VACUUM STIR CAST DEVELOPED ALUMINIUM ALLOY HYBRID NANOCOMPOSITE PERFORMANCE COMPARED WITH GRAVITY CAST: MECHANICAL AND TRIBOLOGICAL CHARACTERISTICS STUDY

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Abstract

The present investigation is focused on enhancing the characteristics of aluminium alloy (Al6061) hybrid nanocomposites synthesized with constant (5 wt%) weight percentage of graphite (Gr) and 5, 7.5, and 10 wt% of silicon carbide (SiC) nanoparticles (50 nm) via liquid state stir vacuum to die cast process. The physical (actual density, theoretical density, and porosity), microstructural, mechanical (stress-strain and microhardness), and wear performance of Al6061 alloy hybrid nanocomposites were studied, and its results were compared with gravity die-cast developed composite samples. The liquid state stirs vacuum die-cast developed composites to facilitate good mechanical and wear characteristics. Moreover, the composite contained 10 wt% SiC, and 5 wt% Gr (sample 4) offered a low porosity level of 0.72%, higher microhardness of 86 ± 1.1 HV, better yield strength of 118 ± 0.5 MPa, an optimum tensile strength of 147 ± 0.58 MPa, and 3.2 mm strain value. Similarly, the sample 4 composite has higher wear resistance with a low wear rate of 0.321 mg/m and a good coefficient of friction (0.41) at 40 N under 0.75 m/sec.

Keywords: *Al6061 hybrid nanocomposites, characteristics, gravity die, vacuum die-cast*

Introduction

The behaviour of aluminium matrix composites was enhanced by the introduction of reinforcement phases like organic (red mud and fly ash) and inorganic (oxides, nitrides, carbides, borides, and others) via liquid state processing.[1] Among the various types of reinforcements, alumina (Al_2O_3), silicon carbide (SiC), and boron carbide (B_4C) facilitate superior mechanical, low coefficient of thermal expansion, and superior tribological behaviour.[2,3] Aluminium matrix composites (AMC) were prepared with hard ceramic particles gathering significance in future trend applications for automotive components (engine blocks, pistons, brakes, and radiator, etc.) due to their enhanced corrosion resistance, high tensile strength, good wear resistance, and high thermal stability.[4–6] Fayomi et al.[7] developed and studied the thermal, electrical, and corrosion resistance behaviour of nano Si_3N_4 particle-reinforced aluminium alloy nanocomposites for automobile applications. The composite containing 20 wt% of nano Si_3N_4 particle offered good thermal, electrical, and corrosion performance compared to conventional cast aluminium alloy (Al8081). The silicon carbide (SiC) reinforced aluminium alloy (AA6063) nanocomposite was synthesized by the stir casting process, and found micro porosity resulted in decreased mechanical properties of the composite.[8] Based on the processing technique, the characteristics of composites were varied.[9,10] The liquid state stir cast process gained importance in metal matrix composite fabrication due to its simple and easy operation, economic, and suitability for mass production.[11] Chandradass et al.[12] developed AA6061 hybrid composite via a stir cast process and studied the effect of SiC and SiC/Al_2O_3 on composites' mechanical and tribological properties. The composite contained 7 wt% of SiC and 3 wt% of Al_2O_3 particles

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found increased tensile strength. The wear rate of the composite is gradually decreased with increasing the load and the SiC particle. Aluminium alloy (Al7075) was synthesized using different weight percentages of SiC particles via squeeze casting process and found superior mechanical properties such as high hardness and tensile strength compared to cast Al7075 alloy.

Moreover, compatibility and wettability are important in deciding composites' properties.[13] The wear, thermal, and corrosion behaviour of stir-cast developed copper matrix composites were studied. SEM analysis revealed uniform particle distribution with effective interfacial bonding between Cu and alumina/graphite. It has to promote good mechanical, thermal, and corrosion properties.[14] An aluminium alloy hybrid composite was recently synthesized by different weight percentages of alumina nanoparticles and mixed with bagasse ash via the vacuum stir casting method. It results in decreased porosity with increased mechanical properties of composite. [15]

Similarly, the various research investigation on aluminium alloy composite made with SiC prepared via conventional technique addressed a few drawbacks such as particle distribution, slag formation, and porous.[16–18] Among the various fabrications technology reported above, liquid state processing is efficient, economical, and can process easily for aluminium alloy matrix composites.[19–21] Aluminium alloy (Al6061) composite was prepared using 0, 1, 2, 3, and 5 wt% of SiC particles via stir casting methods and studied the characteristics of composites. The hardness and tensile strength of the composite (5 wt% SiC) are increased gradually.[22] The silicon nitride reinforced aluminium alloy composite mechanical and wear properties are studied and found to have a low wear rate on high load. The tensile strength of the composite is progressively increased with silicon nitride's content from 0 to 9 wt%.[23] A pin-on-disc wear tester studies the wear behaviour of Al6061/SiC composite, and it reported that the increased content of SiC in an aluminium alloy matrix showed less wear rate on high load. The temperature and load is the prime reason for frictional wear.[24] A pin-on-disc wear tester evaluates the wear properties of SiC-reinforced aluminium alloy (Al2219). The microstructure of the composite is varied due to applied sliding speed, sliding distance, and load. The higher load damages the composite structure and found microcracks.[25]

Recently, Zirconium di-boride (ZrB_2) reinforced aluminium alloy (Al7068) nanocomposite developed by liquid state ultrasonic stir casting route and found homogenous particle distribution resulted in increased mechanical strength of composite.[26] The aluminium alloy (AA7075) hybrid nanocomposite is developed using SiC and TiB_2particles. The effect of reinforcements on mechanical properties was evaluated, and found good tensile strength of composite on improved SiC content of 0, 3, 6, 9, and 12wt%, respectively.[27] The mechanical and wear properties of SiC, GNP, and alumina-reinforced aluminium alloy (Al7075) composite were studied, and it reported that the presence of a hard ceramic particle in Al7075 found improved tensile, hardness, and wear properties compared to unreinforced cast AL7075 alloy.[28] Aluminium alloy (AA7075) composite ductility was enhanced by adding different weight percentages of boron carbide particles and obtaining uniform particle distribution via the stir-casting process. [29] Physical, mechanical, and microstructural properties of stir-cased developed TiO_2 and SiC reinforced aluminium alloy (AA7178) composite was studied, and it found that the presence of hard ceramic in AA7178 matrix has high tensile strength, hardness and good fracture toughness. A few microvoids were found on improved the content of ceramic particles.[30] Aluminium matrix composite was synthesized using 2, 4, and 6wt% of alumina and constant weight percentage (4 wt%) of SiC via stir casting. It was proved that uniform distribution particles enhanced the mechanical properties of composite.[31] SiC-reinforced aluminium alloy (A356)/fly ash composite was made by a stir-assisted squeeze cast and evaluated the mechanical and wear properties of the composite. They found that the composite contained high SiC and fly ash found good mechanical and wear resistance compared to unreinforced aluminium alloy.[32]

Moreover, the properties of the composite were decided by stir-cast process parameters. [33] Bharat et al.[34] developed the AA7178 alloy composites with nano TiO_2 via stir cast route and studied the composites' microstructure, mechanical and wear properties. They reported that TiO_2 influenced to improve the mechanical and wear properties of composites. Statistical tools and the Taguchi ANOVA technique optimized the wear behaviour of the AA7178 alloy hybrid composite. They reported that the composite contained 3 wt% TiO_2 and SiC found maximum wear resistance,[35,36] Artificial Neural Network (ANN) and Grey Relational Analysis (GRA) methods.37 The presence of hard ceramic reinforcement in soft alloy found enhanced wear resistance compared to cast alloy.[38,39] AA7178 alloy composite was synthesized with 1, 2, and 3wt% of SiC via stir casting. They found good interfacial bonding between matrix and reinforcement resulted in high hardness.[40] CFD analysis was conducted to find the temperature path.[41,42] Moreover, the hard ceramic particles had significant hardness, wear and machining capabilities.[43,44]

The aluminium alloy composites were mostly prepared with ceramic particles through a conventional stir-cast process. They found the consequences of poor wettability, porosity, and variations in the composite's mechanical/wear behaviour. The present investigation focuses on enhancing the properties of Al6061 alloy hybrid nanocomposites prepared with the different weight percentages of SiC with a constant weight percentage of graphite nanoparticles via liquid state stir vacuum die casting technique. The developed composite physical, mechanical, and wear properties are compared with conventional stir-cast developed aluminium alloy composites. The enhancement of composite characteristics is detailed in the results and discussion section.

Choice of Matrix and Reinforcement

The aluminium alloy Al6061 grade was chosen due to its benefits over the conventional aluminium alloy, such as low density, superb thermal conductivity, excellent corrosion resistance and good tensile strength. Most researchers utilized an Al6061 alloy matrix for automotive, aerospace, and lightweight applications due to its enhanced physical, mechanical, thermal, and wear characteristics [11, 15, and 17]. The major compositions of a chemical substance in Al6061 alloy are represented in Table 1.

Ceramic-based inorganic silicon carbide (50 nm) and graphite (50 µm) particles were chosen as reinforcement. Silicon carbide (SiC) facilitates maximum thermal stability, high hardness, good wettability, and wear resistance.[16–21] The graphite particles offer high hardness and wear resistance values.[14]

Fabrication of Composites

Figure 1a illustrates the actual aluminium alloy composite fabrication setup consisting of the feeder unit assembly, mechanical stirrer, crucible, stirrer blades, control panel, and bottom pour die cast assembly (gravity and vacuum die assembly). An electronic digital balancing machine weighed the quantity needed of aluminium alloy ingot, SiC and graphite particles with an accuracy of 0.01 g. Table 2 shows the composition details of aluminium alloy hybrid nanocomposite fabrication.

The weighted Al6061 ingots were kept in a steel crucible and preheated at300 °C for 30 mins via an electrical furnace to eliminate the moisture and impurity of the alloy. Meanwhile, the SiC nanoparticles and graphite micron particles are externally preheated at 300 °C for 30 mins. The temperature of the electrical furnace was improved by 700 °C, and melted the aluminium alloy ingots like a molten stage. After the process, the preheated reinforcements were added to the molten Al6061 alloy matrix. Both matrix and reinforcements are blended using a constant stir speed of 650 rpm for 10 mins.[12] The mixed molten materials were poured into preheated (300 °C) uncoated high carbon die (100 mm × 100 mm × 15 mm–Figure 1d) via bottom pour arrangements with an applied vacuum pressure of 2 bars maintained by an electronic control panel.

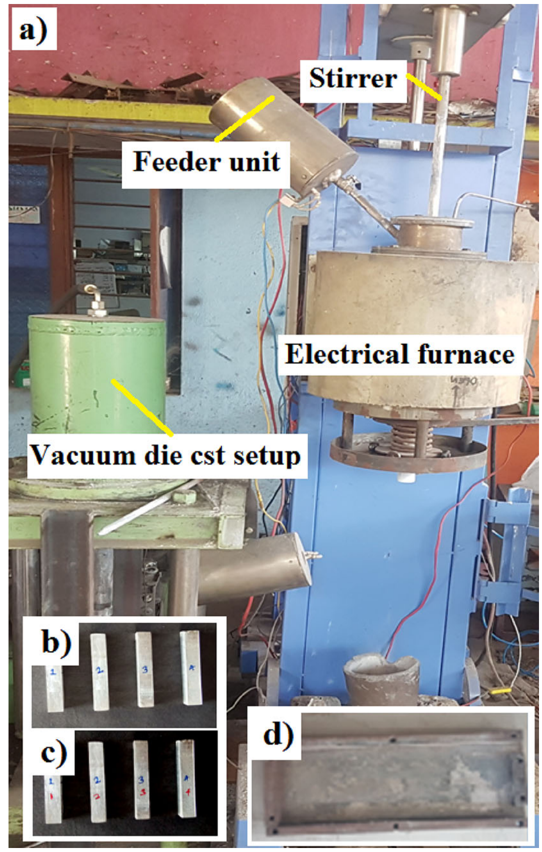

Figure 1. Aluminum alloy composite casting (a) Melting furnace setup (b) gravity developed composite samples, (c) Vacuum developed composite samples, and (d) uncoated high carbon die.

Table 2. Compositions of Aluminium Alloy Composites

Sample ID	Weight percentages in wt.%		
	Al6061	SiC	Gr
1	100	0	0
2	90	5	5
3	87.5	7.5	
4	85	10	

Table 1. Chemical Constitutions of Al6061 Alloy

Constitutions	Al	Mg	Si	Fe	Cu	Cr	Zn	Ti	Mn
Weight %	97.36	0.80	0.40	0.7	0.15	0.04	0.25	0.15	0.15

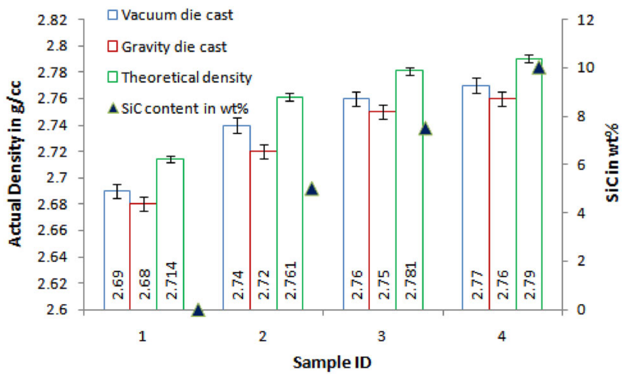

Figure 2. Actual and theoretical density of gravity and vacuum die-cast developed composite samples.

Finally, the gravity and vacuum die-developed composite samples are shown in figure 1b–c. It was cooled naturally and machined per ASTM test standards. (ASTM E8 − 92 mm × 10 mm × 6 mm, and ASTM G-99–8 mm dia and 35 mm length). For each composite, 3 test samples are tested, and the mean value is considered.

Results and Discussions

Density and Porosity

Figure 2 illustrates the actual and theoretical density of cast Al6061 alloy and its hybrid nanocomposites synthesized by liquid stir (gravity and vacuum die cast) process. The density of vacuum die-cast Al6061 alloy without reinforcement (sample 1) is 2.69 ± 0.05 g/cc, and the additions of SiC nanoparticles with constant wt% of Gr showed a gradual improvement in density. The sample 4 composite contained 10 wt% SiC nanoparticles noted as the maximum density of 2.77 ± 0.04 g/cc and increased by 2.97% compared to sample 1. It was noted from Figure 2 that the density of the aluminium alloy composite was gradually increased by increasing SiC nanoparticle content, proving their mixtures.

The measured actual density of vacuum die-cast composites samples was higher than that of gravity die-cast developed composites. The reason for decreased density value was due to casting defects. It is evidenced in Figure 4a–e. However, the composite's theoretical density was higher than the composites' actual density (gravity and vacuum die cast). It was due to voids, pores, and air entrapments inside the composites.[1,2]

Figure 3 represents the porosity percentages of Al6061 ally, and its hybrid nanocomposites were synthesized with different weight percentages of SiC and 5 wt% of Gr particles. It was noted from Figure 3 that the porosity of cast aluminium alloy and its hybrid nanocomposite developed by gravity cast is higher than the porosity of vacuum die-cast developed composites.

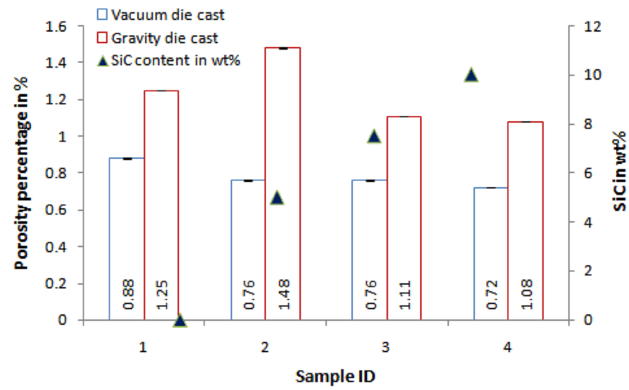

Figure 3. Porosity percentage of gravity and vacuum die-cast developed composite samples.

The porosity percentage for gravity die-cast developed composite samples was shown to be more than 1% due to blowing holes, and microporosity was proven in Figure 4a–d. During the solidification process, the temperature of the molten was more than the temperature matrix melting temperature was the reason for casting defects.[5] It may affect composites' mechanical and wear properties.[9] While the porosity of the vacuum die-cast developed, Al6061 alloy and its hybrid nanocomposite samples were found to be less than 1% of its porosity level. The porosity percentage of vacuum die developed Al6061 alloy (sample 1) was 0.88, and 0.76% was noted by adding 2.5 wt% SiC (sample 2). The least porosity percentage of 0.72% was observed in sample 4. The decreased porosity of the composite was due to the applied vacuum pressure of 2 bar, which enriched unavoidable air entrapments and reduced the porosity inside the composite. So, the vacuum stir developed Al6061 alloy composite offered good density with a reduced porosity level of less than 1%.

Effect of Gravity Dies Cast on the Surface Morphology of Composites.

Figure 4a–d illustrates the SEM micrograph of gravity-developed Al6061 alloy and its hybrid nanocomposites. Figure 4a represents the SEM images of gravity-cast Al6061 alloy with slag formations and found microporosity on sample 2, as shown in Figure 4b. It was shown that the uniform particle distribution improved the composites' mechanical and wear properties.[22]

Figure 4c illustrates the uniform Gr and SiC particle distribution with microporosity. Similarly, composite sample 4 showed a coarse grain structure with an effective interfacial bonded structure, as shown in Figure 4d. This results in improved porosity and decreased mechanical properties of composites.[23]

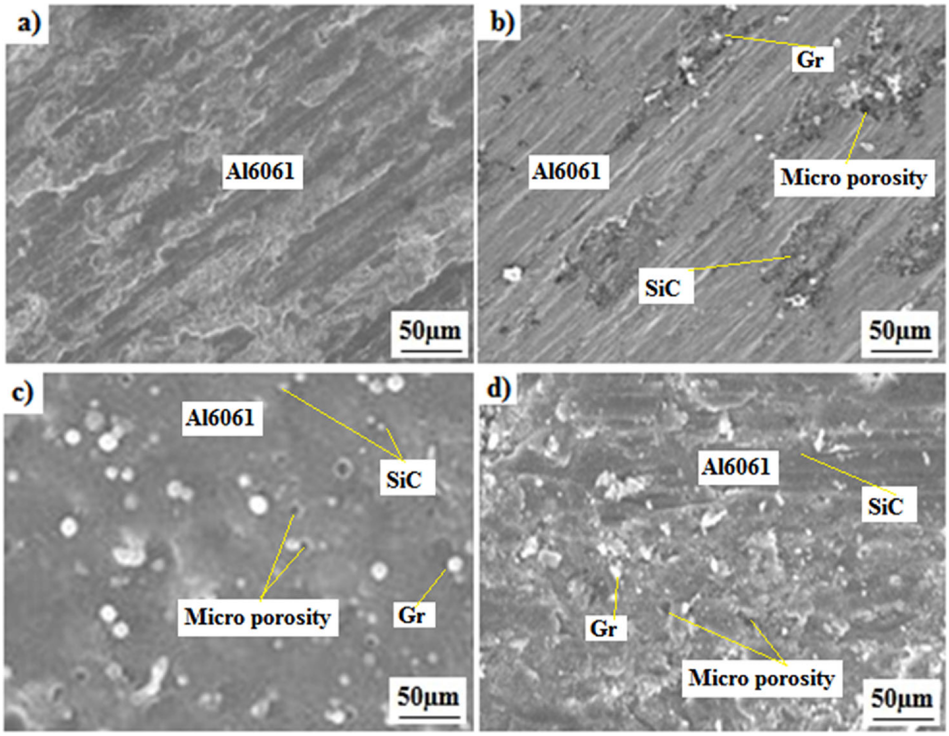

Figure 4. SEM micrograph of gravity developed composite (a) sample 1, (b) sample 2, (c) sample 3, and (d) sample 4.

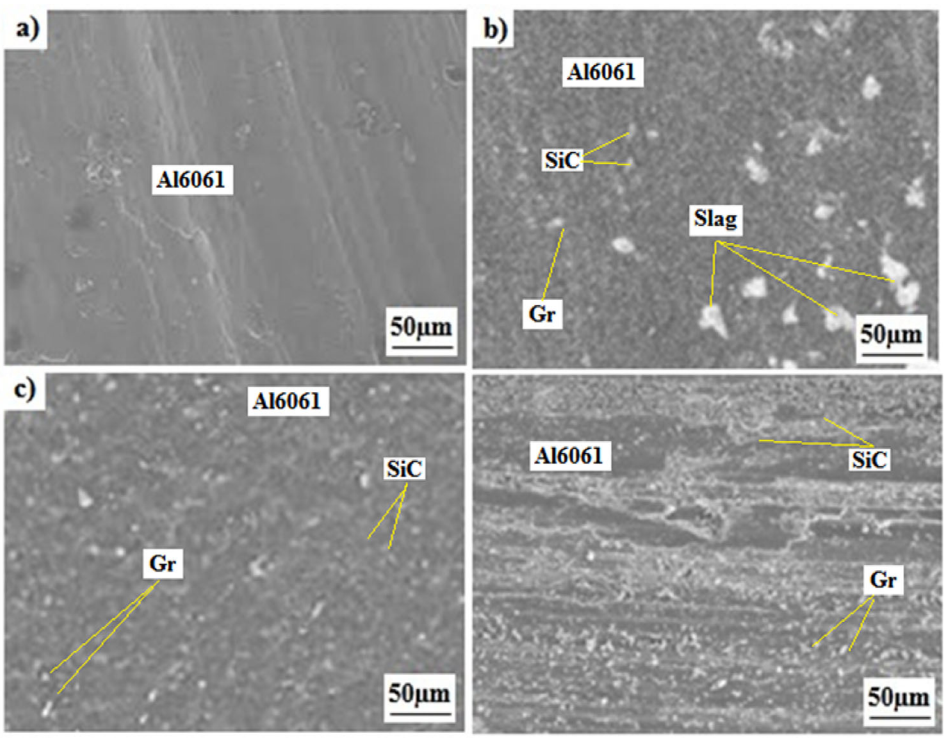

Figure 5. SEM micrograph of vacuum developed composite (a) sample 1, (b) sample 2, (c) sample 3, and (d) sample 4.

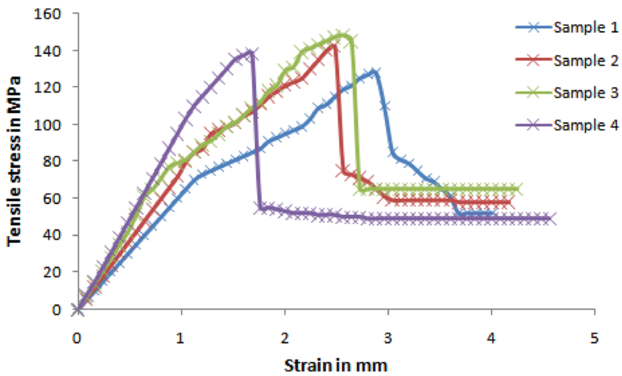

Figure 6. Stress-strain curve–gravity die-cast composite samples.

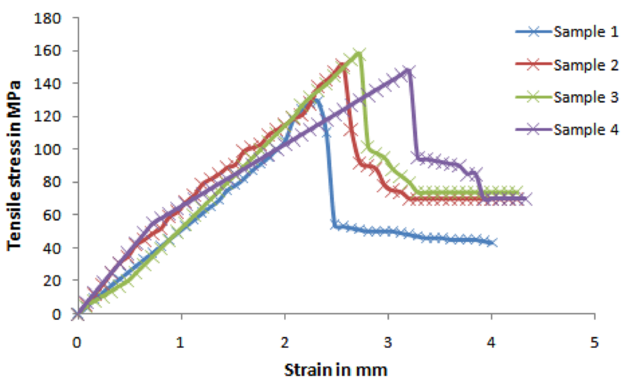

Figure 7. Stress-strain curve–vacuum die-cast composite samples.

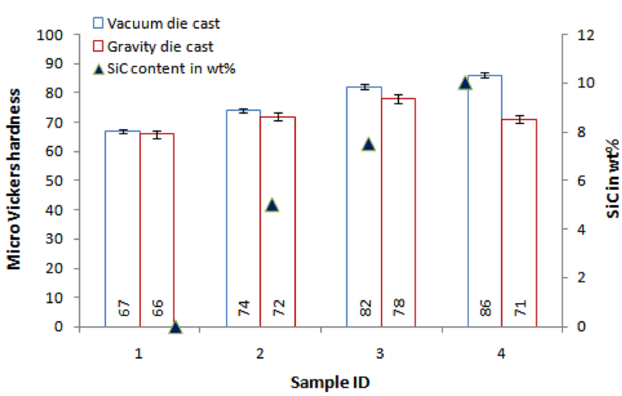

Figure 8. Microhardness of vacuum and gravity die composite samples.

Effect of Vacuum Die-Cast on the Surface Morphology of Composites

Figure 5a–d illustrates the surface morphology of Al6061 alloy and its hybrid nanocomposites. Figure 5a shows the fine grain structure of cast aluminium alloy/5 wt% Gr, and 5, 7.5, and 10 wt% of SiC is shown in Figure 5b–d. It was found that the particles are distributed in the Al7075 alloy matrix as homogenous, which results in increased mechanical properties of the composite, as evidenced in Figures 6, 7, and 8.

Table 3. Output Results for Stress-Strain Plot

Process	Sample	Young's modulus E MPa	Upper yield strength UYS MPa	Tensile strength TS MPa	Strain δ mm
Gravity die-cast	1	17741.95	85	128	2.88
	2	15370.32	107	142	1.68
	3	17737.47	109	148	1.68
	4	16541.83	112	138	1.68
Vacuum die-cast	1	14869.98	87	129	2.32
	2	16536.54	110	151	2.56
	3	16719.58	112	158	2.72
	4	17070.55	118	147	3.2

However, the vacuum die-cast developed composites were proven to their SiC and Gr nanoparticles. The homogenous distributed white and dark field of Gr and SiC facilitates good mechanical and wear behaviour. A similar tendency was reported by Chandla et al.[15]

Effect of Stir (Gravity and Vacuum Die Cast) on Stress–Strain Behaviour of Composites

The tensile strength of aluminium alloy and its hybrid nanocomposites was evaluated by Instron Universal Tensile Test (UTM) machine configured with an electronic stress–strain plotter. The developed composites are shaped by ASTM E8 standard.[12,16] The test sample is fixed between the tensile jaws and operates by 5 mm/min. Figures 6 and 7 illustrate the stress-strain curve for gravity and vacuum die-cast developed aluminium alloy hybrid nanocomposite. It showed the tensile strength composite gradually increased with increased content of SiC nanoparticles. Table.3 shows the outcome results for the stress-strain plot.

The tensile stress of stir gravity die cast developed cast Al6061 alloy showed 128 $\pm$ 1.1 MPa at 2.88 mm of strain rate and increased by 10.9% on 5wt% of SiC nanoparticle (sample 2). The maximum tensile stress of 148 $\pm$ 1.28 MPa was observed by sample 3 (7.5 wt% of SiC nanoparticle reinforced Al6061 alloy) composite and improved by 15.6% compared to sample 1.

The increased tensile stress of the composite was due to the reason for good interfacial bonding between the matrix (Al6061) and reinforcement (SiC), evidenced in Figure 4b–d. Moreover, the tensile stress of the composite is decreased to 138 $\pm$ 1.54 MPa on 10 wt% of SiC nanoparticles (sample 4) due to the reinforcement particles due to microporosity, as noted by Figure 4d. However, the strain rate of the composite decreased from 2.88 mm to 1.68 mm due to the increased content of SiC nanoparticles. The decreased tensile strain was internal pores and particle dislocation during high tensile force. The variations of tensile stress are due to the selection of stir speed, melting temperature, and process selection.[19–21]

The stress-strain diagram of the stir vacuum die-cast developed Al6061 alloy and its hybrid nanocomposite is shown in Figure 7. The tensile stress of the vacuum die-cast developed composite is higher than the value of gravity die-cast composite tensile stress. The cast aluminium alloy (sample 1) is noted by 129 ± 1.02 MPa and improved its tensile stress by 17.05% due to the effective interfacial bonding strength, as proved in Figure 3 (low porosity level of 0.76%). Based on interfacial strength, the tensile stress of the composite was varied.[16,17]

The composite containing 7.5 wt% of SiC nanoparticle (sample 3) found higher tensile stress of 158 ± 1.21 MPa. It was enhanced by 22.4 and 6.7% compared to vacuum stir cast Al6061 alloy, and stir cast developed Al6061/7.5 wt% of SiC composite. Moreover, the vacuum stir-developed composite has enhanced mechanical tensile stress compared to the tensile stress of conventional stir-cast-developed composites. Moreover, the tensile strain of the composite gradually increased from 2.32 to 3.2 mm.

The increase in strain rate is due to reduced pores with uniformly distributed particles, leading to increased bonding quality. While compared to the die-cast gravity sample, the vacuum die-cast composite sample found increased tensile stress and good ductility.

Effect of Stir (Gravity and Vacuum Die Cast) on the Microhardness of Composites

The microhardness of developed composites is measured by a VM50 model microhardness tester with an applied load of 100 g for 20 s. The three trials were taken from each sample, and the mean value was considered. Figure 8 represents the hardness of Al6061 alloy and its hybrid nanocomposites synthesized by stir vacuum and gravity die cast approach. The hardness of the vacuum die-cast developed cast Al6061 alloy is 67 ± 1.01 HV (sample 1). The hardness of samples 2, 3, and 4 significantly increased with SiC nanoparticle content with constant weight percentages of graphite particles in the Al6061 alloy matrix. The maximum hardness of 86 ± 1.1 HV was noted by 10 wt% of SiC nanoparticle-reinforced Al6061 alloy hybrid nanocomposite (sample 4) made by vacuum stir cast. It increased by 28.25% compared to sample 1. The presence of hard SiC nanoparticles leads to resisting the high indentation, and graphite particles withstand the maximum load. Enhancement of hardness mainly depends on the selection of process, matrix, and secondary phase reinforcements.[19–21] The hardness of stir gravity die cast developed cast Al6061 alloy was found to be 66 ± 1.21 HV, and sample 2 shows 72 ± 0.8 HV. The improvement in hardness was due to the presence of hard ceramic SiC nanoparticles in the Al6061 alloy matrix.

Sample 3 hardness was enhanced by 18.18% compared to the unreinforced Al6061 alloy matrix. Further additions of SiC nanoparticles in the Al6061 matrix found decreased hardness. It was due to the porosity of the composite couldn't withstand the high indentation during the hardness evaluation. Higher content of hard SiC results in increased hardness.[16] However, the hardness of vacuum stir-developed composites was higher than that of the stir-cast-developed composite sample.

Effect of Load on the Wear Rate of Composites

The dry state wear properties of aluminium alloy and its hybrid nanocomposites are studied by a Ducom pin-on-disc wear tester constructed with a grey cast-iron disc that operates under the constant sliding distance of 1000m with 1m/sec sliding speed at varied load (10, 20, 30, and 40 N) respectively. Figure 9 illustrates the wear rate of Al6061 cast alloy and its hybrid nanocomposite developed by stir vacuum die-cast. The wear rate of the aluminium alloy composite was decreased gradually with increasing content of SiC nanoparticles in Al6061 alloy. The wear rate of the sample was found to be 0.365, 0.385, 0.408, and 0.411 mg/m on an applied load of 10, 20, 30, and 40 N, respectively. Similarly, sample 2, 3, and 4 gradually increases with increasing the load from 10 to 40 N at 1 m/s sliding velocity.

Sample 4 found the minimum wear rate of 0.321 mg/m on 40 N applied normally under 1 m/s. The reduction of wear rate is due to the presence of SiC nanoparticles, is resist the high frictional force, and graphite particles withstand the maximum frictional temperature between the disc and pin surfaces. However, the strong interfacial bonding between

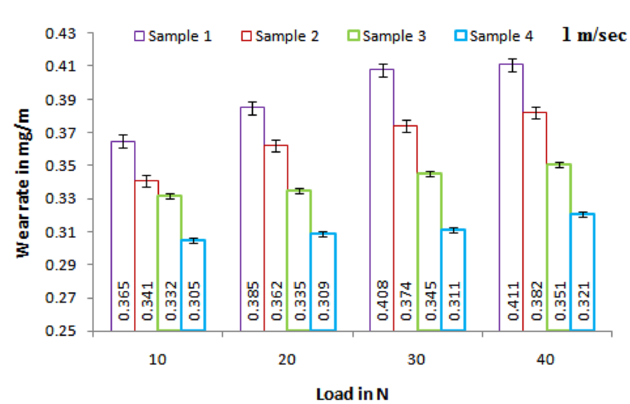

Figure 9. Wear rate of vacuum die-cast composite.

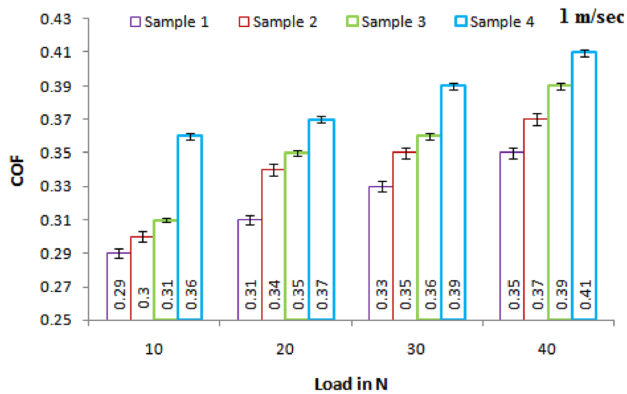

Figure 10. Coefficient of friction of vacuum die-cast composite.

the matrix and reinforcement leads to withstand the high friction force during the wear analysis.[6,24]

Effect of Load on the Coefficient of Friction (COF)

Figure 10 represents the coefficient friction of unreinforced and SiC/Gr reinforced Al6061 alloy hybrid nanocomposite prepared by stir vacuum dies casting. The COF value of the composite sample is increased significantly with increasing the content of SiC nanoparticles with 5 wt% of Gr particles. The COF value of cast sample 1 is 0.29, 0.31, 0.33, and 0.35 with an improved applied load of 10, 20, 30, and 40 N under a high sliding speed of 1 m/s. While the additions of 5 wt% SiC and Gr show the increased COF. The COF value of sample 3 was found to marginal improvement and attained a higher COF of 0.39 under 40 N with the frictional force of 27.89 N at 1 m/s sliding speed.

The maximum COF is 0.41, noted by sample 4 and contains 10 wt% of SiC nanoparticles and 5 wt% of Gr particles. However, the COF of composite is significantly increased with increasing the content of SiC and normal load. The improvement of COF has mainly been attributed to the presence of SiC nanoparticles leading to resistance to the high applied load, and graphite particles withstand the maximum frictional temperature.

SEM Image of Vacuum Developed Composite Wear Test Sample 4

According to the optimum wear resistance of composite sample 4, SEM images were shown in Figure 11. It showed the adhesive wear surfaces with SiC and Gr particles. The high frictional force of 23.81 N leads to an increased temperature between the disc and pin surfaces and found the adhesive wear with an elongated region. The SiC particle proposed the maximum wear resistance and withstood

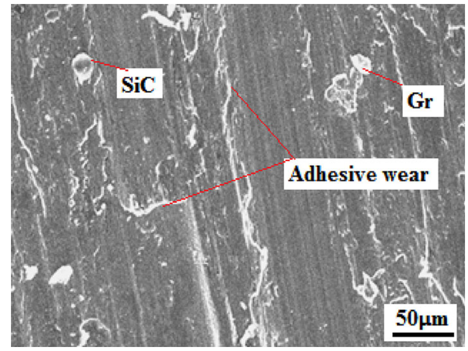

Figure 11. SEM micrograph vacuum developed composite wear test sample 4.

the maximum friction force. Generally, SiC was good thermal stability, high hardness and low thermal expansion coefficient.[16,17]

Conclusions

Al6061 aluminium alloy hybrid nanocomposite with different weight percentages of SiC nanoparticle and 5 wt% of graphite particle is successfully synthesized via stir vacuum die casting route, and its outcome physical and mechanical properties are compared with stir gravity die cast developed hybrid nanocomposite samples. The vacuum stir cast developed Al6061 alloy, and its composite density showed minor variations, but the porosity of the composite was controlled by the vacuum stir cast process as less than 0.9%. The tensile stress of the composite developed with vacuum stir cast found a maximum value of 7.5 wt% of SiC nanoparticle (sample 3). It increased by 22.4 and 6.7% compared to stir vacuum to die cast sample 1 and stir gravity die cast developed sample 3 composite. Al6061/10 wt% SiC nanoparticle/5 wt% Gr composite sample 4 made by vacuum stir cast found 28.25% increased hardness value compared to unreinforced stir cast developed AA6061 alloy (sample 1). Finally, the stir vacuum die-cast developed composites are subjected to wear studies, and sample 4 has a minimum wear rate (0.321 mg/m) under 23.81 N frictional force and an increased COF of 0.41. So, the vacuum stir cast developed hybrid nanocomposite offered good mechanical and wear behaviour with reduced porosity percentage was comparably proved.

Author Contributions

All authors contributed to the study's conception and design. The first draft of the manuscript was written by RV, and the individual contributions of All authors are given below. AB–formal analysis, investigation, APS–methodology, writing, review & editing, MVDP–investigation, writing& language help, RV–original draft preparation, supervision, and validation. All authors read and approved the final manuscript.

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Data Availability

All the data required are available within the manuscript

Competing interests The authors have no relevant financial or non-financial interests to disclose. The authors have no competing interests to declare relevant to this article's content. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

Ethics approval This is an observational study. Vacuum stir cast developed aluminium alloy nanocomposite performance compared with gravity cast: Mechanical and tribological characteristics study, Research Ethics Committee has confirmed that no ethical approval is required.

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