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Research Article

Synthesis and Thermal Adsorption Characteristics of Silver-Based Hybrid Nanocomposites for Automotive Friction Material Application

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Advances in friction materials are imposed on developing multiceramic reinforced hybrid nanocomposites with superior tribomechanical properties. The silver-based matrix metals are gained significance in various applications like bearing, ratchet, and electrical contacts due to their high frictional resistance and good thermal and chemical stability compared to traditional metals. The present research is to develop silver-based hybrid nanocomposites containing alumina (Al_2O_3) and silicon carbide (SiC) nanoparticles of 50 nm mixing with the ratio of 0 wt% Al_2O_3/0 wt% SiC, 5 wt% Al_2O_3/0 wt% SiC, and 5 wt% Al_2O_3/5 wt% SiC via the semisolid vacuum stir-cast technique. The vacuum technology minimizes casting defects and increases composite properties. The casted composite samples are subjected to study the effect of reinforcement on thermal adsorption, conductivity, diffusivity, and frictional resistance. The composite containing 5 wt% Al_2O_{3np}/5 wt% SiC_{np} is to find optimum thermal and frictional behaviour. The thermal adsorption and frictional resistance are increased by 30% and 27% compared to unreinforced cast silver. The Ag/5 wt% Al_2O_{3np}/5 wt% SiC_{np} hybrid nanocomposite is recommended for automotive friction-bearing applications.

1. Introduction

In modern research, the world is forced to search the new advanced material to meet the industrial requirement and fulfill the following qualities: high strength, good thermal stability, enhanced corrosion resistance, ability to withstand high frictional force with reduced wear loss, and increased coefficient of friction. Many researchers have experimentally studied the aluminium alloy-based matrix composite [1–4] due to their lower density, high ductility, good strength, and stiffness compared to conventional materials [5–8]. However, the characteristics of composite with their hybrid systems may be varied due to the particle shape and size, mixing ratio, casting process parameters, and method of processing of composite [9–11]. The particulate-reinforced composite can perform high strength and friction resistance [12]. Specifically, silicon carbide, aluminium oxide, tungsten carbide, boron carbide, and zirconium dioxide-based ceramics to metal matrix result in high hardness, resistance to high frictional force, and high thermal stability [13]. The zinc/lead and nickel-based matrix composite is adopted in aviation and space applications due to its high frictional resistance, anticorrosion, and thermal proof [14, 15]. In the future, silver-based metal matrix composites (SMMCs) will perform extraordinary (solid) lubrication effect and withstand the high thermal stress during high frictional force applied in aerospace motor applications, high friction bearing, and electrical contact applications [16–20]. However, few studies are available on silver matrix composite for automotive friction material applications [21]. Pure silver is characterized by low wear resistance and superior thermoelectrical conductivity. Due to these properties, it was accomplished by several industries alloying with Zn, Cu, Mn, Ni, and aluminium alloy to obtain a specific performance [22]. In the past decades, the frictional properties for different constitutions of aluminium/mica and copper/coated ground mica have been studied for bearing applications. The facilitation of mica influences higher frictional strength [23]. The CSM tribotester estimated the silver-copper-based composite's dry sliding wear characteristics. The result reveals that the composite's worn surface is directly impacted by the friction coefficient and rate of wear [24]. Most matrix materials are bonded with suitable reinforcements via solid-state processing (powder metallurgy), liquid-state processing (gravity, centrifugal, stir, and vacuum stir casting), and vapour-state processing (vapour and spray deposition process) techniques [25, 26]. Among various fabrication techniques listed above, the liquid-state processing distinctively improves physical-chemical properties between matrix and reinforcements resulting in increased product quality and suitability for mass production. Most researchers reported that the liquid-state stir processing is apposite for complex shape production at massive and economical production [27–31]. Based on the above literature, various matrix alloying materials, reinforcements, and their processing methods are discussed with their enhanced properties. The present research is to develop a silver matrix hybrid nanocomposite containing Al_2O_3/SiC nanoparticles via the vacuum sir cast technology. The fabricated samples were studied for their thermal and friction characteristics. The influences of both ceramics on the silver matrix found enhanced thermal adsorption with reduced mass loss, better conductivity, diffusivity, and rate of wear. The ASTM G99-05 standard evaluates the wear rate of advanced composites. Finally, all the test results were compared, and the best constitution having enhanced properties to fulfil the automotive friction material applications was recommended.

2. Experimental Details

2.1. Selection of Primary Matrix Material. The present study chose the silver-based alloy as the primary matrix material. The properties of silver are mentioned in Table 1.

2.2. Selection of Secondary Phase Reinforcements. The complex ceramic aluminium oxide and silicon carbide particle (50 nm) with an average size of 50 nm is chosen as secondary phase reinforcement to obtain better composite performance [28, 30, 31]. The properties of both ceramic phases are represented in Table 2.

2.3. The Mixing Ratio of Composite. Table 3 illustrates the phase constitution of a silver matrix concerning weight percentages of reinforcement used by the production of silver matrix hybrid nanocomposite.

2.4. Method and Processing of Composites. Figures 1(a) and 1(b) represent the silver matrix composite fabrication full setup with vacuum pump assembly. The different-sized silver round bar was preheated at 400°C for 30 min and melted via an electrical furnace with an applied temperature range of 1000°C to 1200°C under an inert atmosphere (supply of argon gas at a constant level of 3 l/h) to avoid the thermal oxidation. The higher temperature may increase the oxidation resulting in an increased porosity [27, 28]. According to the phase constitutions (mixing ratio) reported in Table 3, the preheated reinforcements (Al_2O_3/SiC) are added into a silver molten pool stirred with 500 rpm stir speed. Here, the graphite mechanical stirrer is used to improve the fluidity for surface preparation. A similar concept was reported by silver composite [20]. Thoroughly stirred molten state mixed silver matrix hybrid nanocomposite is developed with an applied vacuum pressure of 1×10^5 bar, resulting in minimized casting defects with increased composite performance. Table 4 represents the processing parameters of silver matrix composites.

2.5. Evaluation of Thermal Characteristics. The thermal characteristics of silver matrix MMCs are evaluated by STA Jupiter make 449/F3 model differential thermal analysis equipment configured with -150°C to 2400°C under argon atmosphere. The laser flash technique is accomplished to find the thermal conductivity ($ʎ$) and its diffusivity as referred follows [20].

$$ʎ(T) = \rho(T) x \alpha(T) x Cp(T). \quad (1)$$

Here $ʎ$ is the thermal conductivity, T the temperature, ρ the density of material, α the thermal diffusivity, and Cp the specific heat coefficient.

The NETZSCH-made DIL 402C and LFA 427 models are considered for evaluating linear thermal expansion and its diffusivity of ϕ8 mm and 25 mm length sample under the ambient temperature of 27°C to 1000°C with 7°C/min heat flow.

2.6. Evaluation of Frictional Characteristics. The dry sliding frictional characteristics of cast silver, nanocomposite, and hybrid nanocomposite were evaluated by rotating pin on disc tribotester configured with a hardened steel disc with an applied load of 10 N, 20 N, and 30 N under the constant sliding velocity of 0.75 m/sec. The above conditions estimated the effect of reinforcement on frictional resistance of the silver matrix. The top view of the wear tester is shown in Figure 1(c).

Table 1: Properties of silver matrix.

Properties	Density	Elastic modulus	Tensile strength	Melting temperature	Thermal conductivity	Emissivity	Specific heat capacity
Ag	10.49 g/cc	76 GPa	140 MPa	962°C	419 W/mK	0.055	0.234 J/g°C

Table 2: Properties of reinforcements.

Reinforcements	Density g/cc	Hardness VHN	Modulus of elasticity GPa	Melting point °C	Thermal conductivity W/mK
Al_2O_3	3.96	1366	375	2055	30.12
SiC	3.1	14450	412	2799	77.54

Table 3: Phase constitutions of silver matrix composite.

Sample	Descriptions	Phase constitutions in wt%		
		Ag	Al_2O_3	SiC
1	Alloy	100	0	0
2	Nanocomposite	95	5	0
3	Hybrid nanocomposite	90	5	5

3. Result and Discussions

3.1. Differential Thermal Effect on Mass Loss of Silver Matrix Composites. Figures 2(a)–2(c) illustrate the differential thermal effect on mass loss of cast silver correlated with Al_2O_3- and SiC-reinforced silver nano- and hybrid nanocomposites evaluated under the thermal region of 27°C to 1000°C. The temperature-to-mass loss of each test sample is explained in detail. When the temperature increases from ambient temperature to high temperature, it shows solid to semisolid phase and liquid phase at the higher temperature (phase transformations—solid/liquid and liquid/solid) of heating and cooling phase during the evaluation of thermal studies. It is revealed from Figure 2(a) that the mass loss of cast silver (Ag) alloy is gradually decreased from 0.02 μV/mg to 0.0098 μV/mg with an increase in temperature of 27° to 825°C under an inert atmosphere. At the same time, increasing the temperature of cast silver by more than 825°C results to the formation of the plastic region with improved mass loss of 0.0302 μV/mg. It was due to the reaction of intermetallic coarse fine grain structure and dissolution of the Ag phase. Similar conditions have been reported by Jakub et al. [20] during the evaluation of silver matrix MMCs. The wettability of the composite was limited by the volume fraction SiC [22].

Figure 2(b) represents the variations in weight loss of cast Ag alloy nanocomposite consisting 5 wt% alumina nanoparticles during differential thermal analysis. The red and blue curve represents the heat and cooling phase of Ag matrix composite processing as per the condition mentioned in Table 2. The heating curve in Figure 2(b) shows a gradually sloping from 0.0213 μV/mg to 0.0086 μV/mg for a semisolid phase temperature of 760°C. In-reversal effect of the heating curve shows that the maximum temperature of 840°C reduces the mass loss on the phase of bonded matrix—reinforcement by an applied stir speed of 500 rpm results in the formation of a homogenous uniform structure. The constant stir speed may reduce the composite's casting defect (weight loss). The selection of stir-cast processing parameters was necessary for the quality of the composite. The discontinued stir action increases the cavity of the composite, resulting in increased porosity [27].

Figure 2(c) represents the phase transformation during the heat and cooling phase of silver matrix hybrid nanocomposite with a varied temperature range of 27°C to 1200°C. The intermediate transition zone (820°C) for both the heat and cooling phases shows a minimum mass loss of less than 0.009 μV/mg. Here, the thermal effect of silver matrix composite varied due to the chemical constitutions and bonding strength between matrix and alumina/silicon carbide nanoparticles.

A similar scenario was reported by Mata and Alcala [9] during the performance friction material. However, both reinforcements are thermally stable at higher temperature (1000°C) for melting silver. The intermediate phase for silver, silver nanocomposite, and silver hybrid nanocomposite was found by differential thermal effect analysis, and the values are tabulated in Table 5.

3.2. Effect of Reinforcement on Thermal Adsorption and Thermal Diffusivity of Silver Matrix Composites. Figure 3 graph describes the detailed heat wave circulation (linear expansion and adsorption) of unreinforced Ag alloy and Al_2O_3/SiC-reinforced composites. The unreinforced Ag alloy is found 18×10^{-6} per K (1.70%). The inclusion of alumina nanoparticle (5 wt%) into Ag alloy shows a 4.8×10^{-6} per K. It was due to the rigid ceramic particles leading to increase hardness and withstand the higher temperature [18]. The circulation of the thermal wave to

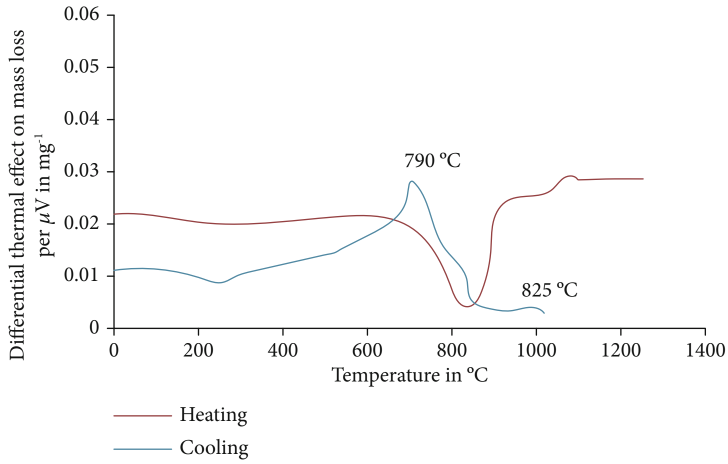
Figure 1: Actual fabrication setup for silver matrix composite. (a) Actual setup. (b) Processing chain with different thermal phase. (c) Pin on disc wear apparatus.

Table 4: Process parameter for silver matrix composites.

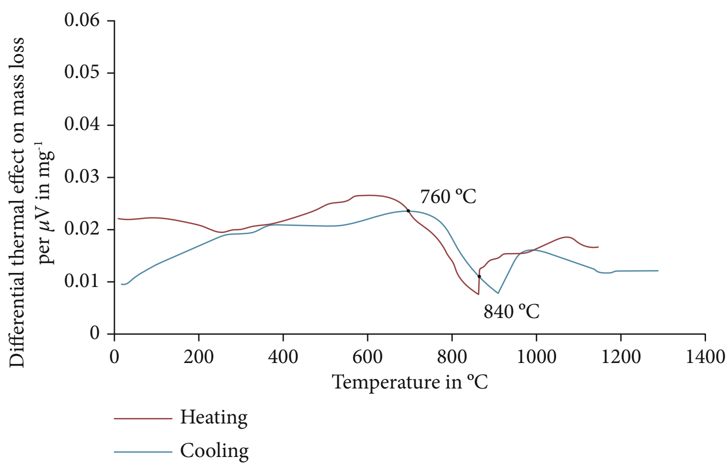
Descriptions	Preheating temperature Matrix	Rotational speed (stir) Reinforcements	Impeller type	Stir time	Feed rate	Die preheat temperature	Vacuum pressure
Units	400°C	500 rpm	Graphite	10 min	0.9 g/sec	350°C	1×10^5 bar

Ag nanocomposite is decreased to 12% compared to unreinforced Ag alloy. The composite contained 5 wt% alumina and silicon carbide nanoparticle is found at 1.42%. Generally, both reinforcements are complex, and high melting temperature reduces linear expansion. The various phase transformation during the evaluation is noted in Figure 3, and its intermediate zone for optimum thermal effect temperature tangent lines is drawn. However, the physical presence of both Al_2O_3 and SiC nanoparticles leads to decreased thermal coefficient and increased composite adsorption. The higher temperature withstand capacity was increased by over 30% compared to Ag alloy at 1000°C.

The experimental results for thermal diffusivity of (a) Ag/0 wt% Al_2O_{3np}/0 wt% SiC_{np}, (b) Ag/5 wt% Al_2O_{3np}/



(a)



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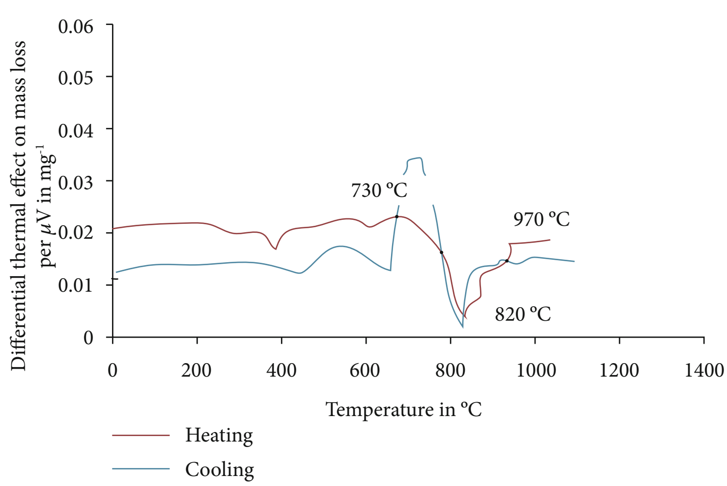

(c)

FIGURE 2: Differential thermal effect on mass loss of silver matrix hybrid nanocomposite. (a) Ag/0 wt% Al_2O_{3np}/0 wt% SiC_{np}, (b) Ag/5 wt% Al_2O_{3np}/0 wt% SiC_{np}, and (c) Ag/5 wt% Al_2O_{3np}/5 wt% SiC_{np}.

0 wt% SiC_{np}, and (c) Ag/5 wt% Al_2O_{3np}/5 wt% SiC_{np} composites are shown in Figure 4. The variations in thermal diffusivity of pure Ag is shown in gradual increase with the increase in the temperature from ambient degree (27° C to 1200°C). The highest thermal diffusivity of 24 mm^2/sec is found on pure Ag. However, the thermal diffusivity of hybrid nanocomposite shows the most negligible value compared to all others. It was due to the effect of phase transformation during high temperatures. It was decided as silver and reinforcement atomic structure [21]. It is distinct

Table 5: Intermediate transition zone for unreinforced and reinforced silver matrix composite by differential thermal analysis.

Sample	Descriptions	Intermediate zone temperature °C	Mass loss μV/mg
1	Alloy	850	0.0098
2	Nanocomposite	840	0.0086
3	Hybrid nanocomposite	820	0.0009

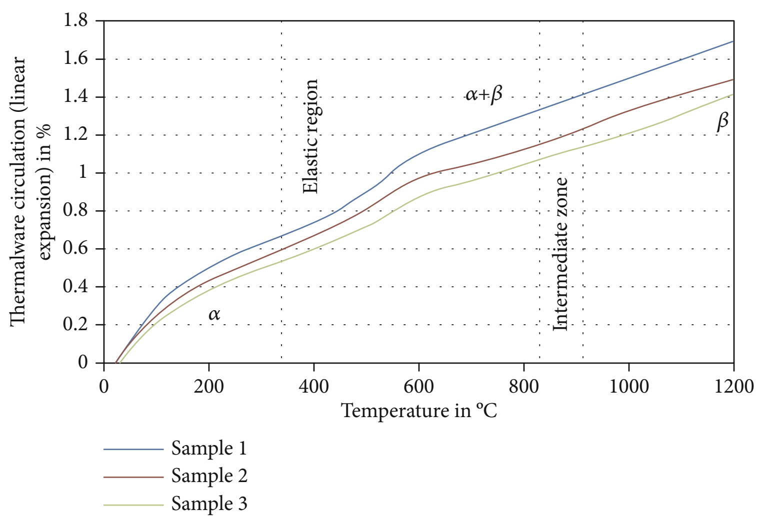

Figure 3: Thermal wave circulation (linear expansion and adsorption) phase transformation of silver matrix hybrid nanocomposite.

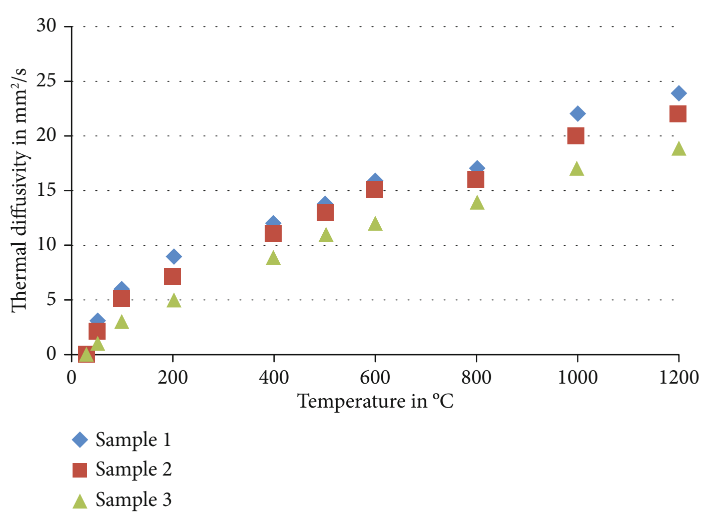

Figure 4: Thermal diffusivity of silver matrix hybrid nanocomposite.

to 820°C of the intermediate phase and gets an effective thermal diffusivity of 15 mm^2/sec. While the temperature increases, it has increased in thermal diffusion to 1000°C. It may be varied due to the bonding of the matrix and reinforcements [20, 21].

3.3. Effect of Reinforcements on Frictional Characteristics of Silver Matrix Composites. The frictional wear loss of unreinforced silver and its composites are shown in Figure 5. The wear loss of silver and its composites are increased linearly with an increase in an applied average load of 10-30 N, respectively. The wear loss of unreinforced silver composite is 10.2 mg on 40 N load under a constant sliding velocity of 0.75 m/sec. At the same time, adding Al_2O_3 nanoparticles in silver shows a minimum wear loss of 7.1 mg on high load and high sliding speed. The reduced wear loss of the

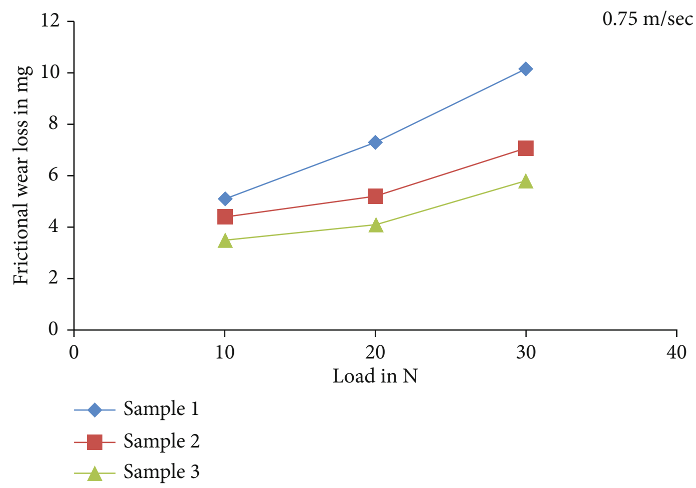

FIGURE 5: Frictional wear loss of silver hybrid nanocomposite.

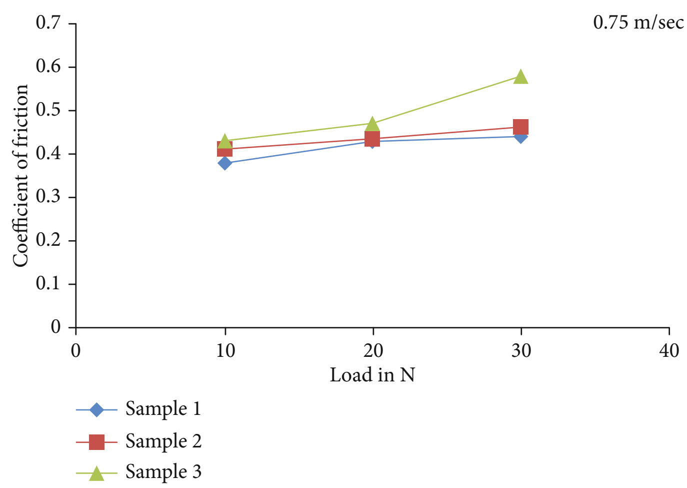

FIGURE 6: Coefficient of friction (COF) of silver hybrid nanocomposite.

composite is mainly attributed to alumina nanoparticles that resist the indentation against the frictional force during high sliding velocity. The alumina and silicon carbide particle combination in the silver matrix has low wear loss compared to all others [30, 31]. The composite contained 5 wt% Al_2O_3/5 wt% SiC 5.8 mg on a 40 N applied load with the frictional force of 23.4 N under 0.75 m/sec. The wear resistance against frictional composite was increased by 56.86% compared to unreinforced silver.

The friction coefficient for silver composites is represented in Figure 6 with different load conditions of 10-30 N at 0.75 m/sec sliding velocity. Sample 1 shows that the COF increases linearly with an increase in load under high sliding velocity. Sample 2 varied from 0.41 to 0.46 with increased content of reinforcements. However, all the test samples were shown increased COF value on the high frictional force. Sample 3 has a maximum COF of 0.58 and improved by 32% compared to sample 1 at 30 N load. It was due to the rigid ceramic particles being diffused within the matrix during high frictional force.

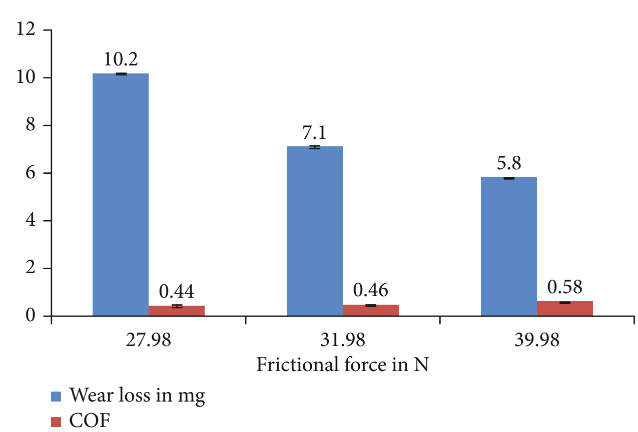

FIGURE 7: Comparisons and effect of the frictional force on wear loss and COF of silver matrix hybrid composite.

Figure 7 illustrates the friction-forced effect on wear loss and coefficient friction of unreinforced and reinforced silver matrix composite. It indicates that composite wear loss decreases gradually with increased frictional force from 27.98 N to 39.98 N. Similarly, the COF curve in Figure 7 represents the improved COF trend on the increased frictional force. However, sample 3 has tribological performance on a 30 N load under 0.75 m/sec sliding speed with 39.98 N frictional force.

4. Conclusions

The silver-based matrix hybrid nanocomposite developed with 5 wt% alumina and 5 wt% silicon carbide nanoparticle via vacuum stir-casting techniques to minimize the casting defect and increase the thermal adsorption composite of the following results are concluded.

(i) The silver matrix hybrid nanocomposite (sample 3) is found to have good thermal characteristics compared to others

(ii) Its intermediate transition zone temperature of 820°C has been adopted for both the heat and cooling phases with a minimum mass loss of 0.009 μV/mg. It saved 16.5% compared to unreinforced cast silver

(iii) The adsorption of hybrid nanocomposite is increased by 30% and thermally stable at higher temperatures, 1000° C

(iv) The adequate thermal wave circulation (linear expansion) of hybrid nanocomposite is 1.42%

(v) The thermal diffusivity of hybrid nanocomposite may be varied due to the bonding strength between the matrix and reinforcements

(vi) Sample 3 is identified as having good wear resistance, and COF has improved by 56.86% and 32% compared to unreinforced silver composite

(vii) It is recommended for automotive friction-bearing applications based on thermal and frictional characteristics

Data Availability

All the data required are available within the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

All authors contributed to the study's conception and design. P. Sakthivel is responsible for investigation and validation. J. Phani Krishna is responsible for data collections and executions. R. Venkatesh is responsible for original draft preparations. C. Ramesh Kannan is responsible for methodology and concept. M. Vivekanandan is responsible for formal analysis and review. S. Dhanabalan is responsible for the collection of test results. T. Thirugnanasambandham is responsible for writing and review. Manaye Majora is responsible for supervision and execution of investigation outline. All authors provided language help, writing assistance, and proofreading of the manuscript. All authors read and approved the final manuscript.

References

[1] J. Rodríguez, M. A. Garrido-Maneiro, P. Poza, and M. T. Gómez-del Río, "Determination of mechanical properties of aluminium matrix composites constituents," *Materials Science and Engineering: A*, vol. 437, no. 2, pp. 406–412, 2006.

[2] C. H. Gireesh, K. D. Prasad, and K. Ramji, "Experimental investigation on mechanical properties of an Al6061 hybrid metal matrix composite," *Journal of Composites Science*, vol. 2, no. 3, p. 49, 2018.

[3] C. R. Kannan, R. Venkatesh, M. Vivekanandan et al., "Synthesis and Characterization of Mechanical Properties of AA8014 + Si_3N_4/ ZrO_2 Hybrid Composites by Stir Casting Process," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 9150442, 11 pages, 2022.

[4] M. O. Bodunrin, K. K. Alaneme, and L. H. Chown, "Aluminium matrix hybrid composites: a review of reinforcement philosophies; mechanical, corrosion and tribological characteristics," *Journal of Materials Research and Technology*, vol. 4, no. 4, pp. 434–445, 2015.

[5] S. V. Prasad and R. Asthana, "Aluminum metal-matrix composites for automotive applications: tribological considerations," *Tribology Letters*, vol. 17, no. 3, pp. 445–453, 2004.

[6] P. K. Rohatgi, "Metal matrix composites," *Defence Science Journal*, vol. 43, no. 4, pp. 323–349, 1993.

[7] D. B. Miracle, "Metal matrix composites - from science to technological significance," *Composites Science and Technology*, vol. 65, no. 15-16, pp. 2526–2540, 2005.

[8] A. Macke, B. F. Schultz, and P. Rohatgi, "Metal matrix composites," *Advanced Materials and Processes*, vol. 170, no. 3, pp. 19–23, 2012.

[9] M. Mata and J. Alcalá, "The role of friction on sharp indentation," *Journal of the Mechanics and Physics of Solids*, vol. 52, no. 1, pp. 145–165, 2004.

[10] R. Karthik, K. Gopalakrishnan, R. Venkatesh, A. Mohana Krishnan, and S. Marimuthu, "Influence of Stir Casting Parameters in Mechanical Strength Analysis of Aluminium Metal Matrix Composites (AMMCs)," *Materials Today: Proceedings*, vol. 62, pp. 1965–1968, 2022.

[11] P. Mohanty, R. Mahapatra, P. Padhi, C. H. V. V. Ramana, and D. K. Mishra, "Ultrasonic cavitation: An approach to synthesize uniformly dispersed metal matrix nanocomposites–A review," *Nano-Structures & Nano-Objects*, vol. 23, article 100475, 2020.

[12] Y. Zhan and G. Zhang, "Graphite and SiC hybrid particles reinforced copper composite and its tribological characteristic," *Journal of Mater Science Letters*, vol. 22, no. 15, pp. 1087–1089, 2003.

[13] Y. H. Liang, H. Y. Wang, Y. F. Yang, Y. Y. Wang, and Q. C. Jiang, "Evolution process of the synthesis of TiC in the Cu-Ti-C system," *Journal of Alloys and Compounds*, vol. 452, no. 2, pp. 298–303, 2008.

[14] R. J. Smith, G. J. Lewi, and D. H. Yates, "Development and application of nickel alloys in aerospace engineering," *Aircraft Engineering and Aerospace Technology*, vol. 73, no. 2, pp. 138–147, 2001.

[15] S. P. Rawal, "Metal-matrix composites for space applications," *Journal of Materials Science*, vol. 53, no. 4, pp. 14–17, 2001.

[16] D. H. He and R. Manory, "A novel electrical contact material with improved self-lubrication for railway current collectors," *Wear*, vol. 249, no. 7, pp. 626–636, 2001.

[17] E. W. Roberts, *Space Tribology Handbook*, AEA Technology Plc, Warrington, UK, 3rd edition, 2002.

[18] F. Findik and H. Uzun, "Microstructure, hardness and electrical properties of silver-based refractory contact materials," *Materials and Design*, vol. 24, no. 7, pp. 489–492, 2003.

[19] B. C. Windom, W. G. Sawyer, and D. W. Hahn, "A Raman spectroscopic study of MoS_2 and MoO_3: applications to tribological systems," *Tribology Letters*, vol. 42, no. 3, pp. 301–310, 2011.

[20] J. Wieczorek, T. Maciąg, K. Kowalczyk, and D. Migas, "Evaluation of thermal properties of MMCp composites with silver alloy matrix," *Journal of Thermal Analysis and Calorimetry*, vol. 142, no. 1, pp. 175–182, 2020.

[21] J. Wieczorek, B. Oleksiak, J. Łabaj, B. Węcki, and M. Mańka, "Silver matrix composites structure and properties," *Archives of Metallurgy and Materials*, vol. 61, no. 1, pp. 323–328, 2016.

[22] L. Jian-Guo, "Wettability of silicon carbide by liquid silver and binary silver-silicon alloy," *Materials Letters*, vol. 18, no. 5-6, pp. 291–298, 1994.

[23] Deona and P. K. Rohatgi, "Cast aluminium alloy composites containing copper-coated ground mica particles," *Journal of Materials Science*, vol. 16, no. 6, pp. 1599–1606, 1981.

[24] J. S. Wu, J. F. Li, L. Zhang, and Z. Y. Qian, "Effects of environment on dry sliding wear behavior of silver-copper based composites containing tungsten disulfide," *Transactions of Nonferrous Metals Society of China*, vol. 27, no. 10, pp. 2202–2213, 2017.

[25] Y. Waku and T. Nagasawa, "Future trends and recent developments of fabrication technology for advanced metal matrix composites," *Materials and Manufacturing Processes*, vol. 9, no. 5, pp. 937–963, 1994.

[26] P. S. Bains, S. S. Sidhu, and H. S. Payal, "Fabrication and machining of metal matrix composites: a review," *Materials and Manufacturing Processes*, vol. 31, no. 5, pp. 553–573, 2015.

[27] M. Rashad, F. Pan, Y. Liu et al., "High temperature formability of graphene nanoplatelets-AZ31 composites fabricated by stir-casting method," *Journal of Magnesium and Alloys*, vol. 4, no. 4, pp. 270–277, 2016.

[28] T. Thirugnanasambandham, J. Chandradass, P. B. Sethupathi, and L. J. Martin, "Fabrication and mechanical properties of alumina nanoparticle reinforced magnesium metal matrix composite by stir casting method," in *SAE Technical Paper*, USA, July 2018.

[29] M. O. Shabani, A. A. Tofigh, F. Heydari, and A. Mazahery, "Superior tribological properties of particulate aluminum matrix nano composites," *Protection of Metals and Physical Chemistry of Surfaces*, vol. 52, no. 2, pp. 244–248, 2016.

[30] M. T. Sijo and K. R. Jayadevan, "Analysis of stir cast aluminium silicon carbide metal matrix composite: a comprehensive review," *Procedia Technology*, vol. 24, pp. 379–385, 2016.

[31] A. Mohana Krishnan, M. Dineshkumar, S. Marimuthu, N. Mohan, and R. Venkatesh, "Evaluation of mechanical strength of the stir casted aluminium metal matrix composites (AMMCs) using Taguchi method," *Materials Today: Proceedings*, vol. 62, pp. 1943–1946, 2022.