investigation of the mechanical properties of a squeeze-cast LM6 aluminium alloy reinforced with a zinc-coated steel-wire mesh," *Materiali in tehnologije*, vol. 52, no. 2, pp. 125–131, 2018.

[27] M. Akbari, A. Khalkhali, S. M. E. Keshavarz, and E. Sarikhani, "The effect of in-process cooling conditions on temperature, force, wear resistance, microstructural, and mechanical properties of friction stir processed A356," *Proceedings of the Institution of Mechanical Engineers - Part L: Journal of Materials: Design and Applications*, vol. 232, no. 5, pp. 429–437, 2018.

[28] M. Akbari, M. H. Shojaeefard, P. Asadi, and A. Khalkhali, "Wear performance of A356 matrix composites reinforced with different types of reinforcing particles," *Journal of Materials Engineering and Performance*, vol. 26, no. 9, pp. 4297–4310, 2017.