TRIBOLOGICAL PERFORMANCE OF ALUMINUM MATRIX COMPOSITES REINFORCED WITH SIC NANOPARTICLES

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ABSTRACT
Finding out how SiC-Fe3O4 nanoparticles affected the composite's microstructure, mechanical, tribology, and corrosion properties was the main goal. Aluminum matrix composite (AMC) is an outstanding lightweight material with multiple functions that has been confirmed by numerous studies. In this work, metal matrix nanocomposites (MMNCs) of Al-Mg-Si alloy reinforced with nano-SiCp particles at volume fractions of 0, 0.5, 1.0, and 1.5% are studied for wear properties. Ultrasonic assisted casting was used to create these nanocomposites. The wear assessment was conducted using the pin-on-disc device. The primary goal of the study was to examine how nanocomposites wear when subjected to dry sliding circumstances. The normal load, sliding distance, sliding velocity, and volume percentage of nano-SiCp were the variables that were analyzed. The results showed that, when the quantity of reinforcement in the metal matrix increases, the wear rate of MMNCs decreases and was significantly lower than that of the unreinforced alloy. The MMNC with the lowest wear rate was the one with a 1.5 vol% nano-SiCp content. Moreover, it was observed that an increase in applied stress, sliding velocity, and sliding distance increases the wear rate of both monolithic alloy and nanocomposites. As the concentration of nano-SiCp increases and the normal load increases, the average friction coefficient decreases gradually. Scanning electron microscopy images revealed that the worn surface of the monolithic Al alloy had long, deep grooves running in the direction of sliding. On the other hand, the worn surfaces of MMNCs showed almost flat surfaces with thin grooves.

Keywords:
Aluminum matrix composites, SiCnanoparticles, nano-SiCp reinforced Al-Mg-Si alloy and tribological Performance.

I. Introduction
The automotive, marine, and aviation industries have all been pushing the industrial sectors to fortify composite materials in order to improve the overall performance of their component parts in recent decades. Among the various kinds of composites, hybrid aluminum metal matrix composites are currently preferred because of their capacity to satisfy industrial demands. Advanced composites known as hybrid aluminium matrix composites (HAMC) have the ability to replace composites with a single reinforcement and improve the performance of current materials by adding new features. Prior research has demonstrated that the properties of the composite material are affected by the presence of nanoparticles. When compared to aluminum, the composite reinforcements show much higher strength and wear resistance. The reinforcement's weight percentage, its chemical interaction with the matrix, its grain size, and the manufacturing process all have an impact on the composite's properties. A variety of techniques, including infiltration, powder metallurgy, squeeze casting, semi-solid processing, and stir casting, can be used to create hybrid aluminum metal matrix composites. Hybrid aluminum matrix

composites can be utilized in place of conventional materials and have a wide range of industrial applications [1]. This is due to their attractive qualities, which include superior wear resistance, improved fatigue resistance, greater stability at high temperatures, superior corrosion resistance, a high strength-to-weight ratio, a lower thermal expansion coefficient, good casting ability, lower density, and higher strength. Composites containing two or more reinforcements, like SiC particles with carbon nanotubes (CNT) or Al_2O_3 reinforced aluminum matrix composites (AMC), have been the subject of numerous investigations. The purpose of these investigations is to develop hybrid aluminum matrix composites and examine its thermal, wear, hardness, and strength characteristics. Because of its exceptional mechanical properties, aluminum matrix composites, or AMCs, are widely used in a wide range of technical applications. Numerous industries, including the automotive, aerospace, and mining extraction sectors, may employ this material. Automobile Manufacturing Companies, or AMCs, are important players in the automotive industry in a number of areas, including drive shafts, cylinder liners, drum brakes, and cylinder blocks. In the aerospace sector, advanced metal composites, or AMCs, are widely employed in the structural components of helicopter bodies, including rotor shafts, rotary plates, and monocoque structures. Because AMCs can increase wear resistance, they are therefore frequently utilized in a variety of sectors. Since improving wear resistance is the main goal of developing AMCs, understanding how materials affect tribological characteristics is essential to creating and understanding novel AMC combinations that have potential uses in real-world scenarios. SiC and aluminum oxide nanoparticles in aluminum metal matrix nanocomposites have demonstrated improved abrasion resistance and wear properties [2]. The Al matrix's hardness and wear resistance are significantly improved by the addition of nanoscale reinforcements. It is difficult to get a uniform dispersion of the nanoparticles in the metal matrix because their surface characteristics are what define them most. Numerous writers endeavored to attain a uniform dispersion of nanoparticles within the metallic matrix. The impact of severe ultrasonic cavitation is the basis for the very effective nanofabrication technology known as ultrasonic aided casting. Several combinations of Al/SiCnanocomposites were successfully produced and tested using the high intensity ultrasonic cavitation technique.

Furthermore, while employing composites as structural materials, it is imperative to consider the assessment of corrosion behavior [3]. The pace of corrosion may be accelerated by strengthening particles interacting with the surrounding structure chemically, physically, or electrochemically. Galvanic interactions between the reinforcement and matrix may also accelerate the rate of corrosion. Aluminum matrix composites have been the subject of numerous corrosion investigations, with a particular emphasis on how susceptible they are to corrosion in sodium chloride (NaCl) solution. Numerous studies have demonstrated that adjusting the quantity and volume of silicon carbide (SiC) has improved the corrosion resistance of aluminum matrix composites (AMCs) [4]. The sample containing 40% Fe_2O_3 demonstrated the most advantageous electrochemical performance due to its lowest I_{corr} and negligible corrosion rate, indicating a singularity revealed by the Taffel extrapolations. However, few investigations have been conducted expressly to examine the corrosion properties of Al-Fe_3O_4-SiC. The purpose of this work is to develop a hybrid composite material (HAMC) by reinforcing it with different weight percentages of SiC and Fe_3O_4. Finding the optimal amount of SiC and Fe_3O_4 to add to the composite is the aim. The microstructure, hardness, tribological, and corrosion properties of the composite were also assessed. The knowledge gained from this research will be very helpful in developing a novel hybrid composite by identifying the ideal amount of filler nanoparticles that may be used for a variety of purposes. Growing demand for materials with high strength and low weight has been primarily caused by the expansion of the automotive and aerospace industries. Because of their remarkable mechanical and thermal properties, metallic materials find extensive application in a wide range of technical applications. However, they suffer from two major drawbacks: excessive wear and insufficient resistance to corrosion. Because of this, and because energy conservation is becoming more and more important as the world becomes more industrialized, scientists are actively looking for ways to improve the properties of metals,

especially their tribological and anti-corrosive properties [5]. However, the development of metal matrix composites (MMCs) has been spurred by the limitations of metals and alloys in meeting the requirements for both exceptional strength and stiffness in demanding engineering applications, as well as the notable drawbacks of high wear and restricted corrosion resistance. Metal matrix composites are ideally suited for usage in difficult engineering applications because they may be developed to display desired properties like a low coefficient of friction, minimal wear, and exceptional resistance to corrosion.
The article's subsequent sections are arranged as follows: A review of the relevant literature is given in Section 2, and the materials and methods are examined in Section 3 before the experimental results are presented in Section 4 and then summarized and concluded in Section 5.

II. Literature review

The stir casting method produces composites proposed by Das et al. [6]. By adjusting the ceramic reinforcements' weight fraction, two unique compositions were produced. Using a pin-on-disc tribometer, an analysis of the composite materials' wear and friction properties was carried out. The purpose of the study was to investigate how wear and friction behavior is affected by sliding speed, sliding distance, and applied normal load. Tests for ribology were performed, and the results were compared. When the sliding speed for the HMMC was increased to 500 rpm, the temperature of the tribo-surface rose and the wear rate deteriorated at a load of 30N. At greater sliding velocities, the coefficient of friction decreased as a result of the addition of ceramic particles, which also reduced the contact area between the mating surfaces. Three main wear processes were noted: abrasion, adhesion, and oxidation. Using energy dispersive spectroscopy and field emission scanning electron microscopy (FESEM) on the worn samples, this was further confirmed. As stated by Moustafa et al. [7], For usage in industrial applications, surface nanocomposites with a hybrid aluminum content were created and investigated. Aluminum oxide (Al2O3), solid lubricant graphene nanoplates (GNPs), silicon carbide (SiC), and other reinforcing nanoparticles were successfully combined and integrated with AA6061 wrought sheets using the friction stir process (FSP). Tribological testing was used to assess the produced nanocomposites' wear resistance and friction coefficient. The results showed that the AA6061/SiC_GNPs hybrid nanocomposite exhibited remarkable resistance to wear and highly refined grains inside the treated area. As a result, the grain size significantly decreased during the course of the FSP—36 times. Furthermore, when combined with the SiC particles, the self-lubricating properties of the GNPs led to a reduction in wear rates by 90% in mass losses and 46% in volume losses. Moreover, there was a 30% decrease in the hybrid AA6061/SiC_GNPs' friction coefficient. The negative effect of the GNPs on the hardness is offset by the SiC nanoparticles. The tribological performance of an aluminum matrix composite (AMC) with graphene-encapsulated SiC nanoparticles during dry sliding wear was investigated by Zhang et al. [8]. Transmission electron microscopy (TEM), three-dimensional laser microscopy, Raman microscopy, and scanning electron microscopy (SEM) were used to characterize the composite. 98.0% and 35.9%, respectively, less wear and friction were found in the composite as compared to the reference sample, which just contained SiC nanoparticles for reinforcement. The uniform dispersion of graphene nanosheets throughout the composite material is probably the cause of the improved tribological properties. During the sliding wear process, these nanosheets disperse over the worn surface to form micro tribofilms rich in graphene.

III. Materials and Methods

Aluminum alloy 6061 (AA6061) is employed as the matrix material to construct the MMNC, while silicon carbide nanoparticles with diameters ranging from 45 to 65 nm are used as the reinforcing agent. The US Research Nanomaterials Lab, situated in Texas, USA, provided the SiC nanoparticles. The SiC nanopowders' morphology is displayed. A revolving type of ultrasonic cavitation assisted casting apparatus was used to make the MMNCs. A non-ferrous melting furnace, a stainless steel crucible, a mechanical stirrer, an ultrasonication probe, and an argon gas arrangement make up the nanomanufacturing system. An Indian company called Ultrasonic Solutions (P) Limited supplied the equipment. The titanium alloy used to build the ultrasonic horn has a 20 mm diameter on the submerged side. Titanium is a material that can withstand high temperatures and is not easily damaged by ultrasonic waves. Through the application of high-intensity cyclic ultrasonic vibrations, the ultrasonication process creates micro-bubbles inside the liquid melt. A large number of micro-bubbles are produced and destroyed by these oscillating ultrasonic waves. Strong implosive energy produced by ultrasonic cavitation efficiently distributes nanoparticles throughout a liquid melt. When the test specimens were cast, they were in their original, undisturbed state. A 10-kg weight was used to assess the Brinell hardness, and the final hardness value was calculated by averaging the outcomes of five indentations. Table 1 displays the measurements of hardness. At room temperature, a dry sliding environment was used to assess the wear resistance of the as-cast AA6061 and its Metal Matrix Nanocomposites (MMNCs). The wear trials were conducted with the Ducom pin-on-disc wear testing instrument. The specimens used in the trials were cylindrical, measuring 30 mm in length and 9 mm in diameter. The chromium steel counter face, a spinning disk with a hardness of 65 RC, was used to test these specimens. Initially, 800, 1000, and 1200 grit emery paper was used to clean the pin and disc. To guarantee the best possible contact between the pin and disc, their surfaces were cleaned. Both before and after the test, the specimens' weights were measured and recorded, and the weight difference was noted for every test. Ethanol is used to clean the pins and discs first, and then acetone. Similarly, the average weight loss (Dm) data was used to calculate the wear rate (Wr) for each specimen post-test. Throughout the measurement procedure, wear debris was kept out of the samples. A formula can be used to calculate the wear rate, which measures the amount of weight lost per unit sliding distance (L).

$$W_r = \Delta n / L \qquad (1)$$

To create the green body, the pre-mixed dry components were put into a graphite mold and squeezed at a low pressure for five to fifteen minutes. The green body was then exposed to a load of 70–85 kN at a temperature between 570 and 600 °C for two to three hours while being protected by N2. This was done using an HP W 25 machine. After sintering, specimens with dimensions of 50 mm x 50 mm × 2.7 mm were collected. A solid aluminum sample was also made under the identical experimental settings to serve as a point of reference.

Each sample underwent a Vickers hardness test, which involved 15 seconds of 10 kg force application. Each sample had four indents made on it, and the measurements were added together.

The experimental and assumed densities of composites were determined, respectively, using the Archimedes principle and the rule-of-mixtures (using distilled water). In this work, the theoretical densities for GNP and aluminum were 2.1 and 2.7 g•cm–3, respectively. By dividing the apparent density by the theoretical volume, the relative densities were found.

Prior research concentrated on maximizing the GO concentration in regard to mechanical and thermal properties, as well as the Al2O3 content in the Al matrix with respect to density and hardness. The results of the experiment showed that the Al-10 Vol%Vol% Al2O3 composition had a maximum hardness of 55.8 HV, which was higher than the hardness values of the loadings of 20 and 30 Vol%Vol%. The scanning electron microscope images demonstrated the homogenous distribution of Al2O3 throughout the Al matrix, which was attributed to the improved properties of Al-10 Vol%Vol% Al2O3. In addition, compared to the pristine and Al-10 Vol% Al2O3 samples, the Al-10 Vol% Al2O3-0.25 wt% GO composite had the lowest thermal expansion of 14.82 ppm °C−1, the highest compressive strength of 180 MPa, and the maximum hardness of 63 HV among the hybrid nanocomposites. The mechanical and thermal properties of the Al-10 Vol% Al2O3-X wt% GO hybrid nanocomposites were thoroughly evaluated in the study. This study's goal is to assess the tribological characteristics of Al-10 Vol% Al2O3-X wt% GO, where X stands for the different GO loadings in the hybrid nanocomposite (0.25, 0.5, and 1 wt%). The prior work provides access to the detailed approach for creating the hybrid nanocomposites, which is also briefly described here. This methodology includes the ball milling and spark plasma sintering parameters. With an average particle size of 20 µm and a purity level of 99.7%, pure aluminum powder made up the composite matrix. Commercially available SiC (average grain size of 2 µm) and Fe3O4 (45-70 nm) particles from MHC Industrial Co., Ltd. in China were used to strengthen the Al matrix. The first step in the manufacturing process was combining the powders of SiC and Fe3O4. Next, the Al matrix particles were mechanically milled for two hours at room temperature in a planetary ball mill (PM 100, Retsch, Haan, Germany) at a speed of 400 rpm. The weight of powder and milling balls was 15:1. An efficient blending procedure is essential to powder metallurgy. The powder-binder combination (Mg Stearate) was poured onto a 20 mm-diameter cylindrical die. Magnesium stearate may be used in ball milling to improve the uniform dispersion of reinforcements throughout the structure and minimize particle clumping. Furthermore, a universal testing device known as the Instron 3382 is used during the compaction process. This equipment is used to turn powder into green compacts. After that, these green compacts undergo a single-direction cold-iso-pressing (CIP) procedure where a pressure of 2500 Kgf/cm is applied for 15 minutes. After going through this process, an initial green density of between 85% and 95% is achieved. 600 °C was the temperature at which we heated the compacts in a Linn High Therm furnace. To prevent oxidation, the sintering process was carried out in an argon environment. For 20 minutes, the temperature was held at 600 °C, warming and cooling at a rate of 5 °C per minute. The material was then allowed to soak in the furnace for a whole day. Eight basic configurations of silicon carbide and magnetic nano iron oxide were reported. Each composition has five percent powdered magnesium stearate. We prepared samples by grinding them on various abrasive sheets with grit sizes of 800, 1200, 2000, and 2500 in order to assess the microstructural properties. After that, we used alumina slur, diamond paste, and ten minutes of ultrasonic cleaning in acetone and deionized water to polish the samples. Ultimately, we dried the samples for an hour at 100 °C.The compositions of silicon carbide, ferrous ferric oxide, and aluminum are presented in Table 1.

Table 1: Silicon carbide, ferrous ferric oxide and aluminium compositions

Different samples for compositions	**SiC (wt %)**	**Fe_2O_4(wt %)**	**Al (wt %)**
1	0	30	65
2	30	15	50
3	20	15	60
4	10	15	70
5	0	15	80

We used a pin-on-disc setup (Ducom Reciprocating Friction Monitor-TR 282 Series) to measure wear in dry sliding situations. Using a back-and-forth sliding motion, this equipment is used to quantify the specimens' wear characteristics and friction. A loading mechanism applies the chosen load to the test samples while a reciprocating engine creates a back-and-forth sliding motion between the samples. Moreover, a friction measuring instrument can quantify the force of friction. A number of selectable features and the coefficient of friction (COF) can be measured and visualized using the "WinDucom" program. The alumina cylindrical pin, measuring 8 mm in length and 6 mm in diameter, starts the dry-sliding experiment when it glides smoothly against a fixed counterpart plate. Both the samples and the pins were cleaned with distilled water and then degreased with acetone before the wear test was carried out. The disc was subjected to a reciprocating motion with a frequency of 10 Hz and an amplitude stroke of 1 ± 0.02 mm, all while maintaining a constant normal load of 10 N. A load cell sensor fixed to the pin-holder arm was used to continually monitor the tangential frictional force, which was then expressed as a root mean square value. For every sample, the kinetic coefficient of friction (µk) was obtained from the instrumentation output during a 150-second duration. By dividing the observed frictional force by the normal load, this coefficient was calculated.

The standard three-electrode setup—a working electrode, an opposing electrode, and a starting electrode—was used for potentiodynamic polarization investigations. The study employed graphite as the counter electrode, composite samples as the working electrode, and a saturated calomel electrode, or SCE, as the reference electrode.One centimeter was the surface area exposed to the electrolyte. A PC computer with EC-Lab software was used to monitor the potentiostat Bio-Logic SP-150, which was used to gather and evaluate experiment data. The potential between -2000 and +2000 mV was shown in the potentiodynamic polarization curves in relation to the SCE reference electrode. The study was carried out with a scanning rate of 1 mVs−1. To establish the steady-state testing condition, the experiment began with a 30-second length. To ensure the consistency of the obtained results, the experiments were conducted three times using the same setups.

A tribometer (UMT-3, Bellerica, MA, USA) was used to conduct ball on disk wear investigations in order to measure the friction and wear parameters of the composites. A 6.3 mm-diameter, 62 RC hardened stainless steel ball with a 440C hardness was utilized as the counterface. A standard load of 3 N was applied during wear tests, and the sliding speed was set at 0.1 m/s for 5000 cycles, or 100 m of sliding distance. With the aid of a 3D optical profilometer (GTK-A, Bruker, Bellerica, MA, USA), the wear volume reduction was recorded. An electron X-ray dispersive (EDS) attachment on a Tescan VEGA3 scanning electron microscope (SEM) was utilized in the investigation to examine wear processes and look into the purpose of wear debris particles. The counterface ball was photographed under an optical microscope to determine how worn it was.

Ten percent by volume of Al2O3 nanoparticles were sonicated in ethanol for an hour in order to obtain a uniform distribution. A probe sonicator (Sonics VCX 750, Newtown, CT, USA) operating at room temperature and with a cycle amplitude of 45% (ON: 20 seconds/Off: 5 seconds) was used for this. The aggregate in GO was broken apart using the same procedure. The calculated amount of Al powder was then mixed with the scattered Al2O3 in zirconia vials for ball milling in Union Process, Inc.'s HD/HDDM/01 machine, which is located in Akron, OH, USA. 200 revolutions per minute of rotation was used during the course of the 24-hour ball milling procedure. To achieve even mixing, 5 millimeter zirconia balls were utilized, and a 10:1 ball to powder ratio was kept constant. To avoid the powders oxidizing during the milling process, an argon atmosphere was created, and 50 milliliters of ethanol was injected to stop any cold welding from happening. After that, the powders were combined and dried in an oven set at 80 °C for 12 hours in order to completely eliminate ethanol. Graphene oxide (GO) was added to the mixture of Al-10 Vol% Al2O3 at different percentages of 0.25, 0.5, and 1 wt% to generate the hybrid powders. The combination was then ground under the same conditions for a full day.

IV. Results and discussion

The Brinell hardness values of the as-cast AA6061 and the various combinations of MMNC specimens are shown in Table 1. The hardness data show a significant increase with increasing weight percentages of nanoparticles in the matrix. Hardness increases when nanoparticles are included. Improved matrix grains and ceramic reinforcements.

Table 1: Hardness outcome

Material	**Brinell Hardness Number (BHN)**
AA6061	39
AA6061/0.5 vol% SiC_p	55
AA601/1.0 vol% SiC_p	64
AA6061/ 1.5 vol% SiC_p	68

The wear resistance properties of AA6061 and its MMNCs under applied stresses of 20 N, 40 N, and 60 N are shown in Figure 1. Figure 1 shows that weight loss decreases when the volume proportion of nano reinforcing increases. The presence of stiff SiC nanoparticles in nanocomposites may have improved their wear resistance. Table 1 illustrates how the addition of nanoparticles significantly increases the nanocomposites' hardness in comparison to the solid alloys. A material's ability to withstand wear and tear improves with increased hardness. Out of all the materials examined in this work, the nanocomposite reinforced with 1.5 vol% SiCp shows the least amount of weight loss.

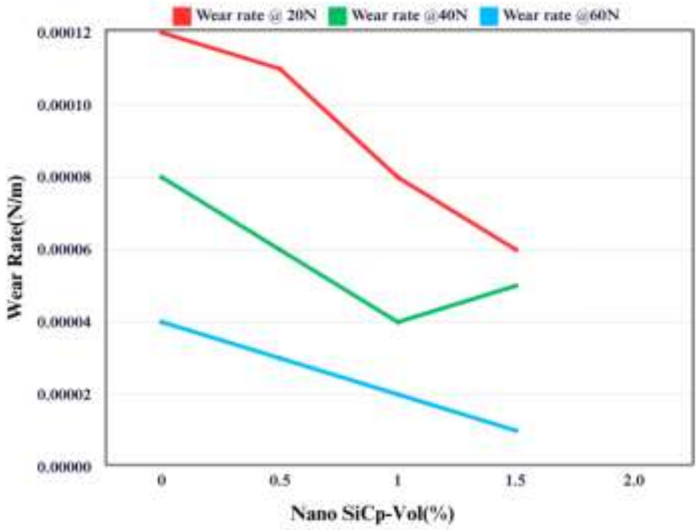

Fig 1: Wear rate vs. nano-SiCp volume fraction

Figure 2 shows the link between sliding velocity and wear rates. The applied stress in these investigations is always fixed at 20 N. As the sliding velocity increases, Figure 2 shows that the wear rate of the as-cast alloy and different combinations of metal matrix nanocomposites has increased. When compared to other materials, the nanocomposite with 1.5 vol% SiCp reinforcement shows the lowest rate of wear. The temperature at the point where the disc and pin make contact rises with increasing sliding motion velocity. As a result, wear rates rise at higher speeds as well. When compared to the other cast nanocomposites, the as-cast alloy's wear rate showed the highest values. To have a comprehensive knowledge, kindly review the next two materials. At a velocity of 1.3089 m/s, the ascast alloy wear rate is 1.9x10-5 N/m, and at a velocity of 2.198 m/s, it climbs to 5.9x105 N/m. At these two rates, the cast alloys' wear rate has increased by almost 209%. The wear rate of AA6061/1.5 vol% SiCp MMNC is 0.9x10-5N/m at a velocity of 1.0389 m/s. The wear rate rises to 2.3x105 N/m when the velocity reaches 2.198 m/s. At these two speeds, there is about 155% increase in the wear rate for AA6061/1.5 vol% SiCp MMNC.

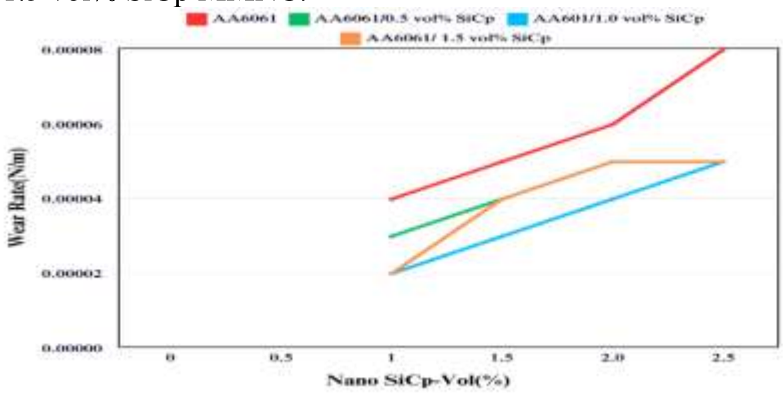

Fig 2: Wear rate vs. sliding velocity

The wear rates of the nanocomposites and monolithic alloy are shown to vary with increasing sliding distance in Figure 3. As the sliding direction increases, the rate of wear is gradually increasing. Compared to nanocomposites, the as-cast alloy experiences a higher rate of wear. The increase in rotational speed causes more heat to be produced, which raises the wear rate. Wear rate increases as a result of the heat softening the matrix in the nugget zone. Comparable outcomes have been seen with Al/Al2O3 nanocomposites

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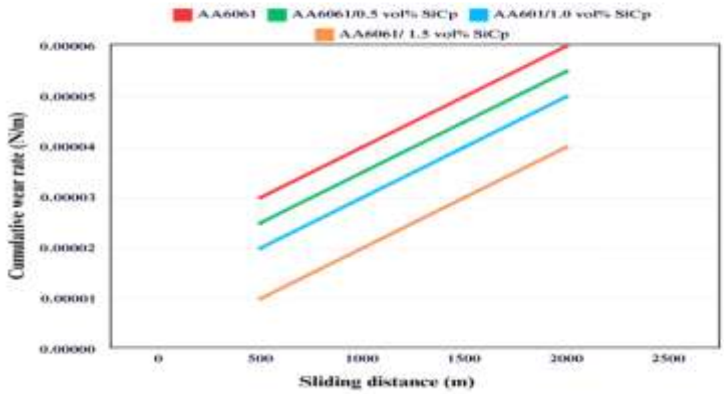

Fig 3: Wear rate vs. sliding distance

The different average values of the coefficient of friction for the cast alloy and cast nanocomposites with respect to the normal load are shown in Fig. 4. Three different velocities are displayed on the charts: 1.3089 m/s, 1.884 m/s, and 2.198 m/s. The graph indicates that an increase in the normal load is associated with a decrease in the average coefficient of friction. When the percentage of nanoparticles in the matrix increases, the coefficient of friction likewise decreases. Similarly, there is evidence of the tendency of tungsten carbide nanoparticles strengthening composites made of aluminum alloy. A period of greater values was seen in the coefficient of friction early on, and after 1500 m of sliding, the material's frictional coefficient dropped. The adhesion between the metal surfaces in direct contact at the beginning of the experiment is what causes the initial larger value of the frictional coefficient. Lower normal loads cause less impact from uneven surfaces on the metal contacts, which causes a ploughing action that raises the coefficient of friction. Furthermore, as the normal load increases, the frictional coefficient will decrease since the contact surfaces won't undergo the plowing effect. In the case of both cast alloy and nanocomposite combinations, the coefficient of friction decreases with an increase in the normal load. A thicker oxide layer forms as the applied load increases, which lowers the coefficient of friction. An increase in load causes an oxide layer to thicken, which decreases the interaction between the asperities of the metallic contacts. The material's surface has an oxide layer that is thicker than before, which offers better defense against serious harm and stops additional weight loss. The oxide layer's thickness increases in direct proportion to the concentration of SiC.

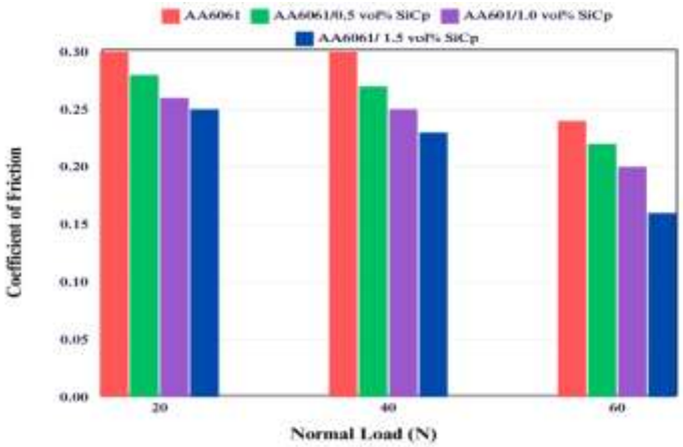

Fig 4: Coefficient of friction vs. normal load

V. Conclusion

It has been demonstrated that the ultrasonic assisted casting process is a very successful method for creating nano-sized silicon carbide particles (nano-SiCp) reinforced aluminum metal matrix nanocomposites. Compared to its monolithic equivalent, the toughness of MMNCs was significantly increased by the use of hard nano-SiCp. In comparison to the monolithic material, the maximum hardness values of the AA6061/1.5 vol% nanocomposite are higher. The rate of wear decreased as the volume % of nano-SiCp in the aluminum matrix rose. At a normal applied stress of 60 N, the wear rate decreased from 0.00012 N/m to 0.00006 N/m by adding 1.5 vol% of nano-SiCp to the Al matrix. As normal load, sliding distance, and sliding velocity increase, so does the wear rate of the nanocomposites and monolithic Al. When compared to monolithic Al, nanocomposites showed better wear resistance characteristics under the same testing conditions. Regardless of the sliding velocities, the friction coefficient decreased as the nano-SiCp content and normal load rose. An increase in the friction coefficient is directly correlated with an increase in the sliding velocity. When the volume % of nano-SiCp in the Al matrix increased from 0 to 1.5, a notable decrease in the friction coefficient (from 0.3 to 0.25) was observed. This was noted with a sliding velocity of 1.3089 m/s and a standard applied stress of 20 N. Adhesion is the main wear mechanism in monolithic aluminum, whereas abrasion is the main wear mechanism in nanocomposites. This is confirmed by elemental mapping scanning energy-dispersive X-ray spectroscopy (EDS) and scanning electron microscopy (SEM). Whereas the nanocomposites have a nearly flat surface with a little groove, the worn surface of the monolithic aluminum shows large, elongated grooves in the direction of sliding.

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