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Mechanical, Microstructure and wear behavior of the material AA6061 reinforced SiC with different leaf ashes using advanced stir casting method

L. Natrayan, V. Sivaprakash, M.S.Santhosh

Abstract— ***In current scenario aluminium and their alloys exchanged by composite materials in the field of automobile because of fewer corrosiveness and less weight. The present work represent as AA6061 used as matrix material, SiC and various leaf ashes (bamboo leaf, neem leaf and tamarind ashes) used as reinforcement. Advance bottom pouring stir casting machine has used to develop the composites. Vickers hardness testing method used to calculate the hardness of composite samples. Finally, the mechanical and tribological properties of the composites were evaluated, and their relation to the corresponding microstructure and wear worn surface of the composites was discussed.***

Keywords: Al6061, microstructure, SiC, stir casting, bamboo leaf ash, neem leaf ash, tamarind leaf ash, density, hardness, wear, worn surface.

I. INTRODUCTION

In recent years Aluminum metal addition of matrix composites (AMMCs) is having accessed comprehended attention. This importance's are due to their colossal light payload behaviour, low thermal expansion coefficient (CTE) limit, cost viability, and upgraded mechanical characteristics, like yield stress 0.2 % (YS), Ultimate tensile stress (UTS), and a shore hardness of the aluminum alloy material. Owing to these advanced properties, aluminum alloys are inevitable in aviation (e.g., lightweight high strength airframes) for its low weight and strength ratio, automobile (e.g., engine pistons) for its corrosion resistance behavior, and auto electronic (e.g., IC mountings) corporations lifelong working tendency [1].

Vortex Stir casting technique is commonly used for producing good alloy mixtures and also accepted for commercially as a basic mixing mechanism and economical appliance for production of AMMCs. Its dominance of AMMCs is combinable lies in its candor of fabrication, flexibility of usages and replacements, and applicability to huge volume and production. This stir casting and machining method look the most affordable and simple among similar available routes of AMMCs production, and it suits for bulk-sized components fabrication in simple, easy applicable approach. However, low weight and good strength AMMCs are beloved the mentioned consecutive attention for grasping AMMCs through stir casting, there is zero or very less conflicting chemical reaction any kind of molecular standpoint reaction between the dispersed material and also in the continues material or alloy, while machining and also casting kind of work only very low porosity are possible.

Content in the AMMCs cast, a low-density material that can easily melt reason of molecular distance are high and also it can be easily quenched while strength wise it is also acceptable material too, wettability reaction between phases, and equal dispersion of composition over the base material. Wettability and reactivity base properties are determined with bonding quality of molecular constituents and through maximum reaction and effect of final properties of the proposed configuration [2].

The following are few generally known inorganic material for selection for the AMMCs. Fly ash, silica, and graphite are a few examples of industrial/inorganic materials that have been used as reinforcement in AMCs [1-3]. Rice husk ash, bagasse ash, and coconut shell material ash are trending usages of few agro waste products which have also been tested as potential and easiest common reinforcing materials [4].

Though pieces of literature observed AMMCs in view of the probability of agro and industrial waste ashes are still skimpy (compared with synthetic dispersed phases), the accessible outcome represents that Aluminium metal based synthesized augmented with fabricated ceramics compounds like SiC and Al2O3 have first-rate properties in correlation with agricultural ash augmented category [5]. Here the influence of billet and tooling temperatures are moderately narrow. The issue of development in die convex angle on tensile strength is infinitesimal but for decreasing the banishment payload its beneficiation amount is high.

In point of mandrel length, it involved nearly eighty percent, for maximizing the tensile strength and very meager less than 1 % for minimizing the extrusion load, the optimal control factor level settings for lowest extrusion load and highest tensile strength of hot [6]. In Metal matrix composites (MMCs) - such as silicon carbide (SiC) used basically as an abrasive naturally particle reinforced shorter latency Al, the properties such as mechanical ability like-wise high strength, stiffness, wear, hardness and corrosion resistance are highly improved because of the composites agents Sic and Al are the most used and known composites.

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***** Correspondence Author (s)
L. Natrayan, SMBS, VIT- Chennai. Tamilnadu, India.(E-mail: natrayanphd@gmail.com)
V. Sivaprakash, SMBS, VIT- Chennai. Tamilnadu, India.
M.S. Santhosh, Selvam composite materials research laboratory, Namakkal, Tamilnadu, India.

SiC one of the hard covalent core material with bonding agent particle reinforced Al it's a one among light metal and energy consumption material and available one due to their (low cost) economical production [2,7]. Al-based composite matrix's material is commonly used in aerospace for its lightweight and highly strengthening bond agents like SiC, automobiles as easy shape made composites industry such as electronic heat sinks commercially use of semiconducting material by presence of SiC compound that used high thermal absorption and low thermal dissipations because of, automotive drive shafts, or explosion engine components these applications depend on the covering material that over cover material does not below the thermal expansion.

II. MATERIAL PREPARATION

2.1. Materials Selection

In this project AA 6061 used as a matrix material and reinforcement are SiC with dried leaves such as bamboo leaf ash (BLA), neem leaf ash (NLA), tamarind leaf ash (TLA) carried from surrounding place.

2.2 Matrix materials

For fabrication of AA6061–SiC – leaf ash composites, AA6061,With the chemical composition core material Mg, Si, Mn, Cu, Fe, Ti, Al presented in the Table 1, was used as the matrix, dried leaves powder average particle size 40-50 µm and SiC average particle size 50 µm were consider in this experiment.

Table 1. Chemical Composition properties of AA 6061

Elements	Mg	Si	Mn	Cu	Fe	Ti	V	Al
Wt %	1.02	0.65	0.55	0.36	0.12	0.03	0.02	Balance

2.3. Preparation of leaf ashes

Dry leaves non aqua condition level was collected from the natural farm lands nearby the trees in the Campus having a huge quantity of Neem, tamarind, bamboo. The non-aqueous tree leaves are kept in an metal bowl and light it and after every 2 mints place the remaining leaves and take a strip and adjust them, so that there won't be any kind of accidents for the operator catching fire [8]. This operation is toted out until the remaining leaves are completely burn without any balance of the leafs. Now wait for 90 minutes so that all of the ashes will be cooled at a stage of operator can easily handle the leaf ashes. The ash sometimes so be hot, that hot may disturb or damage the plastic be condensed when they come into contact. This cooling time helps to cove the extra molecular particle into bond each other and this helps to the ashes can bond with the Al or SiC. So be careful with the ashes to cool with their own in the room temperature while handling the ash. After ash get cooled condition or temperature be in handling condition then we must stir the ash because at the low level ash the fire will be burning so if we stir it, it will become coo [9].

After completing the ash preparation pack it in a steel or plastic box, steel box may increase and decrease the temperature, plastic does not affect by the temperature until it over ~100oC to avoid any damage and also the temperatures affects. Fig 1 shows different leaf ashes abbreviations of BLA, TLA and NLA is Bamboo leaf ash, Tamarind leaf ash and Neem leaf with 40-50 µm particle .

Fig 1: various leaf ashes after conditioning

2.4 Fabrications of Composites

Advance stir casting operation was employed for the production of the aluminium metal matrix composites, Fig 2 shows stir casting setup, the analytical hierarchy process was used to decide the amount of prepared various types of leaf ashes (BLA,TLA. NLA) and SiC.

Sample 1 has consider as pure AA6061, sample 2 has taken 1.5 wt% of SiC with balance wt% of AA6061, Sample 3, 4, 5 exposed Al matrix consisting of 0.75 leaf treated compound ash and 0.75 silicon carbide respectively, composition listed in table 2. The bamboo leaf conditioning ash and silicon carbide (as the bonding agent) particles were preheated separately SiC need more temperature for fully bonding to the superior agent say Ai at the temperature of 2700C for remove the unwanted moisture and it helps the improved wet ability with the molten Al-SiC alloy [10].

Table 2: Variations of samples in composition.

Specimen	Al 6061	SiC	Leaf Ashes	Total
	g	g	g	g
Sample 1	1000	0	0	1000
Sample 2	985	15	0	1000
Sample 3	985	7.5	7.5 (BLA)	1000
Sample 4	985	7.5	7.5 (NLA)	1000
Sample 5	985	7.5	7.5 (TLA)	1000

Al/SiC remind exciting in to the graphite crucible furnace and heated with some initial temperature and increase temperature of 700ºC for ensure the alloy and all the ingredients melts completely it will improve the mechanical and bonding to the material as stronger. The molten alloy Al, Sic, ashes bamboo leaf ashes was then wait for some time allow to cool the furnace up to the condition of semi-solid condition at a temperature about the rage of 620ºC ± 20ºC. Involving the preheated leaf ashes and SiC bonding agent as the particles are along with 0.05 wt% magnesium compound agents were then ready to poured into the melt add at this temperature of 620ºC the magnesium generally used in the car engines material, aircraft, and missile construction because of its lighter than

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Al and the furnace stirring of the slurry slowly upto 20rpm was operated manually for 5 to10 minutes [11].

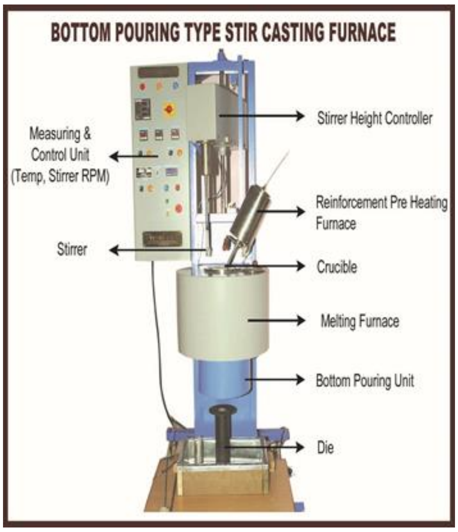

Fig 2: Bottom pour stir casting machine

III. RESULTS AND DISCUSSION

3.1. Measurement discussion on Density

The following table 3 represents all the detailed results of the porosity percent and experimental Density of the composite. The theoretical and experimental values are compared and the values of the matrix composites that little porosities that had less than 2.5% exist in the created composites. The practice of Leaf ashes and SiC as integrated reinforcements in matrix of Al did not ascend in any substantial rise in level of porosity the hybrid composites when compared with the single reinforced Al-2.5wt% SiC composite except in the presence of TLA. Porosity levels more than 4% have been stated to be unacceptable in cast Aluminium matrix composites.

Mixture rule:

$$\rho_{AA/LeafAsh\text{-}SiCp} = (\mathbf{wt}_{AA}\times\rho_{AA}) + (\mathbf{wt}_{LeafAsh}\times\rho_{LeafAsh}) + (\mathbf{wt}_{SiC}\times\rho_{SiC})$$

Where,

$\rho_{AA/LeafAsh\text{-}SiCp}$ = Composite density,

$\mathbf{wt}_{AA}$ = Aluminium alloy weight fraction, ρ_{AA} = Aluminium alloy density ,

$\mathbf{wt}_{LeafAsh}$ = Leaf Ash Weight fraction, $\rho_{LeafAsh}$ = Leaf Ash Density ,

$\mathbf{wt}_{SiC}$ = SiC weight fraction, ρ_{SiC} = SiC Density

% of porosity was calculated by these relations:

$$\%\ \text{porosity} = \left\{ \frac{(\rho T - \rho EX)}{\rho T} \right\} \times 100\%$$

Where, ρ_{EX} =Experimental Density (g/cm^3), ρ_T = Theoretical Density (g/cm^3)

Table 3: Composite density comparison

Material(s)	Weight Ratio of SiC & Leaf Ash	Theoretical Density	Experimental Density	Porosity %
AA 6061	0.00 : 0.00	2.7	2.6491	1.8851
Al 6061 + SiC	0.00 : 1.50	2.7075	2.6478	2.205
Al 6061 + SiC + BLA	0.75 : 0.75	2.6948	2.6195	2.7943
Al 6061 + SiC + NLA	0.75 : 0.75	2.6963	2.6421	2.0102
Al 6061 + SiC + TLA	0.75 : 0.75	2.697	2.661	1.3348

3.2 Measurement discussion on hardness

The Vickers hardness test is mainly to find the plastic deformation. Microscope indentation integrated with the measuring indentation dimensions. As per ASTM standards the minimum level of the distance between the indentations and the distance edge to the indentation of the specimen to be considered. The influence of ash content on composite, hardness is depicted in condition of extruded [12]. It is clearly says that, the material hardness of this composite material is higher than that of the matrix in the as-cast and in the extruded state. Load has applied 50 g and time duration is 15 sec.

Generally, the effect of micro particles less than an micron level the developing or increasing of hardness of the material mainly due to increase the bonding to the superior agents it gives high grain refinement, particle strengthening effects reduce the ingredient's particles size level less than ~2micron like mg, SiC, ashes which act reduce the bonding strength as obstacles to the motion of dislocations. Fig 3 shows that BLA composite get high hardness compare to other fabricated composites.

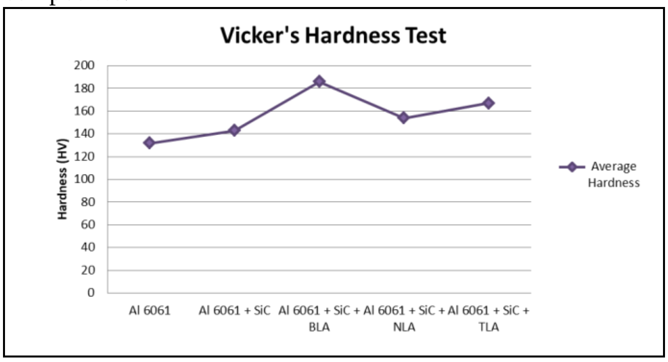

Fig 3: Comparison of Vickers hardness test results

3.3 Resulting discussion on Microstructure

As the microstructure morphological studies plays an important role (because of the bonding agents are must mixed/ fully engaged with the major element – Al) in the overall performance of a material which is made of composites and the physical and chemical properties with compositions these all are depend on the microstructure and bonding to the major element, reinforcement particle size also important to the abrasive bonds, shape as normally and mixing distribution in the alloy. Prepared samples reinforced agents along with the product were examined with the use of microscope machine for microstructure and presence of the ingredients study the distribution pattern of ash in the matrix [13].

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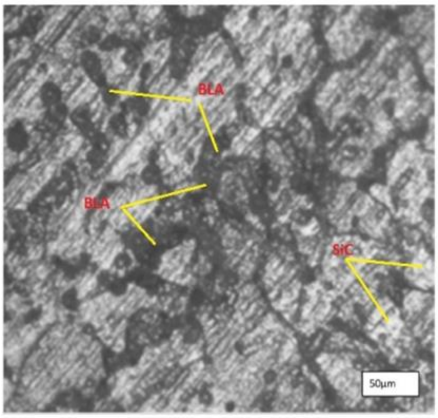

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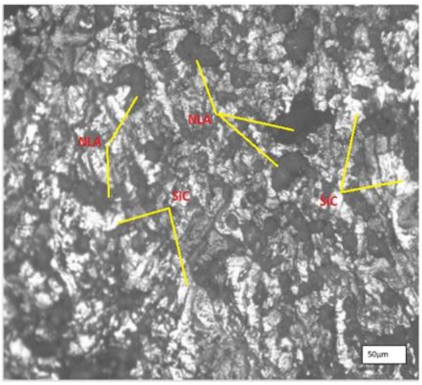

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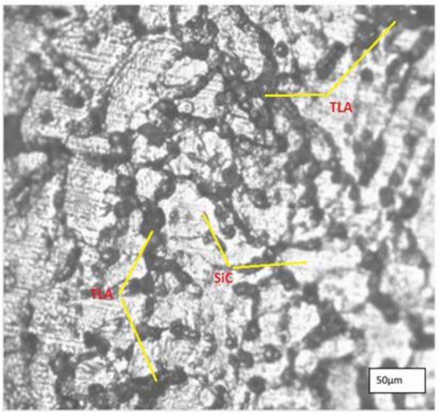

(c)

Fig 4 Microstructure analysis:
(a) Al6061+SiC+BLA, (b) Al6061+SiC+NLA and (c) Al6061+SiC+TLA.

The micrographs shown in fig.4 depict the microstructure of as cast AA 6061+ SiC to fabricated leaf ash. This represents the uniform distribution and without unwanted properties like porous, cracks, invisible particles of ash particles without voids, discontinuities, cracks can be observed from this morphology. The morphology represent as the highly bonding between matrix material Al, mg, Sic and ash particles; however no gap or porous were observed between these particles and matrix composites.

3.4 Resulting discussion on tensile test

Following as per the dimensions of ASTM E8 standard the sample were prepared. All the tests like Ultimate tensile strength, Yield strength and elongation are carried out by using of the high quality computerized universal testing machine. The following table gives an results of Ultimate tensile strength, Yield strength and elongation which gives the result of fabricated samples. Maximum value obtained from the Ultimate tensile strength 154 MPa, the maximum yield strength obtained as 128 MPa results are obtained from the sample 3. The improvements of the strength are obtained because of BLA.

Table 4 Tensile behaviour of aluminium composites

Specimen	UTS (MPa)	Yield strength (MPa)	Elongation (%)
Sample 1	120	98	1
Sample 2	132	102	1.2
Sample 3	154	128	0.9
Sample 4	140	115	1.3
Sample 5	137	120	1.5

3.5 Resulting discussion on Wear

A 50mm diameter of flat and the 5mm thickness of disc were used to study the wear rate of the specimens. 600 basic SiC sand papers were used to polish the sample for the reason of removing the unwanted dust and small particles on the sample surface. Normal load of 2.5kg were apply on the samples to take the wear tests for all the total number of 10 samples.

The entire samples were carried out the tests of wear by pin on disc apparatus (as per ASTM G99-95 standards). The stainless steel metal used as an abrasive medium. Load applied of 2.5Kg with the speed of 500 rpm and the dwell period 2min as a standard were used to take the wear rate. Wear rate was examined with the help of weight loss method. All the samples are carefully examined with the digital weigh balancing machine before and after the experiment carried out.

Examined the weight loss results were finalized for each the specimen. These outcomes are by finding the interaction comparison of samples initial weight losses and final loses of weight. Weight loss method was selected to calculate the wear rate [14]. Table 5 shows that the wear rate results. From the experimental result, BLA wear rate is low compare to TLA and NLA fabricated composites in fig 5.

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Table 5: wear test results

Specimen	Track Radius (mm)	Speed (RPM)	Load (Kg)	Time (Min)	Wear (Micron)
Al 6061	50	500	2.5	2	68
Al 6061 + SiC	50	500	2.5	2	56
Al 6061 + SiC + BLA	50	500	2.5	2	41
Al 6061 + SiC + NLA	50	500	2.5	2	47
Al 6061 + SiC + TLA	50	500	2.5	2	52

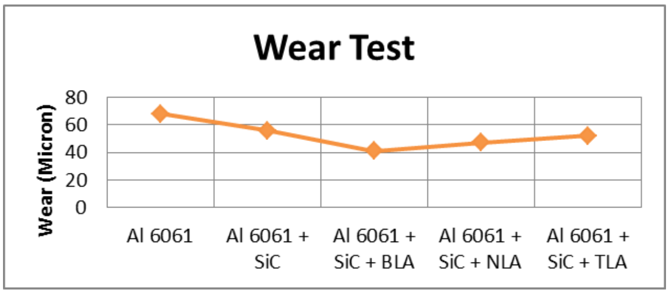
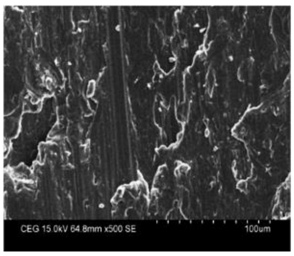


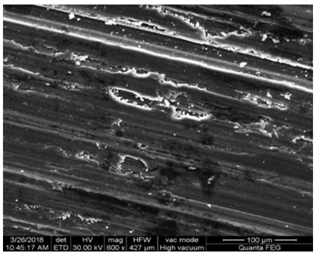
Fig 5: comparison chart for wear test results

3.6 Resulting on wear worn Surface

The surface morphologies of the specimen that clearly visible of the bonding between the AL and ashes were mixed together and also it shows the surface properties also in the following figures. The following figures represent as the small micron level black dots are fly ashes bond with the material. The surface morphology of the samples are shown in the fig. 6 denotes the after finishing the wear test that gives a Fig.6b as the good surface morphological result among all the rest of samples. Surfaces are represents the stability of leaf ashes are highly stable in the leaf ashes/SiC are thermodynamically strong enough in the results. Compare to the Mg, SiC, Al are not stable at the pay condition and this denotes the thermodynamically unstable at this condition. AA6061/SiC/BLA worn surface interface acts as load behavior capacity of AMC, Patching shows very less and abrasive has not acted on the worn surface, Its exposed exhibited mechanical and wear properties.



(a)



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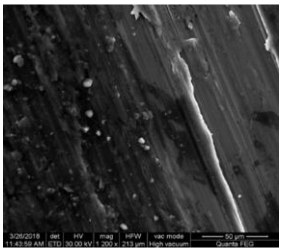

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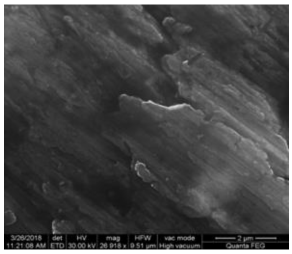

(d)

Fig 6 : SEM morphology of the worn surfaces (a) Al6061+SiC (b) Al6061+SiC+BLA , (c) Al6061+SiC+NLA and (d) Al6061+SiC+TLA

On the surface of the specimen layer it is clearly see the small crack are visible. All the crack are only visible over the 50µm level it represent the small cracks are not a defect in this king of levels. Fig d shows separate groves in the worn surface. Its formed aggressive wear and surface furrow has increased with increasing the applied load. From the results sample 3 such as AA6061/SiC/BLA (fig 6b) shows better wear properties compare to other samples.

IV. CONCLUSION

Mechanical and wear properties of AA6061 matrix metal containing separate leaf ashes and silicon carbide as reinforcement was studied. The results display that:

- In generally presence of ash particles micro or nano level allows to increases the mechanical property hardness of the materials. According to our observation BLA has tends to induce more hardness of the material compared with TLA and NLA.
- Density has decreased with increasing in the leaf ash content; BLA has less density compared to pure AA6061. Its shows maximum porosity 2.7943%.
- AA6061/SiC/BLA shows better ultimate tensile strength and yield strength compared to the other fabricated samples.
- Microstructure shows mixing of the leaf ashes and SiC with matrix. it's clearly reveals of that the composites materials produced by stir casting method shows without voids and discontinuities of SiC/ leaf ashes particulates in the Al6061 metal matrix.
- Pin on disc apparatus has used to find the wear in this investigation, specimen were prepared as per ASTM standard, wear resistance of fabricated samples shown in result table, AA6061 and AA6061/SiC fabricated samples shows low wear resistance, wear resistance increased with Adding the leaf ashes in AA6061/SiC molten metal.
- The wear surface shows different parallel groves throughout the worn surface and presence of micro cracks (analysis in the SEM) on the sliding surface has observed.
- Compare to other leaf ashes, bamboo leaf ash shows exhibited mechanical and wear properties, the preparation of low expenditure of Al6061/SiC/bamboo leaf suggested wear resistance application..

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