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Experimental Investigations on Aluminium Composites Materials Using Stir Casting Process

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Abstract

In physical operations, accoutrements in motorcars and aeronautical machine factors, aluminium and its alloys are extensively used. In this study an effort is made to ameliorate the properties of aluminium essence matrix compound (A356) for manufacturing of machine rudiments taking High Tensile strength, Hardness, Wear resistance and low coefficient of friction, aluminium alloy (A356) reinforced with aluminium oxide, graphite and silicon carbide. In the current work, A356 as base metal is prepared from samples with a composition of SiC (10% & 20%), 3% Gr, 10% alumina. The microstructural, mechanical and tribological characterization of the samples is carried out using the stir casting process. Microstructure tests showed that samples produced using the stir cast system had lower dispersion of strengthening points. The results show that compared to the base amalgamation, the mechanical parcels and indeed distribution of the SiC, Gr and alumina patches are significantly bettered. Disquisition of the mechanical attributes and wear rate of the samples prepared using the shifting approach revealed that they displayed superior strength, hardness, and wear rate to the samples made using the stirring technique. This study is substantially concentrated to ameliorate mechanical and Tribological characteristics of Base Metal.

Keywords: Stir Casting Process, aluminium 365, mechanical properties, microstructures

INTRODUCTION

Increasing utilization of lightweight materials, especially Aluminium alloys characterized by their high specific strengths, has resulted from efforts to conserve energy and safeguard the environment. Al alloy based MMC's often improved with mechanical properties added by weight to the molten metal [1, 3]. Different weight percentages of particles like B_4C, MgO nano particles reinforced by Stir casting method comprehended to increase in high tensile compressive strengths, hardness and decrease in density, porosity and crack propagations [7, 8, 9, 12, 14, 15, 19,]. Addition of the SiC particles with Aluminium exhibit better mechanical and wear resistances. Hardness and Tensile strength of the composites set up to be increased with addition of SiC at different probabilities [11, 16, 18]. Slightly distributed TiB_2, Mg_2Si are slightly distributed in aluminium matrix mixes that bettered mechanical properties and rigidity decreases due to dimples that indicate rupture in fracture medium [10, 17, 26]. Dry sliding wear behavior of aluminium alloy-based composites, reinforced with silicon carbide particles and solid lubricants such as graphite/antimony tri (Sb_2S_3) revealed that the

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proposed composites have lower friction coefficient, less temperature rise and low noise level [5]. The failure of two- dimensional microstructure models under tensile loading conditions were analyzed on the microstructure of random and clustered particles to determine its effect on strength and failure mechanisms. The analysis was apparent that the clustering nature of particles in the matrix dominates the failure modes of particle corroborated metal matrix composites [6]. The homogeneity of the $MoSi_2$ distribution significantly increased and the reinforcing particles combined with the homogeneous reinforcement distribution produced advanced tensile properties without losing rigidity after being processed by powder metallurgy of AA6061/$MoSi_2$ composites were each given a different reinforcement size and high energy ball milling time [13]. Al 7075/$A1_2O_3$/graphite hybrid compound are set up to be increased by increased weight percentage, hardness, tensile strength, flexural strength and compression strength and wear properties of the hybrid composites containing graphite exhibited the superior wear- resistance properties [22, 40, 44]. Hybrid TiO_2 & CuO nanoparticles as the reinforcing materials were mixed with aluminum (Al) powder using a planetary ball mill, and sintering fashion resulted in invariant dissipation of particles, enhancement of mechanical properties and wear resistances [23]. Fabrication of AA6061 (SiC/Fly Ash) hybrid compound, study of microstructure and sliding wear behavior with different weight chance of reinforcement and microstructure studies has revealed homogenous dissipation of particles, increased hardness and tensile strength of matrix mixes [24]. Effect of ZrB_2- Si_3N_4 on the particles of AA8011 essence matrix mixes (AMMCs) by stir casting process developed mechanical particles of mixes with increased weight percent fraction of reinforcements [25]. Hybrid (ZrB_2 $A1_3Zr$)/AA5052 matrix mixes with varying amount of ZrB_2 in which Tensile results indicate that the UTS and YS improve up to 3% vol. of ZrB_2 but beyond this composition a decreasing trend is observed, a nonstop adding trend is observed in bulk hardness. Fracture studies of $A1_3Zr$ particles and dimples of matrix, but with addition of ZrB_2 dimple size decreases. Increase in ZrB_2 leads to quasi cleavage fracture and debonding of ZrB_2 clusters [27]. Higher dislocation density in the nanostructure and proper bonding in the matrix/reinforcement Al_2O_3 (μm) & The Si_3N_4 (nm) interface with premixed Al particles was identified as the main strengthening mechanism. Double-reinforced composites showed better tensile properties than single-reinforced composites, better bonding between matrix and reinforcement, and better grain structure [28]. The increase in the content of Al_2O_3 and Gr particles and the extension of the grinding time have a great influence on the structural development of the Al matrix during the mechanical grinding process and the low wear rate. The Al/Al_2O_3/Gr hybrid composites are due to the presence of Al_2O_3 and Gr, which played the roles of load-bearing elements and solid lubricants, respectively [29, 46]. Aluminum reinforced hybrid composites blends with rice husks, MoS_2 and B_4C prepared by stir casting showed improved tensile and compressive strength, hardness and wear resistance, achieving a friction reading [30, 31, 33]. The mechanical properties and wear resistance attributed to the constant distribution of graphite and its composites in the matrix resulted in improvement under dry sliding conditions [39]. Characterization of microstructure and mechanical properties in commercial Al-Si casting alloys reinforced with nano particles like Zirconium dioxide, Silicon Carbide composites and Alumina, Fly ash micro particles shown an increasing Tensile yield strength and decreased density [34, 35, 38, 41, 42, 43, 45, 47, 48]. An experimental study on the mechanical properties of samples of graphite, alumina and silicon carbide reinforced aluminum alloys were used in the stir casting process [2] with a constant weight tip with different weight probability showed an improvement in tensile strength, hardness, wear rate and invariant particle distribution in the matrix.

MATERIALS AND EXPERIMENTATION METHODS

Composite Preparation

Aluminium (A356) was the base material, Silicon carbide (200 μm), Graphite (40 μm, 325 mesh) and Aluminum oxide (12 μm) are the reinforcements. It's substantially concentrated goods of these reinforcements on the aluminium alloy A356. The aluminum and silicon carbide powder were fed into a carbon furnace in a graphite crucible. The aluminum parts were preheated to 450°C for 3–4 hours and the SiC powder was also preheated to 900°C, the graphite particles were preheated to 1200°C,

Al_2O_3 was preheated to 800ºC and all the preheated mixtures were also mechanically mixed with each other below their melting points. These metal- matrix Al composites were also poured into the graphite crucible and put in to the coal- fired furnace at 760ºC temperature. The furnace temperature was first increased above the composites temperature to completely melt the pieces of the aluminum and also cooled down just below the composite's temperature, kept it in a semi-solid state. At this stage the preheated SiC particles were added and manually mixed with each other. At this stage it's very delicate to mix by machine or by stirrer where metal-matrix mixes are in semi molten state. It's preferred with the homemade mixing and also automatic shifting is carried for 10 minutes with normal 400 rpm of stirring speed. The temperature rate of the coal- fired furnace is controlled at 760°C to 770°C in the final mixing process. After reinforcing the composites, the melted material is poured into a mould and allowed to solidify. Four Metal matrix mixes were fabricated by stir casting system as shown in Figure 1. The below Table 1 shows the weight of the samples' composition.

These Aluminium material-matrix composites were also cast in a graphite crucible and placed in a charcoal-fired oven at 760°C. The oven temperature was first increased above the temperature of the mixture to completely melt the aluminum parts and then cooled to just below the temperature of the composite, leaving it in a semi-solid state. At this point, the heated particles were manually added and mixed. Mechanical blending or blending with the mixer is certainly difficult when the metal matrix blends are in a semi-molten state. Once the automatic mixing is completed, the automatic mixing will also be carried out within 10 minutes at the normal mixing speed of 400 rpm. The temperature of the charcoal kiln must be maintained between 760°C and 770°C during the final mixing process. Once the process is complete, the dough is placed in the sand mold for 30 seconds to set. The test must be carried out on solidified composite materials. This test must be carried out continuously by varying the composition of the SiC composite powder (10% and 20%). A total of two samples were prepared with graphite and two samples were prepared using the same procedure without adding graphite. Figure 2 shows casted samples of Aluminium composite.

Figure 1. Stir Casting Machine.

Table 1. Weight Percentages of Aluminium & its composites

S.N.	Composition
1	A356+10% SiC+ 3% Graphite +10% Al_2O_3
2	A356+20% SiC+ 3% Graphite + 10% Al_2O_3
3	A356+10% SiC+10% Al_2O_3
4	A356+20% SiC+10% Al_2O_3

Figure 2. Casted Samples of Aluminium composite.

Wear Test

A pin on disc wear test rig Figure 3 was used to estimate the wear characteristics of aluminium material matrix compound (A356) [20]. The wear sample was prepared from the fabricated and followed by heat treated compound samples. The compound sample pin of 10 mm diameter and 30 mm length was allowed to slide against a rotating EN32 steel disc with hardness HRC 62, circumference 57 mm and 8 mm thickness

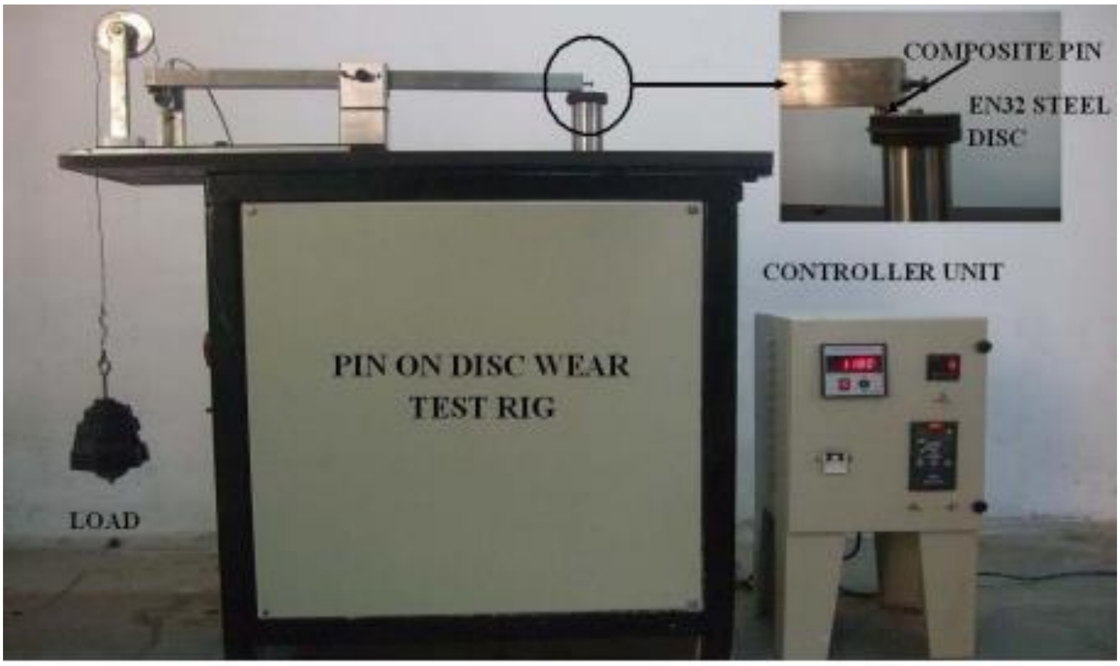


Figure 3. Pictorial view of Pin- On- Disc Wear Test Rig.

RESULTS AND DISCUSSIONS

Microstructure & SEM Analysis

Metallographic examinations were performed on aluminum samples applying a Scanning Electron Microscope (SEM) in order to anatomize the presence of microstructural porosity [32]. Furthermore, the aluminum matrix and reinforced particles were studied using an Optical Metallurgical Microscope at magnifications of 100X and 200X, as depicted in Figures 4–7 especially. Below figures shows an indeed distribution of reinforced particles throughout the sample.

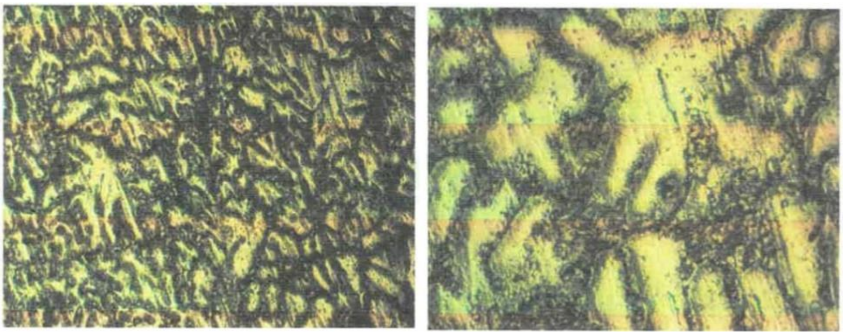


Figure 4. Microstructure of sample 1 at (a) 100X and (b) 200X.

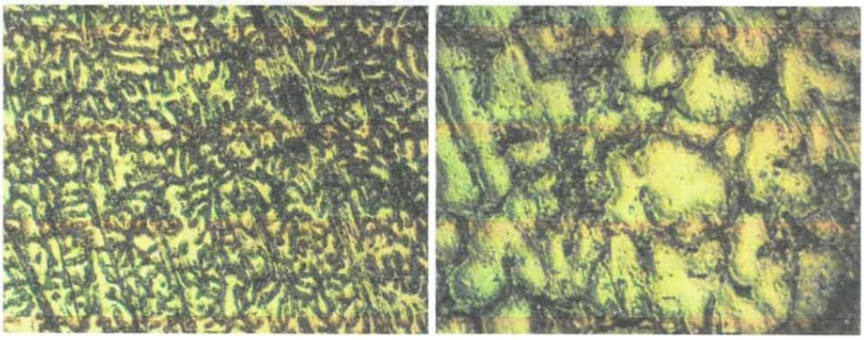


Figure 5. Microstructure of sample 2 at (a) 100X and (b) 200X.

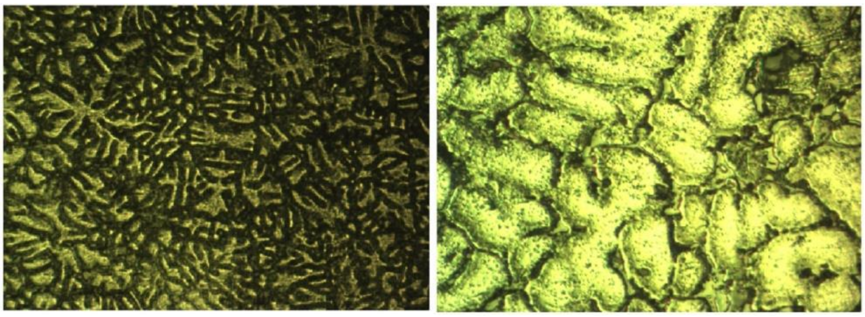


Figure 6. Microstructure of sample 3 at (a) 100X and (b) 200X.

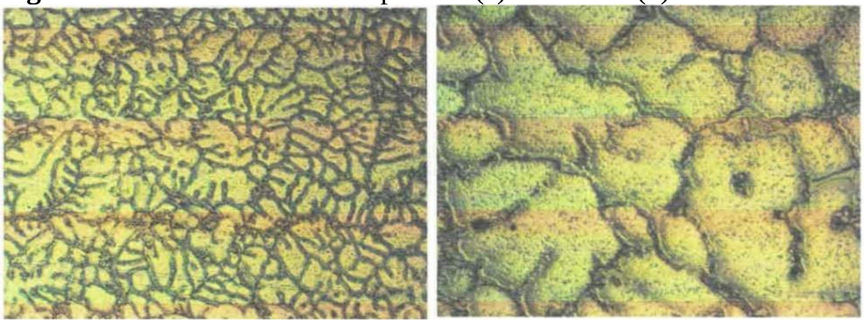
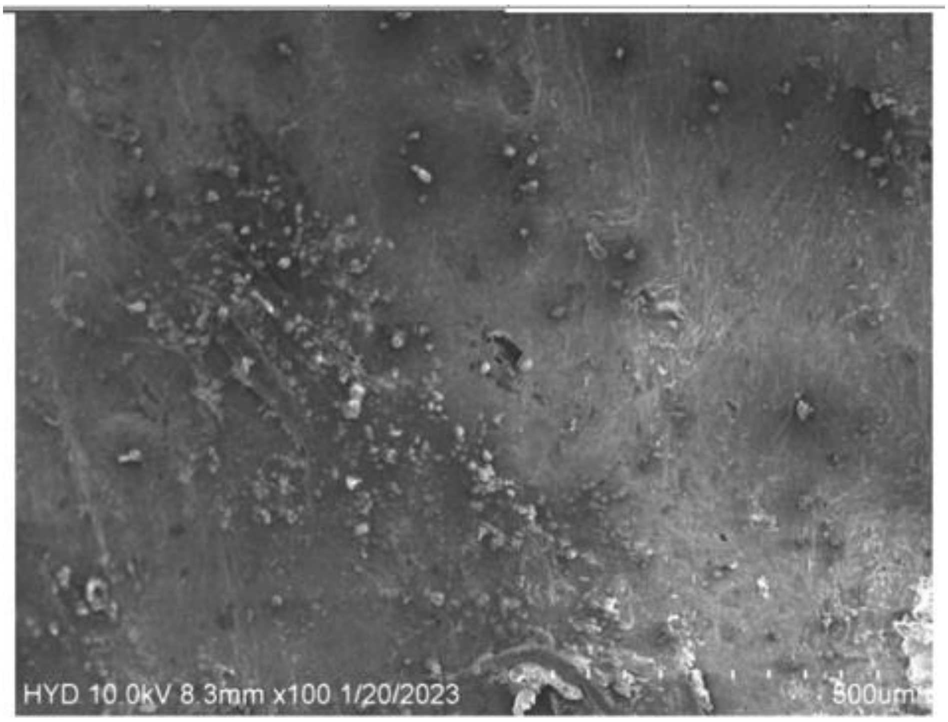
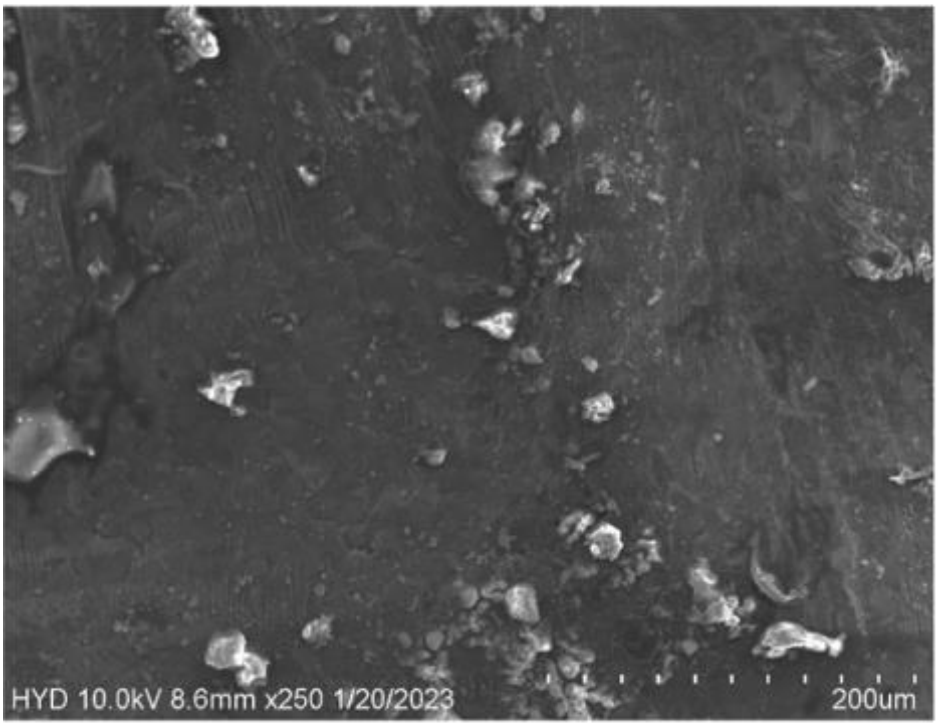
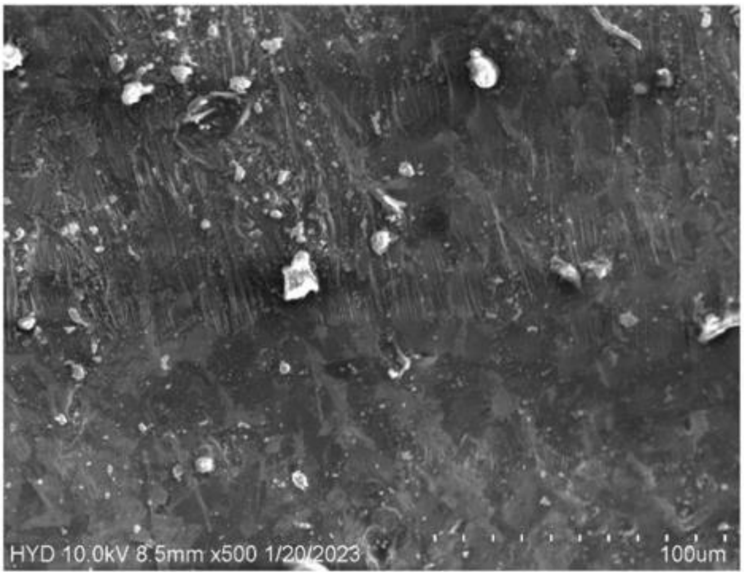


Figure 7. Microstructure of sample-4 at (a) 100 X and (b) 200X.

Figures 8 & 9, 10 &11 shows the SEM photographs of the A356 reinforced with varying Silicon carbide, Graphite, with and without Alumina particles. Large size particles have resistances against the adhesion due to strong interfacial strength with matrix material. The particle form a cluster in the compound which reduces the interfacial adhesion strength of the composite with large size corroborated compound. From the micrographs it is evident that with addition of 10% and 20% SiC with and without graphite particles distribution are visible and are uniformly distributed in the Matrix composite. The SiC, Graphite and Aluminium matrix composite more homogeneous compared to the composite without graphite. There is no perceptibility in bonded and reinforced particles.



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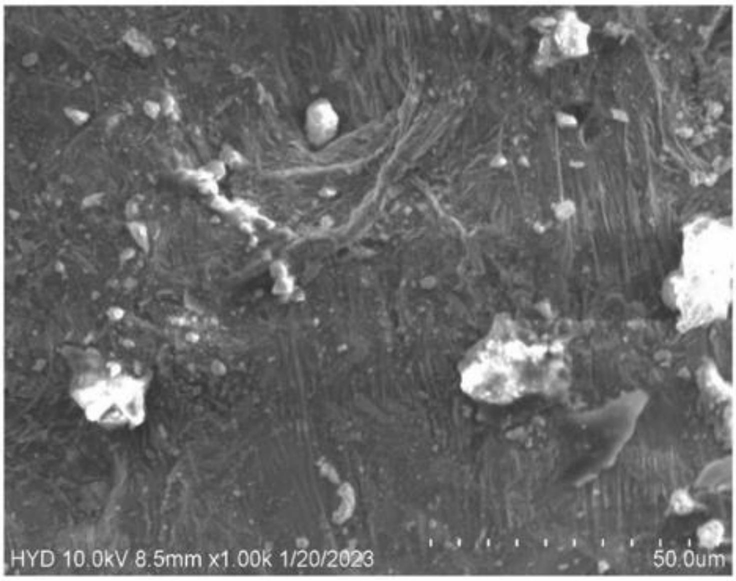
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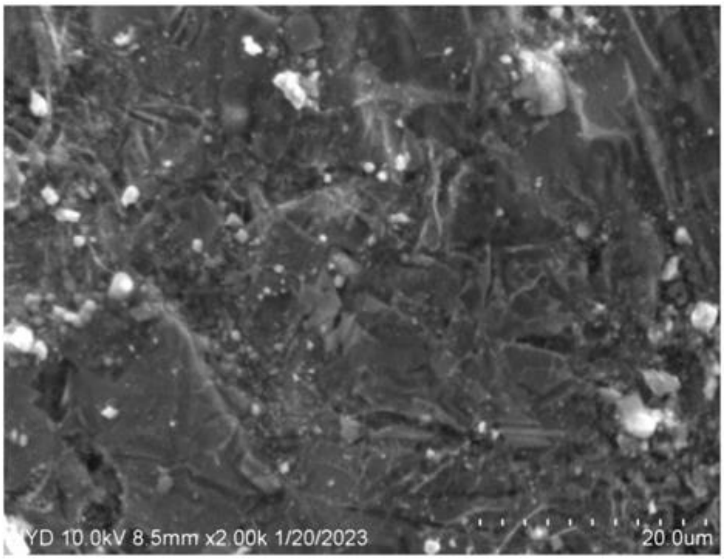
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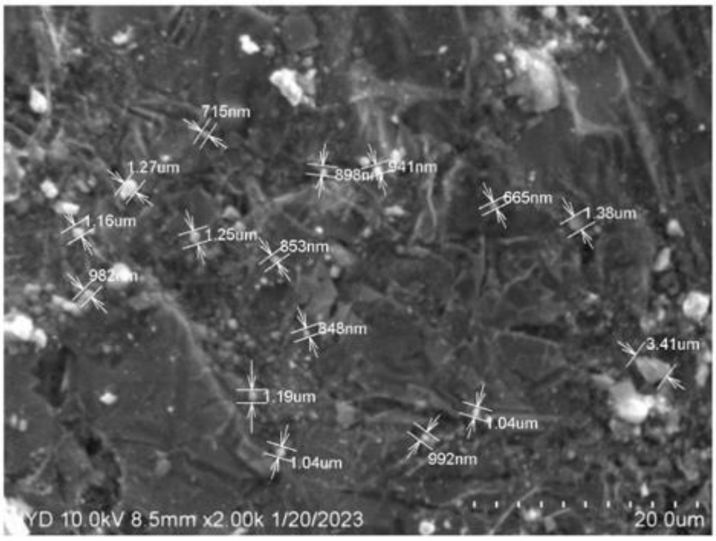
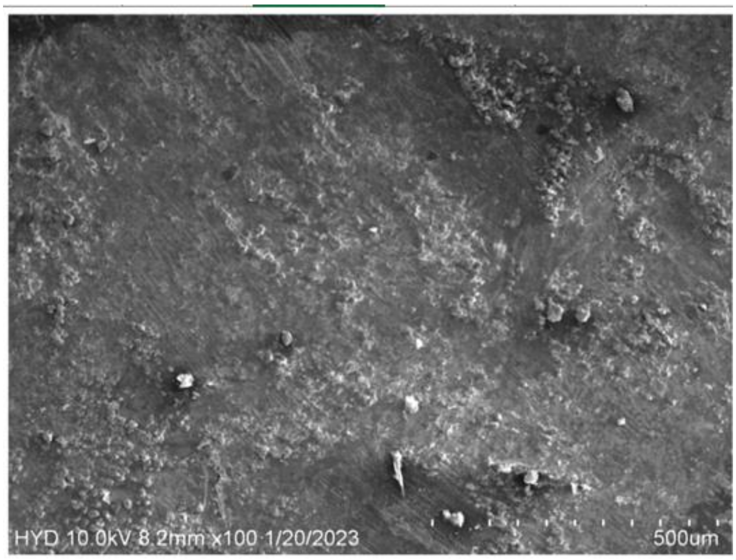
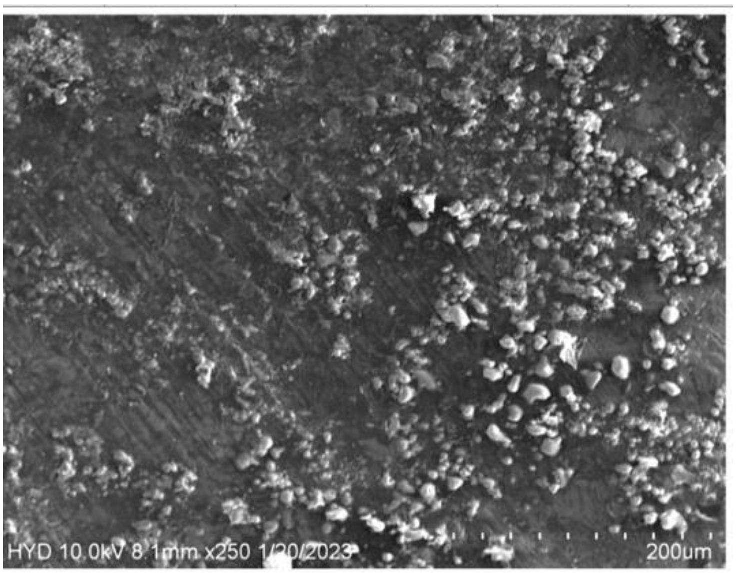
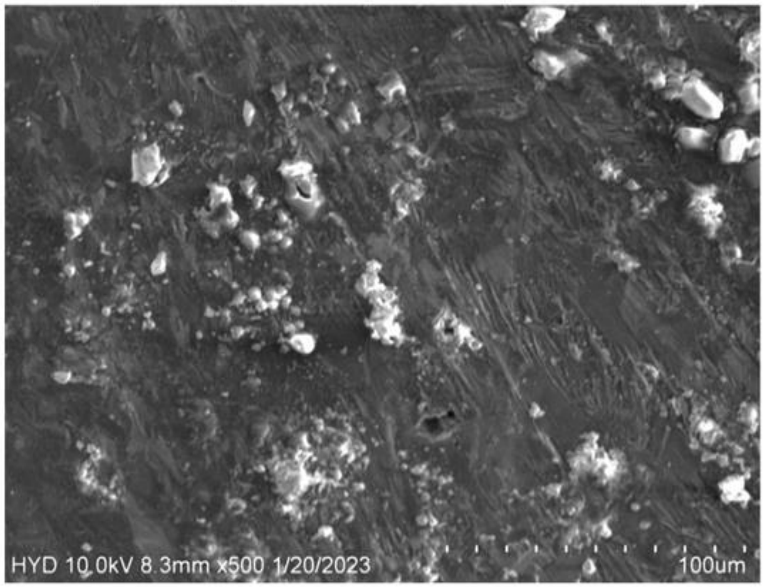


Figure 8. SEM images at sample 1 Aluminium(A356).



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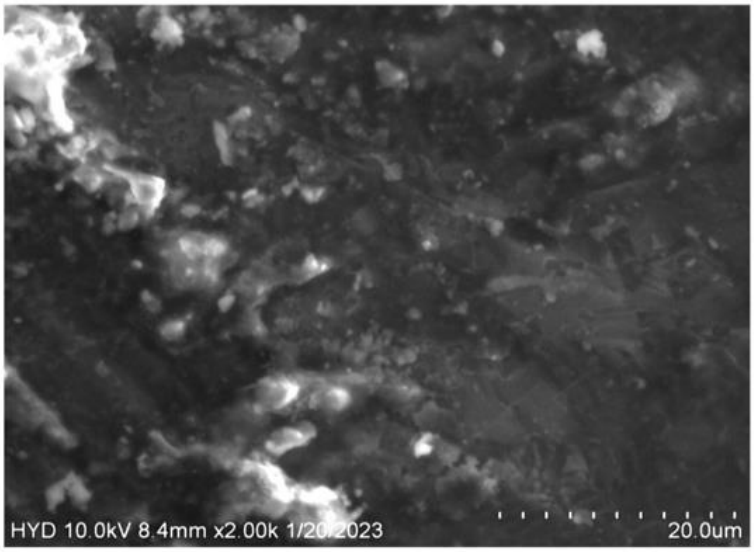
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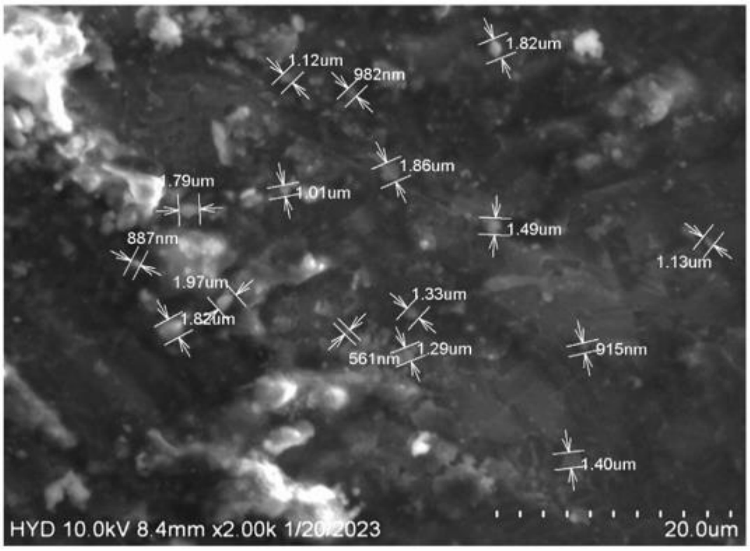
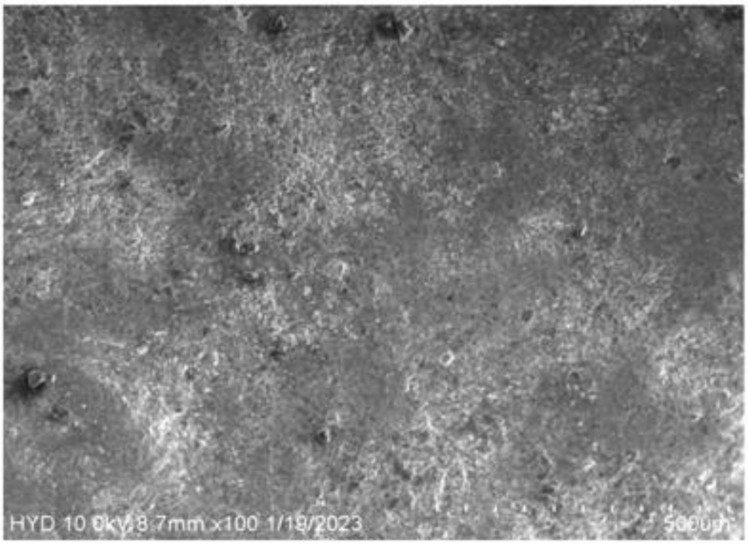
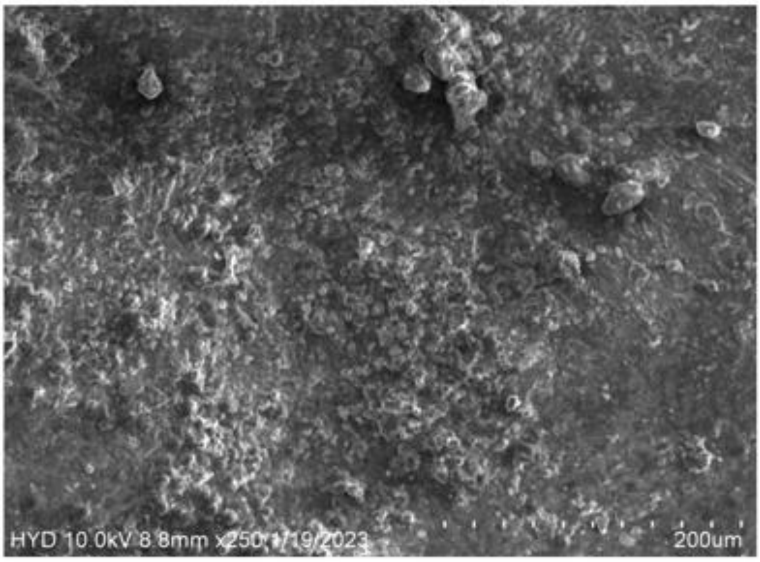
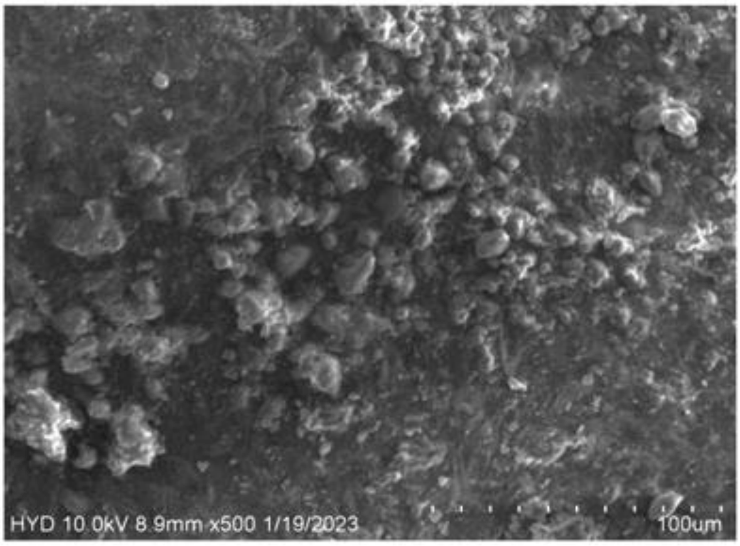


Figure 9. SEM images of sample-2 Aluminium(A356) composite.



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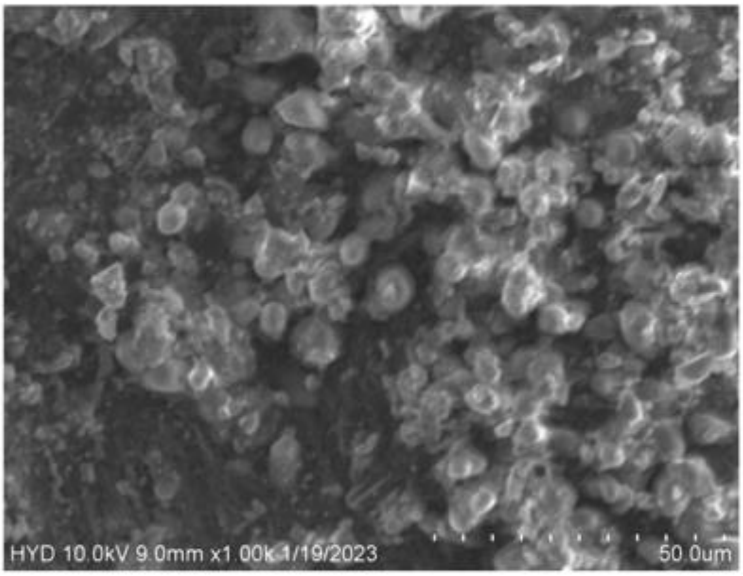
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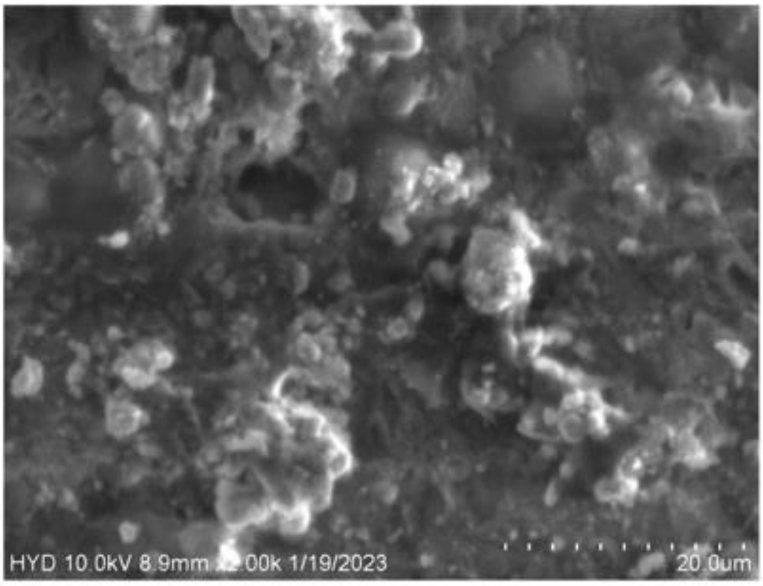
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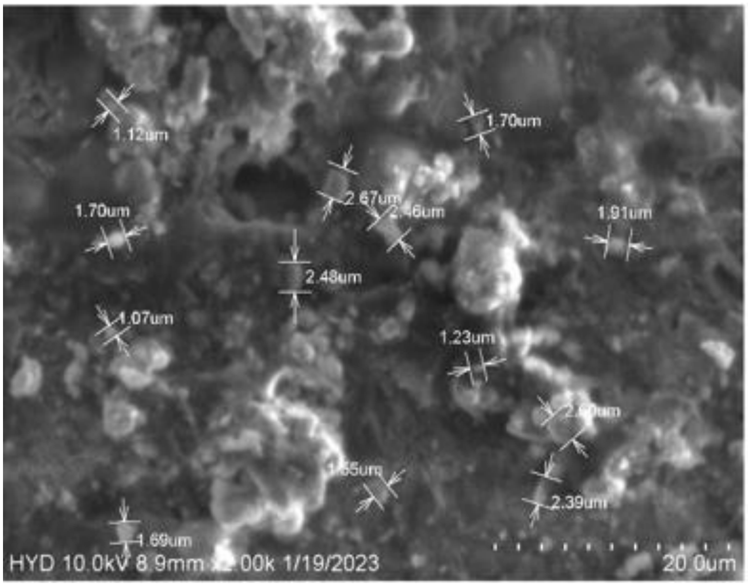
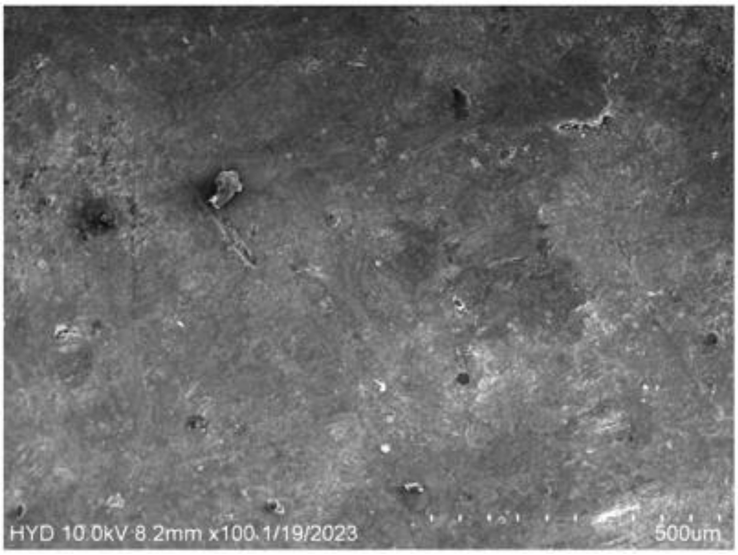
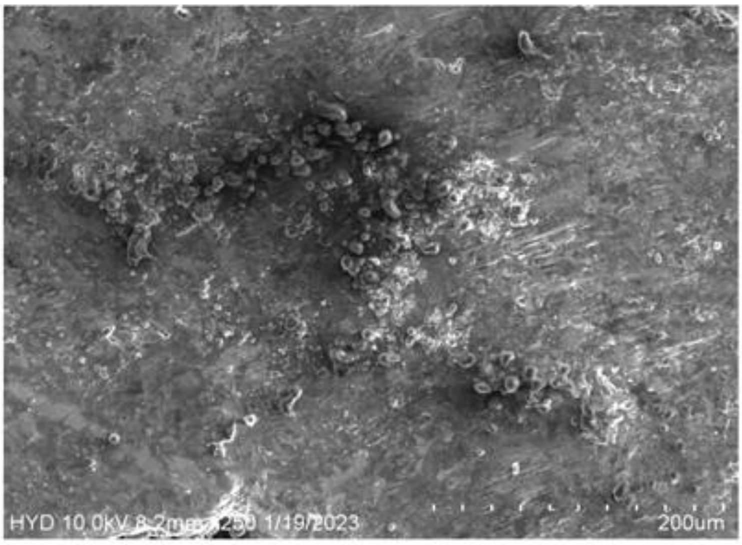
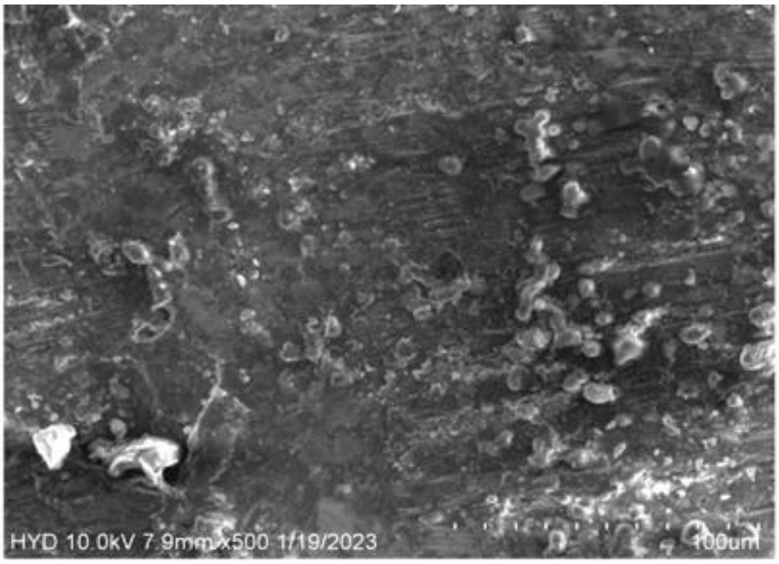


Figure 10. SEM images of sample-3 Aluminium (A356) composite.



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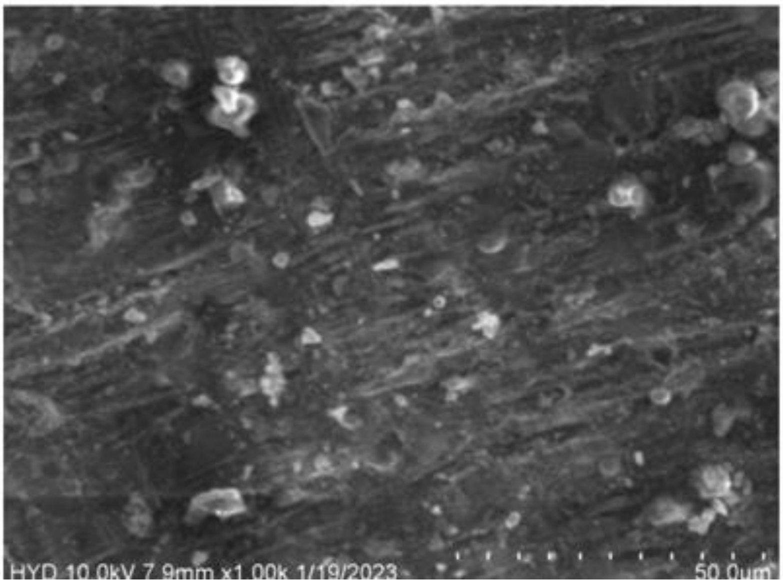
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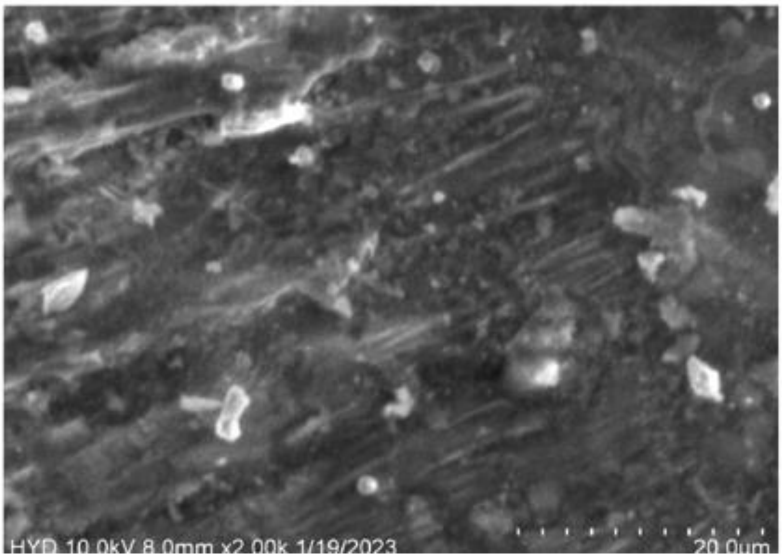
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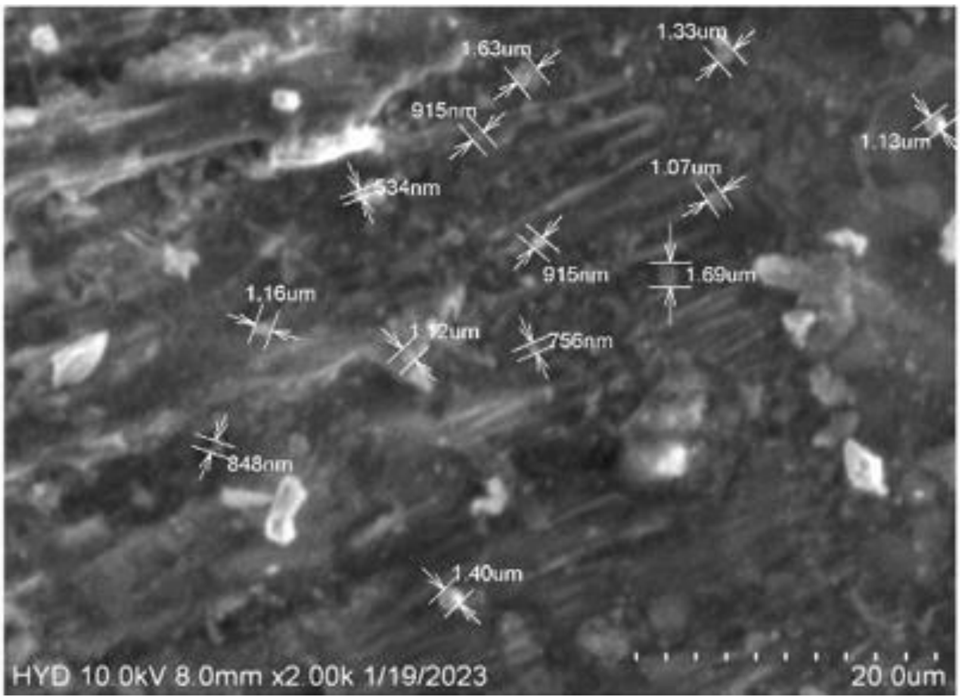


Figure 11. SEM images of sample-4 Aluminium (A356) composite.

Microhardness & Wear Tests

Brinell hardness tester was used for carrying the test. The test was performed with a force of 3000 N and 5 mm periphery of carbide ball. This test was performed according to ASTM E 10 norms. The test procedure is as follows Specimen was taken on to the tester. Acclimated the position of the sample below the indenter, applied a cargo of 3000 N for 12 seconds. Noted the readings, same procedure has been carried for the other samples Figure 12.

Figure 12. Samples of Aluminium (A356) composite after Hardness Test.

The Table 2 lists out the different compositions corroborated with the suitable accoutrements and the compositions with their hardness independently. From the below table, it was observed that by the increased addition of silicon carbide led to proliferation in hardness. Addition of graphite slightly affects the hardness. Addition of 10% silicon carbide and 10% Alumina gives lesser hardness comparing with other compositions. Addition of graphite to this composition leads to lesser reduction in hardness. A356+10%SiC have maximum hardness of 107.4 and minimum hardness for weight composition have 100.40.

Figure 13. Vicker's Hardness Tester.

Table 2. Hardness of Aluminium (A356) & its composites

S.N.	Composition	Hardness Value (BHN)
1	A356+10%Sic+3%Gr+10%Al_2O3	107.4
2.	A356+20%Sic+3%Gr+10%Al_2O_3	103
3.	A356+10%Sic+10%Al_2O_3	100.40
4.	A356+20%Sic+10%Al_2O_3	107

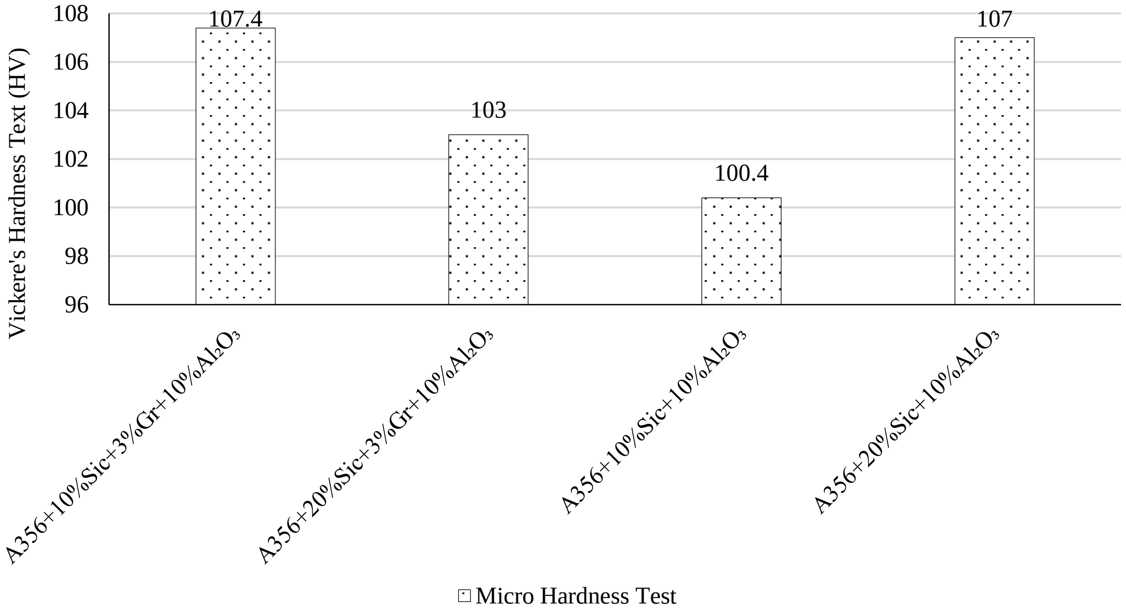


Figure 14. Graph for Hardness Test of Aluminium samples.

Figure 15 shows the volumetric wear losses of all MMCs at different sliding distances. It's apparent from the wear angles that the volume losses of all MMCs drop with adding $A1_2O_3$ weight bit and increase with adding sliding distance still, the volume losses of all the MMCs produced by circumfluous processing were significantly lower than those of MMCs produced by conventional shifting and this can easily be seen as the weight bit of $A1_20_3$ increase. There's a good agreement between the hardness values given in Table 2 and the wear rate of the MMCs. The wear rate resistance of the MMCs increases with the increase in their hardness values. The wear rate also increases with adding sliding distance, while as the $A1_20_3$ weight bit increases, wear rate diminishes. The wear rates were in the range of 2.98 × 10^{5}-18.86 × 10^5 mm ^{3}/N. m for MMCs produced by semi solid. In order to probe the wear rate medium, the worn shells were examined under SEM. Figure shows the SEM micrographs of the worn shells of the MMCs produced using circumfluous processing, tested at loads of 20 N.

From the graph as shown in Figure 15. It is shown that wear rate decreases with increase in volume percentage. Rate of drop in wear and high at low volume bit from experimental compliances A356+10% SiC+ 3% Graphite +10% Al_2O_3 at 15 N is high and at 10 N is low, A356+20% SiC+ 3% Graphite + 10% Al_2O_3 at 20 N is high and at 10 N is low, similarly, A356+10% SiC+10% Al_2O_3 at 20 N is high and at 10 N is low, finally A356+20% SiC+10% Al_2O_3 at 20 N is high and at 10 N is low.

Tensile Strength

Stress-strain relation and tensile test results of the samples can be seen in above Figures 16, 17. It can be concluded that total extension of the fabricated mixes is further than that of base essence, it means rigidity has bettered with the preface of mounts. This change in rigidity can be attributed to proper dissipation and bordering quilting of underpinning flyspeck in the matrix. There's drastic increase in tensile strength of the fabricated samples compared to the base material.

Table 3. Wear rates of MMCS produced by Friction Stir Casting Process

S.N.	Sample	10 N	15 N	20 N
1	A356+10% SiC+ 3% Graphite +10% Al_2O_3	5	7.8	9.2
2	A356+20% SiC+ 3% Graphite + 10% Al_2O_3	3.7	5.2	7.4
3	A356+10% SiC+10% Al_2O_3	2.6	3.8	6.8
4	A356+20% SiC+10% Al_2O_3	2.1	3.3	4.2

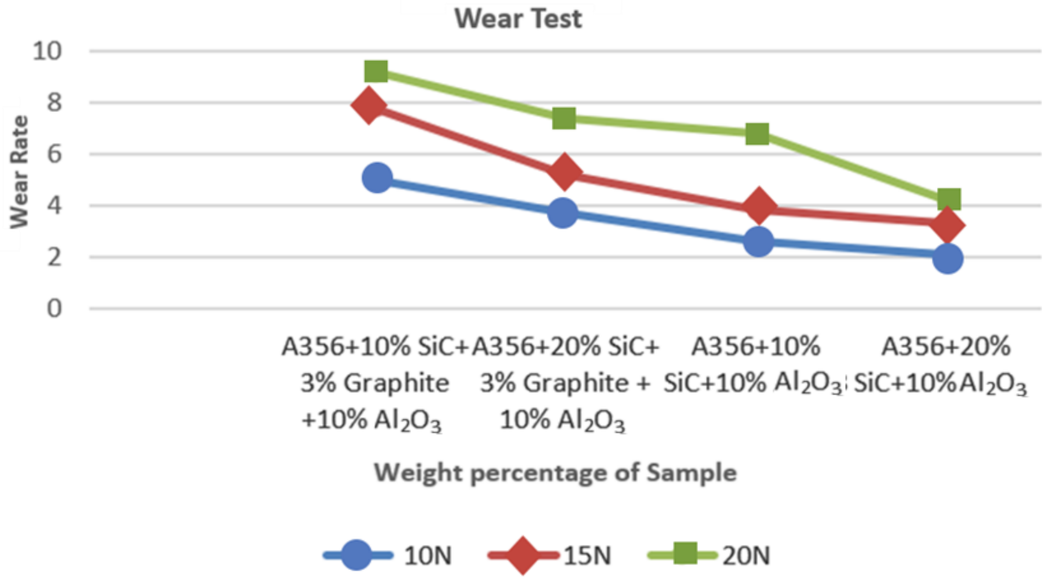
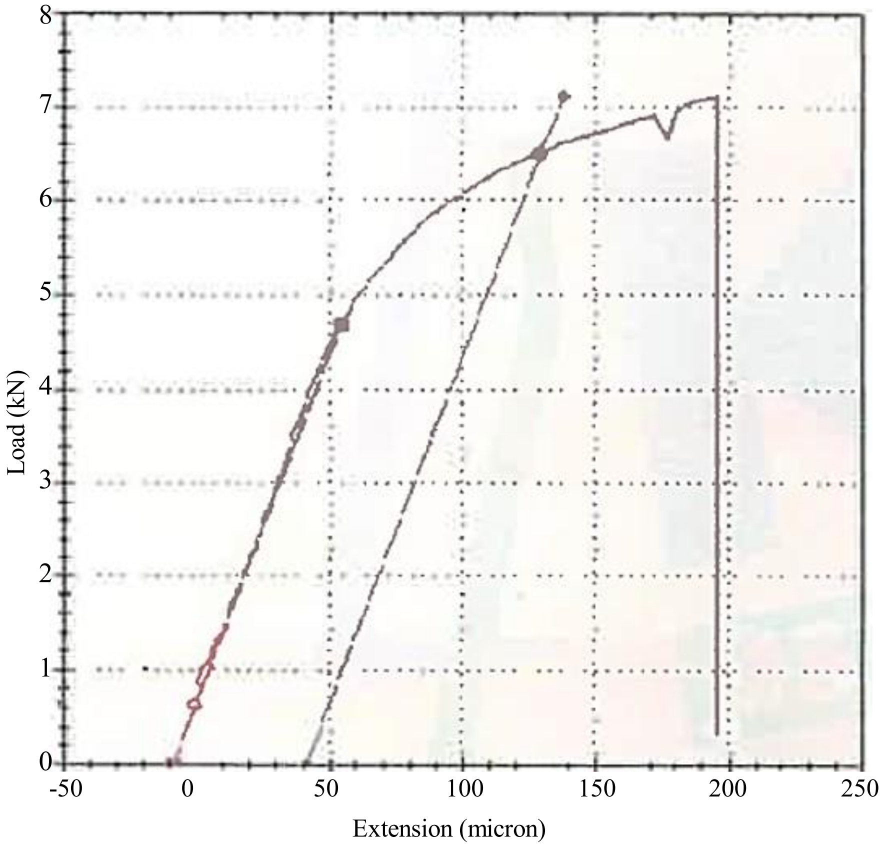


Figure 15. Graph for wear to weight percentage of sample.

Table 4. Process parameters for Tensile Strength

S.N.	Rotational Speed (rpm)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Elongation (%)
1	200	229.93	6.76	0.32
2	400	231.75	6.94	0.66
3	600	235.9	7.12	1.05



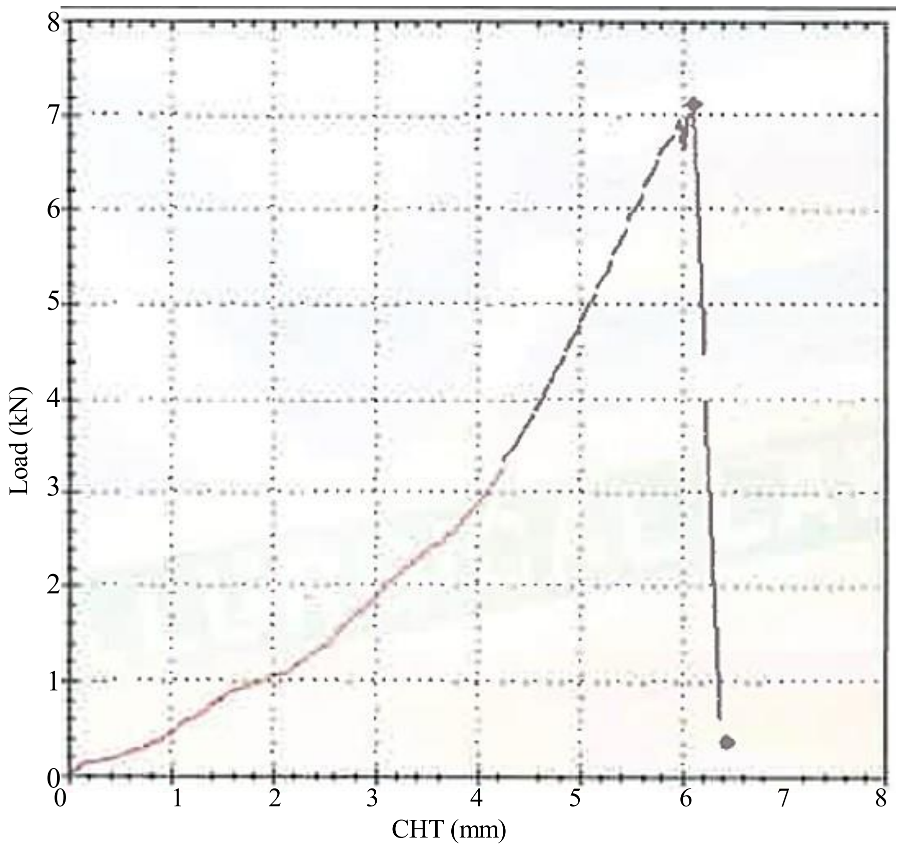
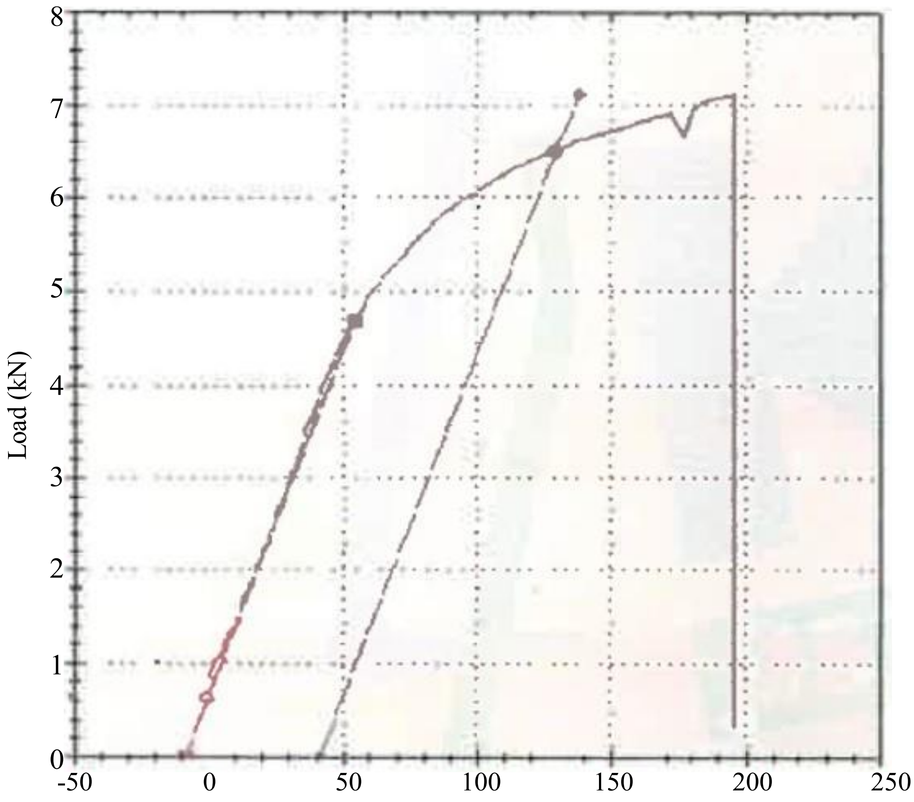


Figure 16. Graph for load Vs Extension.



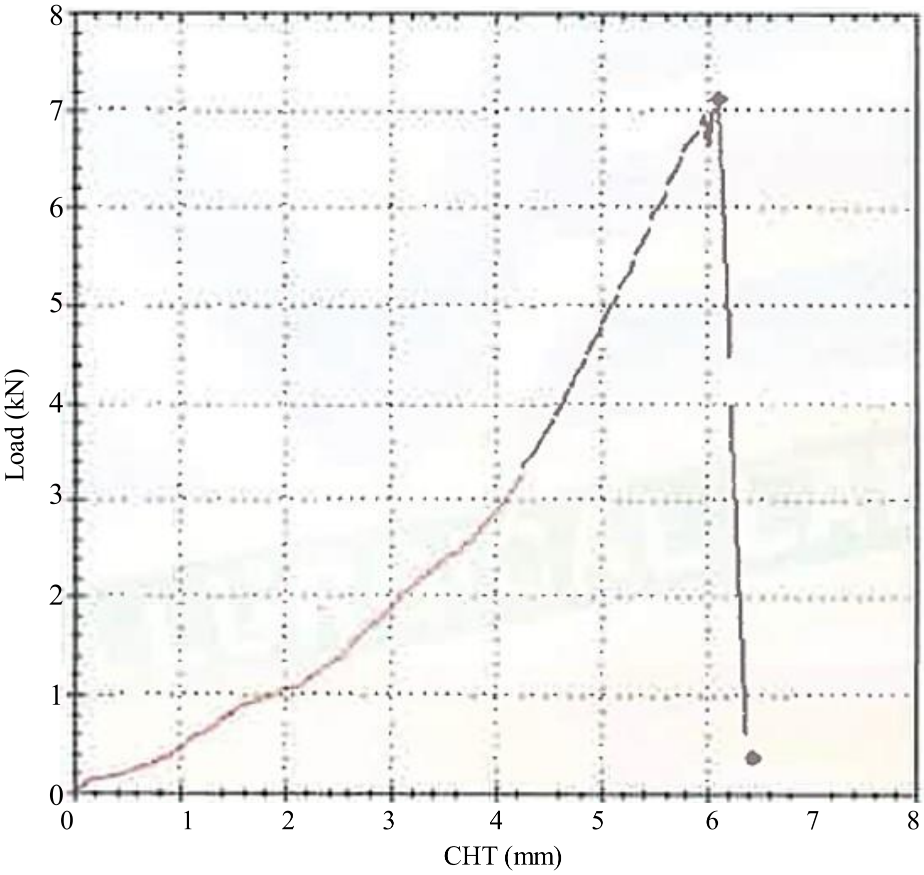


Figure 17. Graph for load Vs Extension.

CONCLUSIONS

Stir Casting Method, the essence matrix mixes have been successfully fabricated and from the details handed in the below sections, the conclusions drawn are.

1. Using Vickers hardness tester, hardness of four samples has been set up out and from graphs handed above it's apparent that compound with 10 wt of Al_2O_3 has advanced hardness fairly.
2. An increase in the quantum of underpinning in the base matrix is set up to be perfecting the mechanical parcels of the whole compound.
3. For studying tribologial parcels similar as Wear, Coefficient o Firiction. wear test has been conducted for constant sliding haste, sliding haste, sliding distance and contatn cargo.
4. From the graphs of wear and tear test, we can infer that as underpinning increases, wear and tear of the compound diminishments and measure of Friction is also lower for mixes over the base matrix.
5. Wear Resistance of the mixes increases with underpinning. From micrographs, we can notice the symmetrical division of Al_2O_3 patches throughout the face and compound face appears thick with an increase in wt of underpinning.
6. The whirlpool formed while the stirrer is running, eliminates dendrites because of high frictional commerce between patches and Al matrix, and induces invariant distribution. Aluminum amalgamation matrix can be developed successfully with the addition of Cu- Zn- Mg essence and corroborated with" Al_2O_3" using simple foundry melting alloying and casting route.
7. Results show that" Al_2O_3" patches up to 10 increase the tensile strength 235.9 MPa and extension 1.0 in aluminum amalgamation matrix containing Cu- Zn- Mg in aluminum.
8. The oxide phase dispersed slightly in the MMCs (like SiC, Cu). XRD results shows that the underpinning patches SiC and Cu admixture are in invariant rate.

9. The face roughness also decreases by the slice speed aluminium MMCs. The cutting force increases on the proliferation fo a depth of cut. By stir casting fashion the mongrel essence matrix compound can be developed effectively.

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