EXPERIMENTAL ANALYSIS OF MECHANICAL, TRIBOLOGICAL, MORPHOLOGICAL OF AA5022 BASED NANO-SCALED VANADIUM AND TIN REINFORCED COMPOSITES

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ABSTRACT

This research work investigates the mechanical and dry friction wear behavior of the AA5022 matrix reinforced with nano-scaledparticles. In this work, nano-scaled vanadium and tin were blended with an aluminum matrix, and the aluminum compositesamples with different weight percentages of nano-scaled vanadium and tin at 0–10 wt.%rangewere fabricated through a muffle furnace and stir-casting techniques. The obtained results reveal thetensile strength and microhardnessprogressively increase with nano-scaled vanadium and tin addition in the aluminum matrix to 6 wt% of each. The wear loss and wear rategradually decrease in the same samples. The internal structure of nano-scaled vanadium and tin reinforced hybrid aluminum composite samples was examined by scanning electron microscopy, which reveals that, sample C (6wt% of nano-scaled vanadium and tin particles) microstructure appeared uniform distributionanddispersed intensively in the aluminum matrix. The pure AA5022 was also studied to compare the mechanical and tribological properties. The sample C improved by 39% in tensile strength and improved by 22% in micro hardness. Moreover, hybrid aluminum compositesamplesshowed improved wear-resistant characteristics, which can be used for various tribological applications, especially in electric automotive and modern aerospace.

Keywords: *AA5022; Hybrid Composites; Vanadium; Tin ;Tribology*.

1.0 INTRODUCTION

In the over few years, the universal need for minimum cost, higher performance, and superior quality materials has been carried out on composite materials by numerous researchers.The operating low- cost, low wear performanceand high strength-to-weight ratio play a vital role in modern aerospace, automobile, and other related modern industries. Aluminum is the most extensively used metal matrix composite in the modern scenario. It is mainly because of the distinctive characteristics of low density, good mechanical properties, low electrical resistance, good machinability, and excellent corrosion resistance. Modern engineering applications have a lot of more current demands; hybrid aluminum composites have the great potential to satisfy their demands. Al 6061-Albite-Graphite reinforced hybrid composites show good tribologicalbehavior, which emerges as an attractive alternative hybrid composite material for high-end applications[1]. The prediction of wear properties performance is of supreme significance in the present industrial scenario, to evaluate the life span of friction-based components in advance to avoid huge financial losses acquired on account of wear [2]. The hybrid aluminumcompositesdensityimproves with reinforcements like TiC, SiC, and etc. The addition of reinforcements such as fly ash, mica, and rice husk reduces the density of the hybrid composites [3]. The reinforcement particle size, shape, type, and distribution in the matrix leads to internal microstructure and the volume fraction of reinforcement, which determines the composite surface and wear characteristics [4]. The aluminum composite performance is mostly reliant on choosingtheright combination of reinforcing particles and processing parameters [5]. The inclusion of B_4C particle reinforcement leads to decreases in the wear rate and improves the wear resistance performance of the aluminumhybridcomposites [6]. The mechanical and mechanicalbehavior of hybrid composites improved with combination of fly ash and SiC particles [7]. The wear performanceof hybrid composites decreased with the increase of the graphite inclusion in the aluminum matrix to 1.5 wt%, and hence graphite is not supported by the wear properties [8]. The mechanical properties of the aluminum matrix improve with the addition of SiC, B_4C, and alumina particles[9]. The wear rate is not affected notably with load and sliding velocity, but reinforcement particle size significantly affects the wear properties.[10-11]. The addition of micro and nano reinforcement particles in the aluminum matrix has improved the mechanical and wear performance [12]. The superior strength of aluminum or its combination is not all around investigated. Even though, a few studies have resulted in a significant increment in mechanical and wearcharacteristicsofhybridaluminum composites and therefore, more investigation is required in this spot of further development inhybridaluminum matrix[13].The uniform dispersion of nano-sized metal particles in the hybrid aluminum matrix plays a vital roledue to their strong tendency fortheagglomeration and good interface bonding, which resulted for enhancing the characterization of the hybrid aluminum matrix [14].The inclusion of reinforcement in the form of discontinuous or irregular reinforcement particles ofboron carbide and zirconium carbide particles leads to an improving the characterization of aluminum metal matrix composites [15].Nowadays, most vehicle body structures are employed with lightweight and high-strength nano metal matrix composites, and the most important properties of light-weight and high-strength are simultaneously demanded in mostmodern applications [16].The improved mechanical and wear properties of the multi-component aluminummatrix can be accomplished by the inclusion of low refractory and melting metal particles. To facilitate superiorcharacterization, metal nano-scaled particles are added into the aluminum matrix and further investigations are needed for the determination of the best possible content of nano-scaled particles in the aluminum matrix with an improved set of mechanical and wear properties [17]. The hybrid metal matrix composites are attractive materials for applications of mechanical, multi-functional, medical, energy and industrial and thus, it can be considered for the development of second generation of composite materials[18].The vanadium carbideparticle reinforced metal matrix composites were developed due to spontaneous growth of vanadium carbide during solidification, and uniformly distributed vanadium carbide in metal matrix, which results in goodmetallurgical bonding [19]. The aluminium composites reinforced with fly ash in different sizes of particles showed suitability in numerous applications like highway signs, automobile components, and industrial products.The minimum particle sized reinforced compositesare found to be enhanced mechanical performance [20-21]. The nano-sized particle quantity and its dispersion in the matrix are dependent on the development of composites in bettercharacteristics[22].The abrasive wear accounts for 50% of wear in the most components of industrial applications [23]. The wear performance of any material depends on input parameters such as load applied, sliding distance, slidingvelocity, property of material, machine characteristics, and environmental conditions of the machining operations [24]. The nano-sized particles reinforced aluminum composites significantly enhances the wear characteristics of matrix [25]. The material surface damages induces a change in the geometry of the components, which increased the surface crack propagation and tends to increase the tribologicalrate [26]. The improvement in the mechanical, and tribological performance of different aluminummatrix depends on the percentage of reinforcement particles, number of reinforced particles and ranges of particle sizes in the fabricated aluminum composites [27]. The wear rate is greatly affected by the volume fraction of reinforced particles in the aluminum matrix, and the relationship between reinforced particlegrain size, volume fraction, and sliding distance is important for the wear properties of the hybrid aluminumcomposites[28].Investigation of Al/20Cu/10Mg reinforced composites exhibited significant improvements in mechanical properties. Theyare composed of two different metals with good solubility, whichprovide better interfacial bonding by forming intermetallics, whereas dissolved particles help to achieve dispersion strengthening in composite structures [29]. The reinforced particle shape, size, and volume fraction, manufacturing process, and the interface between the matrix and the reinforcement phases of the composites affect the mechanical and wear behavor of Metal Matrix Composites [30].

Consequently, mechanical and wear behavior of different metal matrix composites has been studied in the literature. However, to our knowledge, effect ofvanadium(hard particle) and tin (soft particle) content on mechanical and wear behaviors of AA5022 hybrid composites has not been investigated**.** The main aim of present work is to fabricate hybrid aluminum composites using reinforcement of nano-scaled vanadium and tin particles to analyze the mechanicaland dry sliding wear performances. In this research, we analyzed the effects of different proportions of nana-scaled vanadium and tin reinforcements on the density, microstructure, mechanical (tensile strength, hardness, and % of elongation), and wear properties of an AA5022 matrix. Based on the results obtained, the developed hybrid aluminum composites could be used as an innovative standpoint in enhancing the performance of composites in electric automotive and aerospace applications.

2. EXPERIMENTAL

2.1Materials

AA5022 is an aluminum alloy, and it has high strength, high formability panel material, soft coat baking reduced proof stress. It is also capable of being improved by utilizing adding the proper reinforcing materials. Vanadium(V) is a shiny grey, malleable, ductile transition soft metal and its density of vanadium is 2. 56g/cm3.Vanadium nanoparticles provides ultra-high surface area (particle size range : 40-60nm). Tin(Sn) is a silvery-white color hard metal and its density of tin 4.67 g/cm3.Tin nanoparticles provides good surface area (particle size range : 30-60 nm). This research work is intent to study the performance of mechanical and tribologicalbehaviorof aluminum matrix with incorporation of both soft and hard nano-scaled particles. The different proportions of nano-scaled vanadium and tinparticles reinforced with aluminum alloy were used for this researchwork. The ingots of AA5022 were provided by Navstar Steel

CorporationLimited, Mumbai, India with its Chemical distribution of AA 5022 is tabulated in Table 1 and Table 2 represented the formulation table, which is used to fabricate the hybrid aluminum composites.

2.2 Hybrid Composites Preparation

Stir casting is the most preferable process or method for the fabrication of hybrid composite materials. First, clean the plunger, furnace, mold, and stirrer using carbide paste to avoid settling molten metal when they contact it. Place the furnace and plunger into the stir casting machine. The reinforced nano-scaled materials(V and Sn) having different material nature and meting temperatures and hence dissimilar methods and time periods were used for vanadium and tin respectively. Place the mold at the bottom of the setup in the correct position. Switch on the setup, adjust the initial temperature to 85^{o}C and place the base material, AA5022, into the furnace and allow the temperature to rise further by closing the furnace. At the same time, preheat the vanadium in the muffle furnace at a temperature of about 600^{o}C. After attaining a definite temperature, take the vanadium carefully from the muffle furnace and put that into the stir casting furnace. Wait till the materials change into molten form at about 720^{o}C to 780^{o}C. Then add tin carefully at the last of the fabrication process due to tin material has a lower melting temperature (232^{o}C). Fix the stirrer carefully into the motor, and after fixing, turn on the motor switch and allow a rotating stirrer by giving low speed, making the AA5022-vanadium – tinblended properly in a molten metal form. Then**,** turn off the motor switch, after 3-5minutes turn on the pneumatic switch, which makes the plunger move backward and allows the molten metal to fall into the mold kept at the bottom. The cylindrical tube mold was used to fabricate the hybrid aluminum composites in this research work. After some time, take out the mold, loosen the bolts and then take the upper part of the mold and remove the material. The Aluminum alloy with various proportions of nano-scaled vanadium and tin (hybrid aluminum composites) were fabricated based on the above formulation table. Then, the samples were prepared according to the mechanicalandtribologicaltestings as per ASTM standards. The machinery used for the fabrication process and fabricated hybrid aluminum composites are shown in figure 1.

2.3. Testing of Density of material

The density of the aluminum hybrid composites was computed using both the geometric method and the Archimedes technique (with distilled water at 25^{o}C as the submersion liquid). The relative density of the hybrid aluminum composite sample was calculated using the rule of mixture blends, which utilizes the theoretical bulk thickness values of all the aluminum hybrid composite samples.

2.4 Testing of Mechanical Characterization

The fabricated hybridaluminum composite samples were used for the testing of various mechanicalcharacterizations like tensile properties and hardness.The tensile tests were performed at room temperature on a UTM at the cross-head speeds of 600 mm/min. The dumb-bell specimen was prepared according to ASTM D-412. Hardness was tested using BHN with test standards as per the ASTM E10-14, usestungstencarbideindenter. The 100Nload was applied for15 seconds with indentation speed of 40 mm/s. The indentation image displayed by the computer, which was processed through dedicated software to computetheBrinell hardness numbers. Five iterations of the test were conducted, and the mean was noted.

2.5 Testing of TribologicalCharacterization

Pin-on-disc test apparatus was used to determine the dry sliding wear characteristics of the aluminum hybrid compositesamples as per the ASTM G99-95 standards with Model TR 20-LE, Ducom. The wear test is conducted by taking the parameters like sliding velocity, load, and sliding distance. The initial weight of the sampleistobe properly cleaned and measured using the electronic weighing machine. The specimens were machined to a pin size of 10 × 25 mm. Wear testing is used to test the wear resistance of solid materials. The wear rate unit is (mm^3/N.m).

2.6 Testing of Morphological Characterization

The morphology testing was carried out in Scanning Electron Microscope—model TESCAN VEGA3, which produces images of a sample and the electrons interact with atoms, producing various signals that contain information about the samples of surface topography and composition of aluminum hybrid composites.

3. RESULTS AND DISCUSSION

3.1 Analysis of MechanicalProperties

The density, microhardness, and tensile properties were used to assess the mechanical characterization of the hybrid aluminum composites. In this study, 5 samples (S_1, S_2, S_3, S_4, S_5) for each fabricated aluminum hybrid composites were subjected to testing and the average value was recorded, which has been shown in Table 3 along with vanadium and tin materials.

The density of hybrid composites is improved with the incorporation of nano-scaled vanadium and tin particles. Figure 2 shows that the density of the hybrid aluminum matrix slightly increases when the reinforcement particles increase which is due to the agglomeration of dual nanoparticles.Inotherwords, the density increaed with increasing the reinforcement dual materials and the hybrid composites showed improved density due to its higher densification ability and more agglomeration. It is obivious that there is not much difference among the pure aluminum alloy and reinforment particles and it confirms the preparation suitability of hybrid composites for stir casting processes.Moreover, theoretical and experimenaldenity of different hybrid aluminum compoite samples are recorded in the Table 4.

The micro hardness is improved upon incorporating nano-scaled vanadium and tin particles in the aluminum matrix. Figure 3 shows the hardness progressively increased with the addition of nano-scaled vanadium and tin particles in the aluminum matrix. It was due to the addition of reinforced nano-scaled particles acting as an encumbrance to dislocation motion, further due to satisfactory bonding between the aluminum matrix and reinforced material.

In addition to more V and Sn in matrix, it is observed that microhardness slightly decreases and is due to the formation of void nucleation by increasing more reinforced particles and it led to a decrease in microhardness. Also, It can be concluded that the agglomeration of particles in the matrix with a high percentage of reinforcement particles, which results in higher porosity due to the formation of voids and pits, leads to decrease the micro hardness[31].

The tensile stress-strain curves of the hybrid nanocomposites increases linearly with the increase in dual reinforcement with compared to pure aluminum matrix as shown in the Fig, 4.. It was due to the reduction in grain size, uniform distribution and amount of soft and hard reinforcing particles into the matrix.Themaximumtensile strength (145.36 Mpa) of the sample C nano-scaled composite was approximately 39% more than the tensile strength (106.32Mpa) of the AA5022 sample.

Figure 5 shows the tensile strength gradually increased with V and Sn loading in hybrid aluminum matrix up to 6 wt%, which was due touniform distribution of the V and Sn reinforcements and the more efficient load transfer from the matrix to the reinforcement in the metal matrix due to the two different reinforcement materialsandthisreinforced particles build much strength to matrix by offering additional resistance to tensile stresses[32 33]. The addition of more reinforced particles into the matrix, loosens its tensile strength, which was due to a more dual particles agglomeration,andinhomogeneousdistribution of reinforcing particles, which causes of strain felds in the matrix.

The elongation at break is enhanced with the addition of nano-scaled vanadium and tin particles. Figure 6 shows the elongation at break steeply increases with V and Sn loading in hybrid aluminum matrix up to 6 wt%, and it shows the addition of these nano reinforced particles enhances the ductility levels of the composites. It was due to the homogeneous dispersion of V and Sn in the aluminum matrix, and the thermal mismatch between the matrix and the reinforced particles, which reasonsforsuperior dislocation density in the matrix [34]. With the further inclusion of more nano-scaled reinforced particles, elongation of the hybrid aluminum composites drastically reduced due to an increase intheweight percentage of reinforcementsandtheformation of void nucleation because of this, elongation at break decreases[35].

3.2 Analysis of Wear properties

The wear loss and wear rate were used to assess the tribological characterization of the hybrid aluminum composites. In this study, five samples are subjected to all these testing and the corresponding values were recorded in Table 5.

The abrasion loss of aluminum hybrid composite material was assessed in terms of wear rate in different parameters like load variation, sliding velocity, and sliding distances. The loads (10N, 20N, 30N, 40N, and 50N), Sliding distances (500m, 1000m, 1500m, 2000m, and 2500m), and Sliding velocity (1.2m/s. 2.4m/s, 3.6 m/s, 4.8m/s and 6.0m/s) are different parameters to undergone for the tribological testing to determine the wear characterization of hybrid aluminum composites as indicated in Table 6.

Figure7 shows that the wear rate gradually decreased with the addition of nano vanadium and tin particles loading in aluminum matrix up to 6 wt% in all load variations. As load increases, the abrasion loss also increases and relates to the coefficient of wear rate is increased with an increase in load conditions. It is observed that the average abrasion loss of the hybrid composite is relatively low compared to pure alloy.

The homogeneous dispersion of nanoparticles in the matrixled to improving the Interfacial reaction and proper distribution among the V and Sn in the matrix. The inclusion of additionalreinforcements in the matrix loses their interfacial reaction and improper distribution and hence loosens the wear characteristics of aluminum hybrid composites.

Figure 8 shows the wear rate of hybrid aluminum composites at different sliding distance conditions, in which incorporation of V and Sn particles in the matrix, improves the wear resistance of hybrid aluminum composites upto 6wt%. Incorporation of more same nanoparticles that lose their interfacial reaction and loosen their wear resistances and hence wear rate increases.Figure 9 shows the wear rate of hybrid aluminum composites at different sliding velocities.It results improve the wear resistance of hybrid aluminum composites upto 6 wt %, which is due to uniform dispersion and the good interfacial reaction of nanoparticles in the matrix. Theincorporation of more same particles lose their wear resistance and hence wear rate increases. With the increase of sliding velocity in all specimens, the wear rate tends to increase since the reinforced particles unevenly spread on the surface, which leads to unable to protect the composite surfaces, and hence wear rate increases.

3.3 Analysis of Micrographs

Figure 10 shows the wear surface of samples of pure alloy and all hybrid aluminum composites containing nano-scaled vanadium andtin in different proportions. Sample A facilitated a good interfacial reaction between V and Sn in the aluminum matrix and it observed that significant dimple pattern and small wear debris, which leads to improved mechanical and wear properties compared to pure alloy (sample O). The accumulation of the more nano-scaled particles in the matrix (B sample) which leads to presence of some wear debrises on the worn surfaces. Sample

C facilitates better interfacial reaction and bonding between V and Sn particles in the aluminum matrix, and it is observed that settled dimple pattern and also less wear debris and there are no shallow grooves, which leads to improving the tensile and wear properties.

Sample D and E facilitated improper interfacial reaction and nonuniform distribution of reinforced particles are detached from the worn surfaces during the wear tests.andit is observed that more minor wear debris and shallow grooves,which correlates to the micro-crack and micro-void formation in hybrid aluminum composites[36]. It led to a decrease in the tensile and wear properties of aluminum hybrid composite, Similar wear results were obtained from the previous study on the tribologicalproperties.Hence, the all morphology samples were analyzed and it reveals that 6 wt% of nano-scaled vanadium and tin particles dispersed intensively in the AA5022 matrix(sample C), which will show the bettermechanical and tribological performance of the hybrid aluminum composites,

4.0 CONCLUSIONS

This research aims to improve the mechanical and tribological properties of hybrid aluminum composites. The following conclusions arrived for the samples made of different compositions of nano-scaled vanadium and tin particles in the aluminum matrix, and the mechanical, tribological characterization and morphological analysis were carried out for all fabricated hybrid composites.

1. The density of hybrid composites increases with nano-scaled vanadium and tin particles, which indicates that there are not many differences between the pure aluminum alloy and hybrid aluminum composites, and it confirms the preparation suitability of hybrid composites in the stir casting process.
2. The microhardness gradually increases with the incorporationofnano-scaled vanadium and tin particles in the aluminum matrix to 6 wt%. The addition of more same particles loosens the microhardness, Moreover, sample C of micro hardness improved approximately by 22%when compared with pure alloy.
3. The tensile strength gradually increases with the loading of nanoscaled vanadium and tin particles in the aluminum matrix to 6wt%. The addition of more same particles loosens

the tensile strength. Moreover, tensile strength of sample C improved by 39% more thanwhen compared with pure alloy.

4. The Elongation at break gradually increases with nanoscaled vanadium and tin particles in the aluminum matrix till 6 wt%. The addition of more same particles loosens the Elongation,
5. The wear loss and wear rate gradually reduces with the incorporation of nanoscaled vanadium and tin particles in the matrix of all hybrid composites fabricated when compared to pure alloy.
6. Tribological properties reveals that, the wear rate of nano-scaled vanadium and tin particles reinforced hybrid composites showed less value when compared to pure alloy with various parameters like load, sliding distance, and sliding velocity.
7. The samples' morphology revealed that 6 wt% of nanoscaled vanadium and tin particles dispersed intensively in the AA5022 matrix, which will improve the mechanical and tribological performance of the hybrid aluminum composites.
8. Moreover, this research work concludes that hybrid aluminum composites containing 6wt% V and 6wt% Sn nano-scaled particles suitable for applications where mechanical and wear performances are more important, especially in the electric modern automotive andaerospaceapplications.

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TABLE CAPTIONS

Table 1. Chemical composition of AA5022 alloy (wt%)

Si	Fe	Cu	Mg	Mn	Cr	Al
0.25	0.4	0.2-0.5	0.2	3.5 – 4.9	0.1	Bal.

Table 2. The Formulation of hybrid Aluminum composites with nanoscaled vanadium and tin

S.No	Sample code	Aluminum AA 5022(wt%)	Nano-scaled vanadium (wt%)	Nano-scaled tin (wt%)
1	**O**	**100**	**-**	**-**
2	**A**	96	2	2
3	**B**	92	4	4
4	**C**	88	6	6
5	**D**	84	8	8
6	**E**	80	10	10

Table 3. The mechanical properties of Hybrid Aluminum Composites

Type of Testing	Vanadium	Tin	Sample O	Sample A	Sample B	Sample C	Sample D	Sample E
Micro Hardness in HBW	36± 0.02	51 ± 0.03	49 ± 0.34	54 ± 0.19	55 ± 0.22	60± 0.42	58 ± 0.13	57± 0.18
Tensile Strength in MPa	110.3± 0.04	67.63 ± 0.02	106.32 ± 0.16	118.82 ± 0.30	128.43 ± 0.38	145.36 ± 0.46	131.94 ± 0.26	127.47 ± 0.33
Elongation at Break in %	2.36± 0.03	1.64 ± 0.04	1.86 ± 0.14	1.96 ± 0.13	6.96 ± 0.18	8.70 ± 0.24	2.32 ± 0.10	1.46 ± 0.18

Table 4. Theoretical and Experimenaldenity of different hybrid aluminum compoites

Sample Code	Theoretical Density (g/ cm3)	Experimental Density (g/cm3)
Sample O	2.5903	2.5709±0.0003
Sample A	2.6406	2.6303±0.0010
Sample B	2.6901	2.6708±0.0009
Sample C	2.7003	2.6802±0.0012
Sample D	2.7202	2.7001±0.0011
Sample E	2.7004	2.6803±0.0015

Table 5. The Tribological properties of Hybrid Aluminum Composites

Type of Testing	**Sample O**	**Sample A**	**Sample B**	**Sample C**	**Sample D**	**Sample E**
Initial Weight ingms	5.50	5.42	5.84	6.74	6.68	6.59
Final Weight in gms	5.15	5.16	5.58	6.56	6.43	6.33
Wear Loss in gms	0.35	0.25	0.26	0.17	0.25	0.26
Wear Rate in mm^3 / N-m	6.33	4.62	4.48	2.62	3.73	3.94

Table 6. Wear Rate in different parameters (Load, sliding distance, and Sliding velocity)

Load		Sample O	Sample A	Sample B	Sample C	Sample D	Sample E
		Wear Rate (mm^3 / N-m)					
Test-1	10 N	6.33	4.62	4.48	2.62	3.73	3.94
Test-2	20 N	7.14	5.83	5.64	4.74	4.82	4.96
Test-3	30 N	7.94	6.22	6.78	5.11	5.21	5.54
Test-4	40 N	8.34	7.12	7.48	6.62	6.73	6.94
Test-5	50 N	8.84	7.62	7.98	6.94	6.85	7.18
Sliding Distance		Wear Rate (mm^3 / N-m)					
Test-1	500m	7.11	5.41	5.28	4.48	4.52	4.71
Test-2	1000m	7.91	6.43	6.32	5.52	5.61	5.74
Test-3	1500m	8.71	7.02	7.48	5.99	6.01	6.31
Test-4	2000m	9.11	8.14	8.12	7.12	7.46	7.74
Test-5	2500m	9.66	8.53	8.51	7.78	7.80	8.21
Sliding Velocity		Wear Rate (mm^3 / N-m)					
Test-1	1.2 m/s	6.01	4.12	3.93	2.11	3.22	3.45
Test-2	2.4 m/s	6.64	5.31	5.14	3.13	4.29	4.45
Test-3	3.6 m/s	7.34	5.77	6.11	4.53	4.76	5.04
Test-4	4.8 m/s	7.85	6.66	7.00	5.11	6.22	6.47
Test-5	6.0 m/s	8.32	7.11	7.45	6.44	6.52	6.83

FIGURE CAPTIONS

Figure 1. Fabrication process and hybrid composites

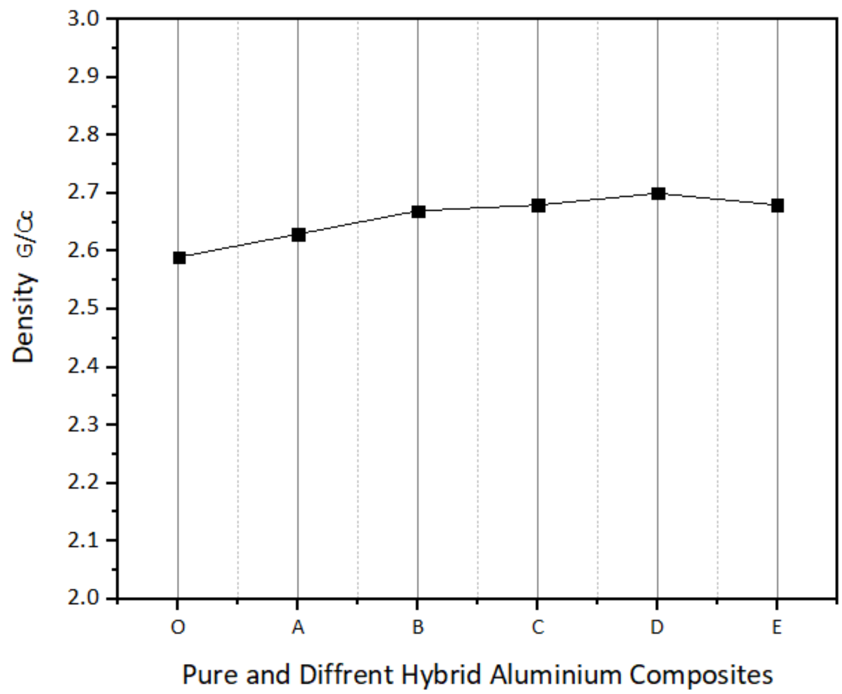

Figure 2. Density of all hybrid composites filled with V&Sn

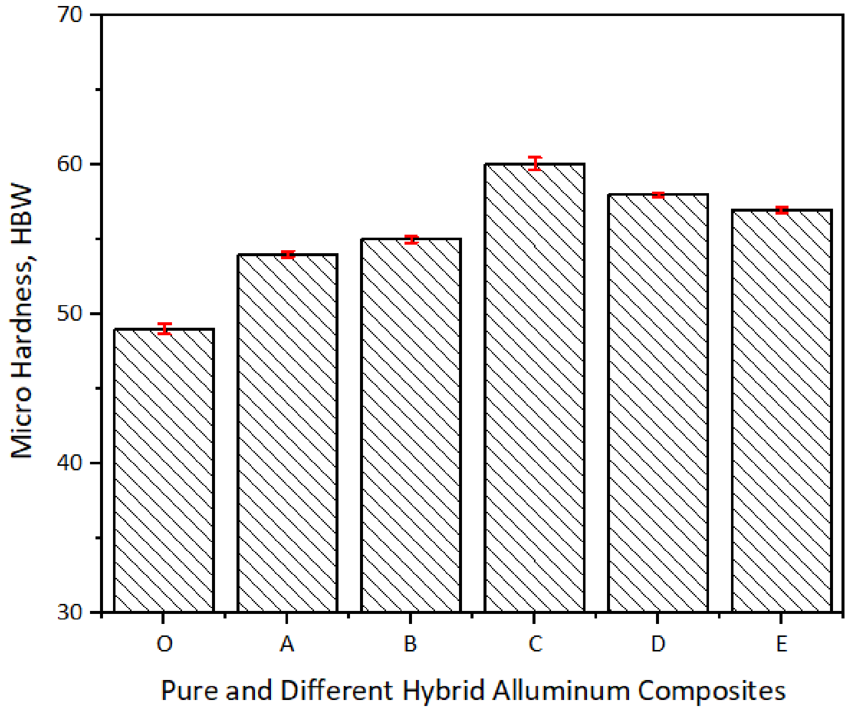

Figure 3. Micro Hardness of all hybrid composites filled with V&Sn

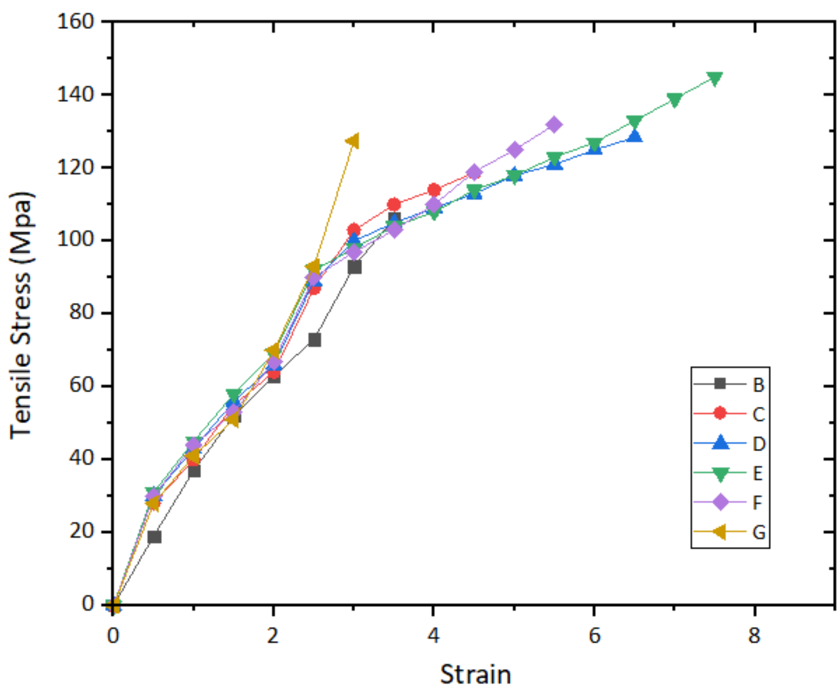

Figure 4. Tensile stress-strain curves for different hybrid nano-scaled composites and AA5022

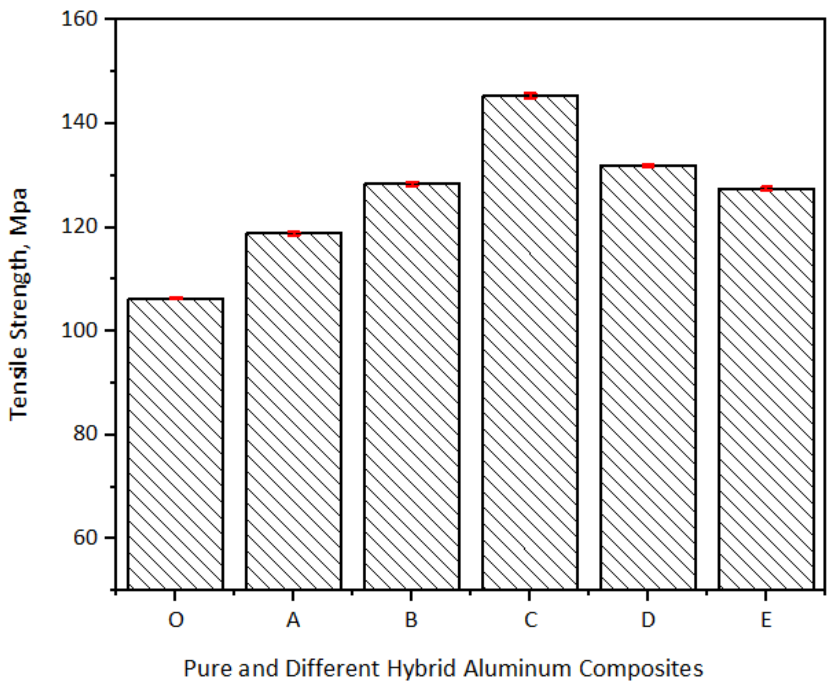

Figure 5. Tensile strength of hybrid composites filled with V&Sn

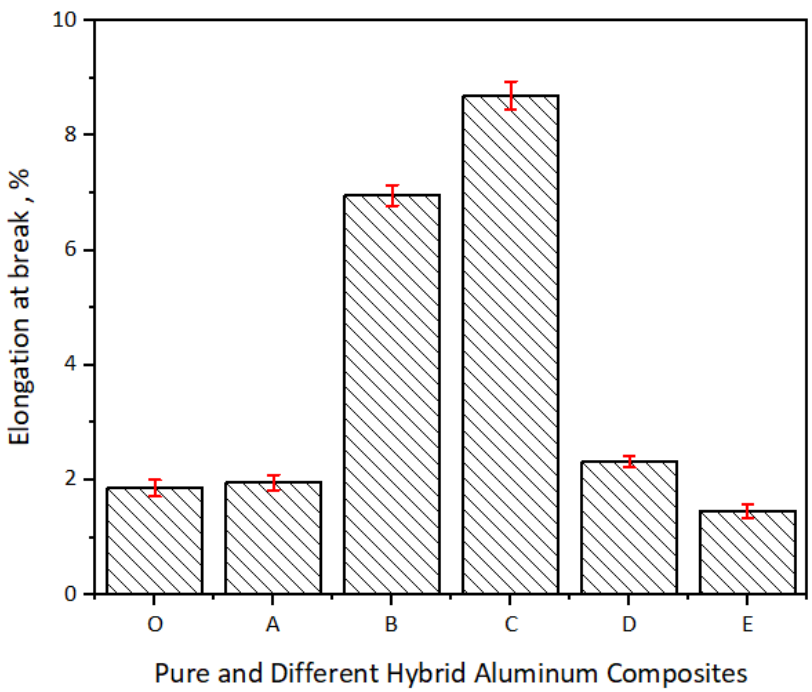

Figure 6. Elongation at break of all hybrid composites filled with V&Sn

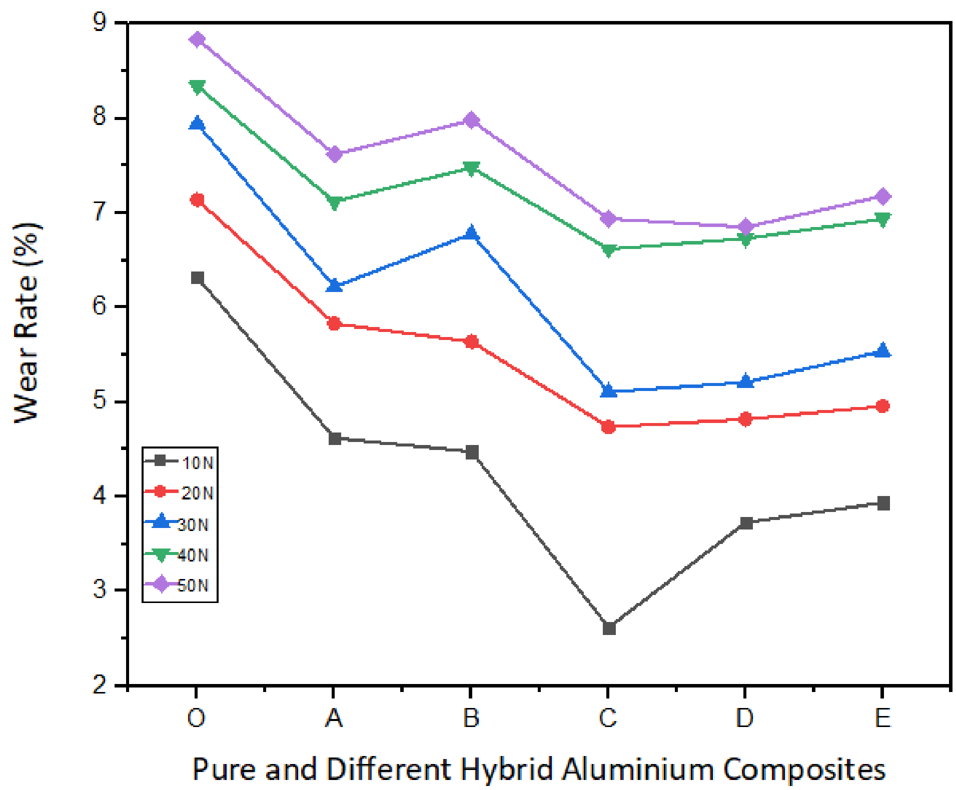

Figure 7. Wear rate of pure and hybrid composites at load variation

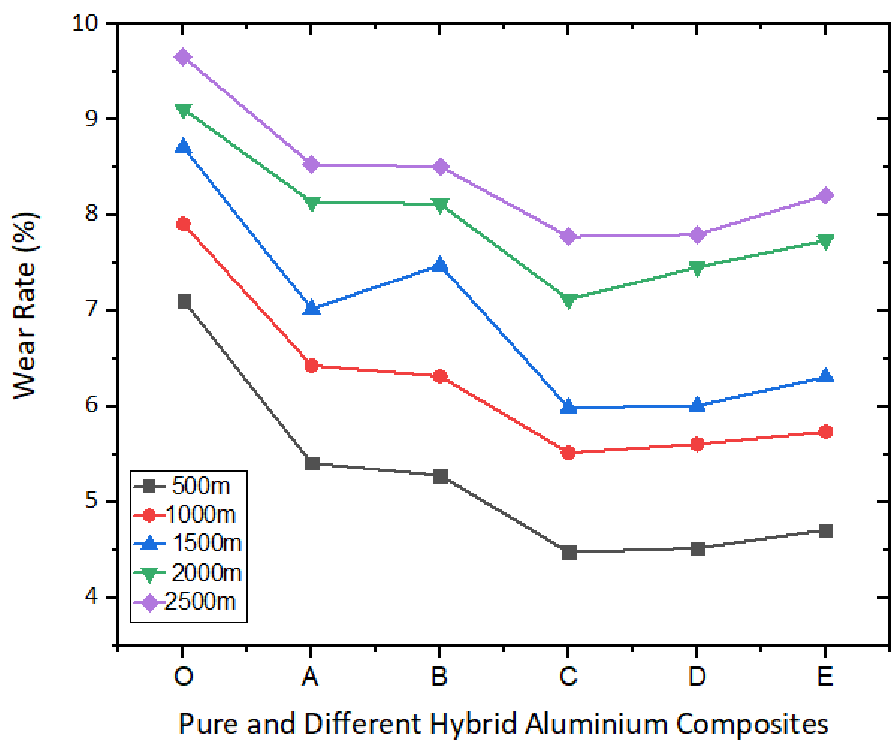

Figure 8. Wear rate of pure and hybrid composites at sliding distance variati

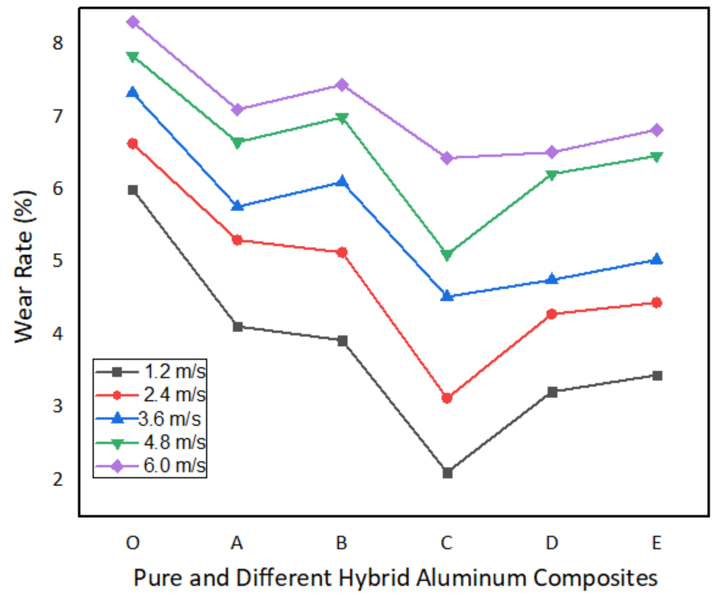

Figure 9. Wear rate of pure and hybrid composites at sliding velocity variation

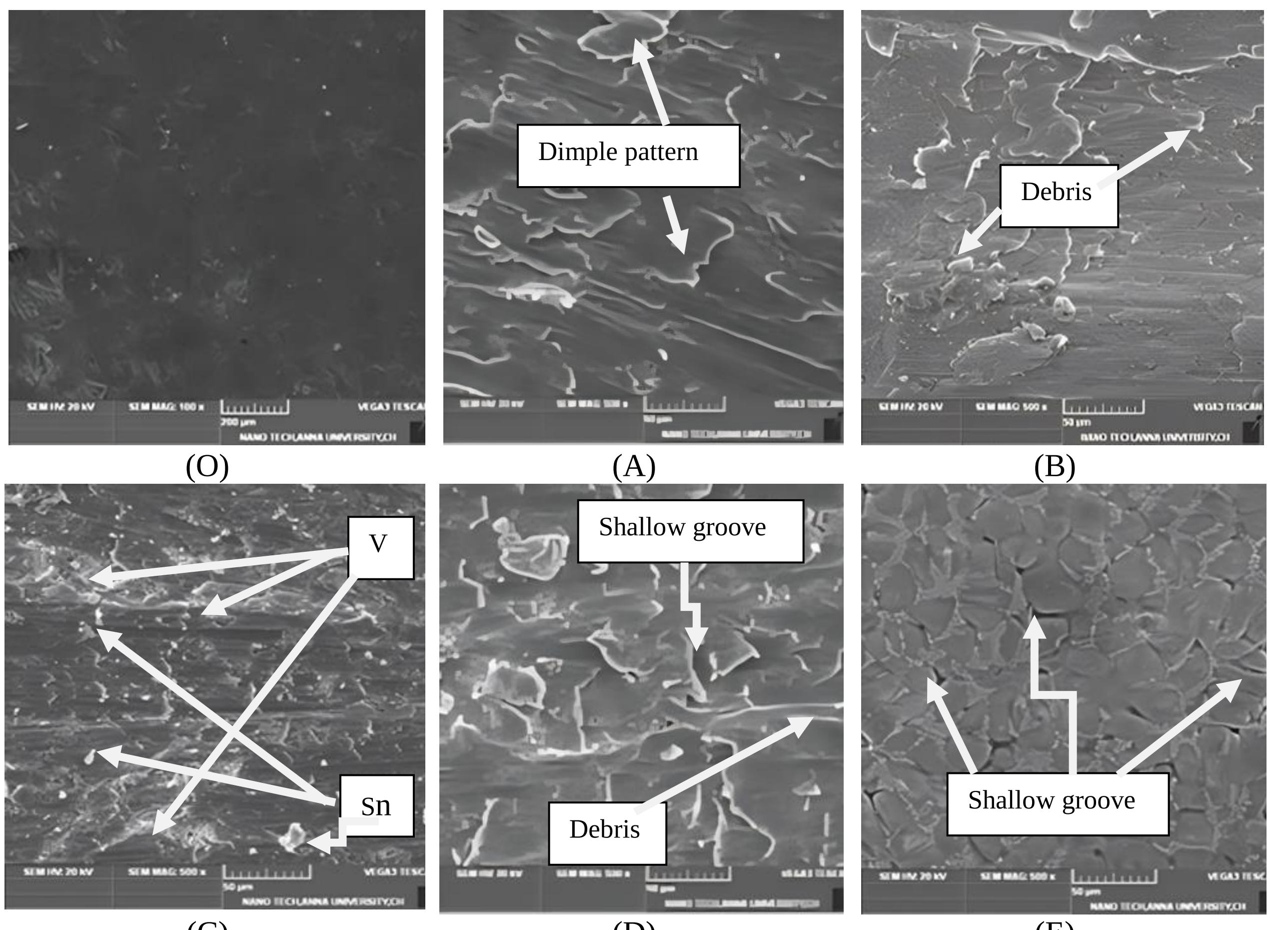

Figure 10. The SEM images of the worn surfaces of all hybrid composites containing nano-scaled V &Sn particles

BIOGRAPHY

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