Characterization of Al 6061- Coconut Shell Ash metal matrix composites using Stir Casting

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Abstract — *The distinctive characteristics of the composite materials for the particular needs makes these materials additional in style during a kind of applications like automotive bearings, automotive cylinder liners, structural parts, pistons, and aerospace leading to savings of energy and material. In this paper aluminium alloy Al 6061 with Coconut shell ash as reinforcement, at numerous proportions of 1%, 3% and 5% synthesized with Stir Casting method is taken into account. Metal matrix composites made by stir casting method have additional benefits compare with alternative ways. Mechanical properties of mmcs like micro hardness, density, porosity, tensile strength and wear characteristics as completely different variables like load, speed and track diameter are determined.*

Keywords — *Al 6061, Coconut Shell Ash (CSA), Mechanical Properties, Wear characteristics, Stir Casting, MMCs.*

I. INTRODUCTION

A Composite material can be formed by combining two or more dissimilar materials together. The mechanical properties of the composites will be better than the individual components. The composite materials will be composed of two or more phases. They are matrix and reinforcement. [2]

A metal or metal alloy is the matrix material in Metal matrix composite and the reinforcement material can be taken as fibers, whiskers, particles. MMC contains high mechanical properties, good electrical conductivity. A hybrid composite is one which involves more than two constituting materials. [2]. Aluminium Matrix Composites are extensively used due to their desirable properties like low weight, low cost, better thermal conductivity and stiffness. Their applications are diversified in production, thermal, marine and automobile industries. To name a few, ships, aircrafts, cars, electrical wires and household utensils use aluminium because it is the most abundant material on earth. [6]. T.Nithyanandhan, K.Rohith, C.G Sidharath, C.Sachin, Sarayu Jagadesh investigated the mechanical characteristics of Al metal matrix hybrid composite containing different percentage of B_4C & CSA as reinforcement. The mechanical behaviour of Aluminium metal matrix hybrid composite containing different percentage of B_4C & coconut shell ash as reinforcement has been investigated. The decreasing trend of hardness slightly with the comparison of Al6061 and reduction of tensile strength of composite was obtained with the comparison of Aluminium 6061. [5]. D.S.Yawas, P.B Madakson, and A. Apasi, was made an attempt to investigated the properties of CSA using metallurgical analysis. The coconut shell ash has density of 2.05g/cm3. This can be used in production of low weight MMCs component with better thermal conditions. [6].

P. Lakshmi Kanthan, Dr. B. Prabu, focused on synthesis and determination of mechanical and tribological properties of aluminium alloy Al6061-Coconut Shell Ash (CSA). It is observed that 6% CSA reinforced composite has the maximum tensile strength, maximum hardness and minimum wear. The reasons for the initial increase in tensile strength and hardness and initial decrease in wear at lower % of CSA (up to 6%) in composites because of CSA particles presences to the dislocations when load is applied and also the presence of ceramic particles and metal oxides in the reinforcement. [8].

II. MATERIALS AND METHODS

A. Preparation of Reinforcement

The coconut shell ash is prepared by burning the dried coconut shells in the open air atmosphere, so as to avoid the formation of charcoal (which may burn during stir casting process) and to facilitate the complete burning of coconut shells into ash. This ash is sieved in order to get ash particle size of less than 150 μm size.

Table I. Composition of Al 6061

Element	Mg	Si	Fe	Cu	Ti
Weight %	1.08	0.63	0.17	0.32	0.02
Cr	Zn	Mn	Others	Al	
0.014	0.25	0.52	0.05	remaining	

Table II. Composition of CSA

Element	Al_2O_3	Fe_2O_3	CaO	K_2O
Weight %	15.6	12.4	0.57	0.52
MgO	Na_2O	MnO	Si_2O	Al
16.2	0.45	0.22	45.05	0.3

B. Experimental work

*1) **Methodlogy:*** A charge of 1.5 kg of Al6061 alloy was placed in stir casting machine to heat up to 750^{0}C, along with 1.0 wt. % preheated flux, and wt.% reinforcement at 300^{0}C in an oven. Argon gas was allowed to pass during melting of alloy to avoid oxidation. The furnace temperature was raised to 750^{0}C. Preheated flux was added to the melt and allowed for homogenization for 5–6 min by agitating of stirrer in the melt. After cleaning the surface of the melt, preheated (up to 300^{0}C) CSA particles were added into the vortex of the melt during stirring. The composite melt was stirred with stainless steel impeller at 600 rpm for 10 min. Then the melt is allowed into the die of 270mm length and 22mm diameter of 2 fingers while stirrer is rotating. The same process is repeated for pure Al6061 alloy and also for reinforcement Coconut Shell Ash (CSA) 1%, 3% and 5%. The ingots of the composites and unreinforced Al6061 alloy were subjected to a heat treatment for 24 hrs at 110^{0}C in muffle furnace.

Table III. Compositions of Composites

Sample. No	Composition	Al6061 Wt%	CSA Wt%
C1	Al 6061	100	0
C2	Al 6061 + CSA (1%)	99	1
C3	Al 6061 + CSA (3%)	97	3
C4	Al 6061 + CSA (5%)	95	5

III. RESULTS AND DISCUSSION

i. Density

The particle density of CSA determined was 2.05g.cm^{-3} while the density of the Al6061 alloy was 2.67g.cm^{-3}.Since CSA has lower density than Al6061 alloy, its addition to the composite will make the density of the composite to be less than that of the alloy. At the same volume, Al 6061+CSA composite will weigh less than aluminium alloy and its respective composites were given in Table III. It was observed that the addition of CSA into the Al 6061 alloy matrix significantly decreased the density of the resultant composites in compare to the base alloy.

Table III. Comparison of Densities

S. No	Composition	Theoretical Density (g/cc)	Experimental Density(g/cc)
1	C1	2.7	2.69
2	C2	2.68	2.67
3	C3	2.67	2.61
4	C4	2.58	2.59

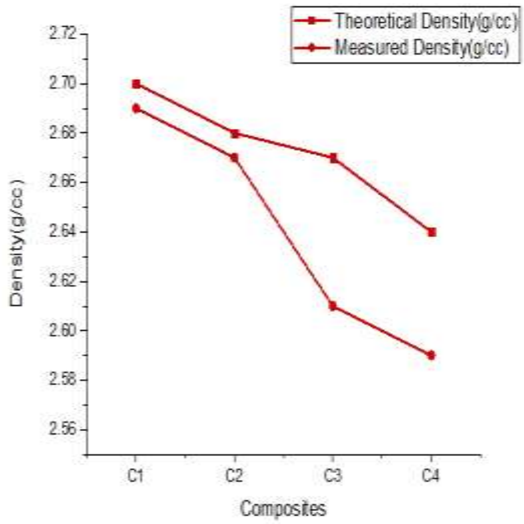

Fig.1 Comparison of Densities(g/cc)

Porosity Measurement

S. No	Sample	Theoretical Density(g/cc)	Measured Density(g/cc)	%Porosity = $\frac{\text{The}-\text{Meas}}{\text{The}} * 100$
1	C1	2.7	2.69	0.37
2	C2	2.68	2.66	0.75
3	C3	2.62	2.60	0.76
4	C4	2.58	2.59	0.38

ii. Micro Vickers Hardness

The micro hardness of composites showed increase in hardness with increase of wt% of reinforcement. The composite C4 exhibited improvement in hardness over that of the alloy.

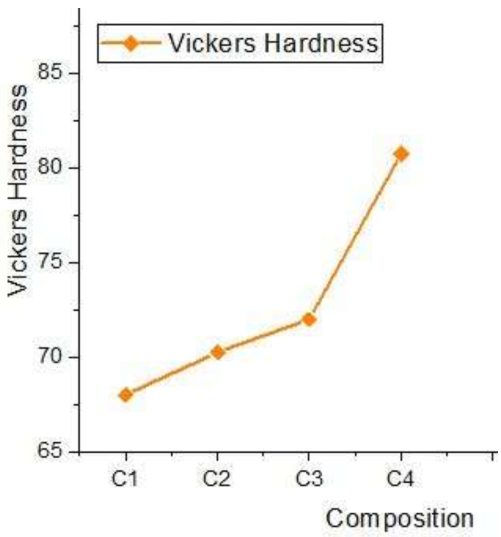

Fig.2 Variation of Vickers Hardness Number

iii. Tensile behaviour of Al 6061 with CSA

Tensile test helped to determine the tensile strengths of different composite it was found that there was a remarkable increase in tensile strength with an increase in addition of reinforcement.

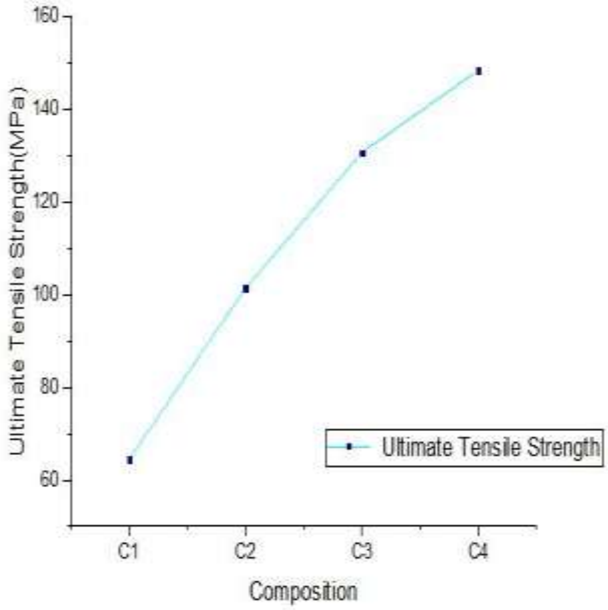

Fig.3 Variation of Ultimate Tensile Stress (Mpa)

Maximum tensile stress obtained was 143.66MPa for Al 6061 + 5% CSA reinforced aluminum composites.

iv. Wear Test

The wear test was conducted and the average wear rates of various composites at different sliding distances and loads are measured and these are plotted on the graph below illustrative.

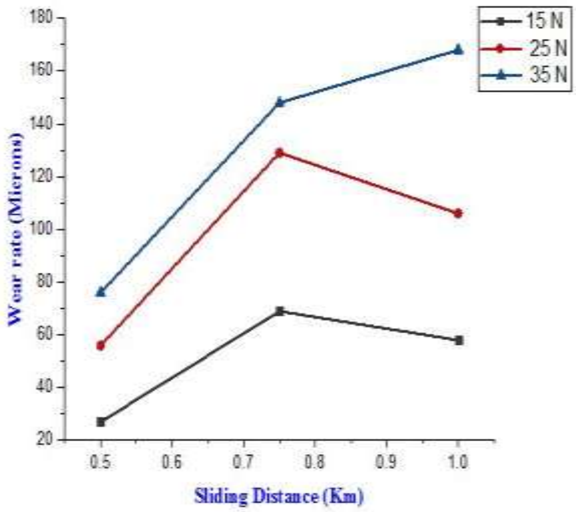

Fig.4 C2- Variation of Wear rate

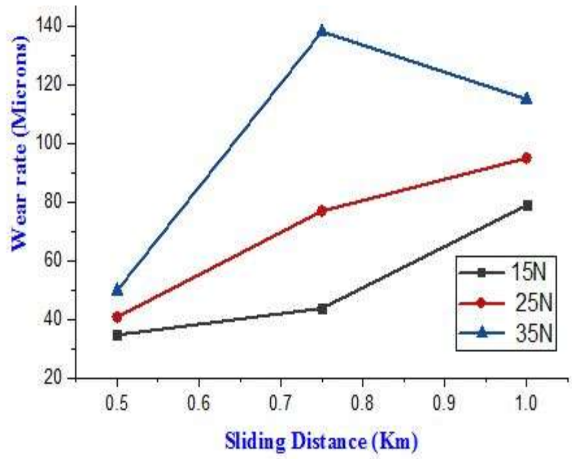

Fig.5 C3- Variation of Wear rate

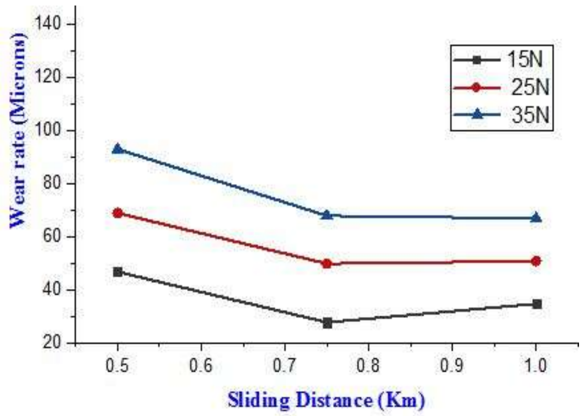

Fig.6 C4- Variation of Wear rate

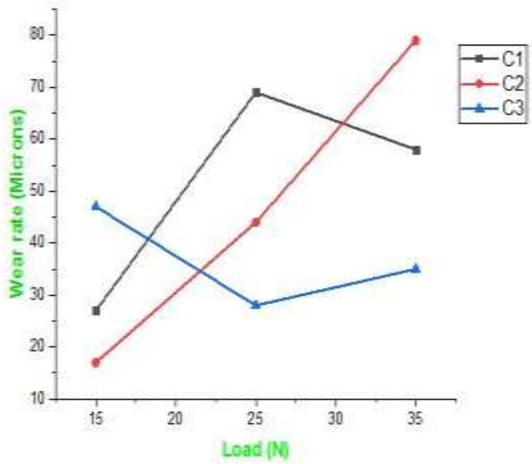

Fig.7 Comparison of Wear rate for various Composites.

Fig.4 show that variations of average wear rate of Al6061+1%CSA with varying sliding distance and load. It is observed that at35N load the average wear rate is 16.8x10^{-3} mm3.m-1. With decreasing in the load the ware rate is also decreased and it is recorded that at 15N load the average wear rate is 5.816x10^{-3} mm3.m^{-1}.

Fig.5 shows the variation of average wear rates with increase in load and travel distance for 3% CSA composites. It is observed that there is a very high average wear rate when the specimen is loaded with 35N and made to slide for a distance of 0.75km and is recorded as 13.8 x10^{-3} mm3.m^{-1}.

Fig.6 shows the variation of average wear rates with increase in load and travel distance for 5% CSA composites. It is observed that there is a very high average wear rate when the specimen is loaded with 35N and made to slide for a distance of 500m and is recorded as 9.3 x10-3 mm3.m^{-1}.
Fig.7 shows the variation of wear rates of composites varying with the % of CSA, it is found that the composites with 5% of CSA has outperformed all the remaining materials providing a low average wear rate.

v. Metallographic and surface morphology

Fig.8 illustrates SEM images of the pure Al6061 alloy. As shown in (Fig.8), the 0 wt. % of coconut shell ash display a fractured area, indicating smooth surface but in the 1 wt. % coconut shell ash composite, there are toughening mechanisms cause of csa particle like deboning and crack deflection. It can be seen these mechanisms in (Fig.9). In addition to this, fracture surface of 3wt. % coconut shell ash composite has large plastic deformation areas. So, it can be easily understand that why adding coconut shell ash to improve the strength and strain of composite materials.

EDS analysis (Fig. 12-16) showed the presence of elements such as Si, C, Al, Ca, Mg, and Fe.

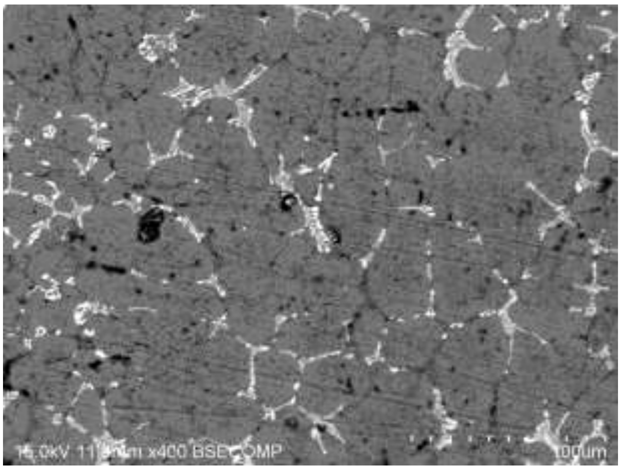

Fig. 8. SEM image of sample 1

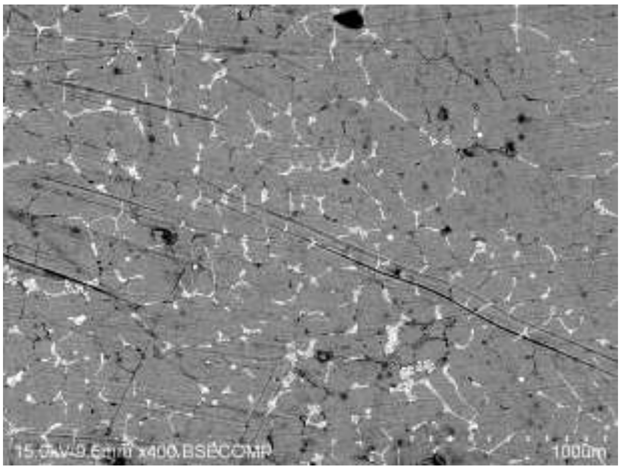

Fig. 9. SEM image of sample 2

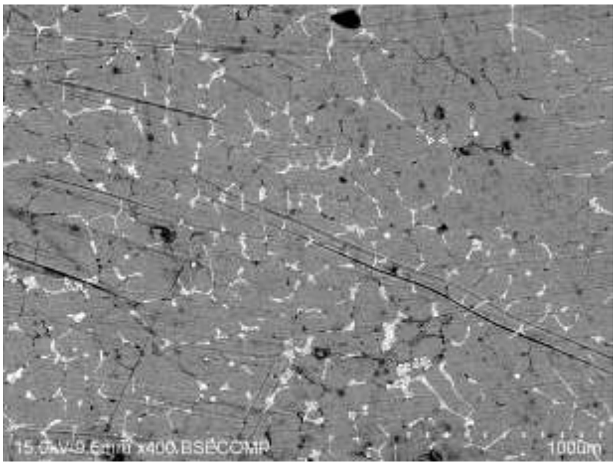

Fig. 10. SEM image of sample 3

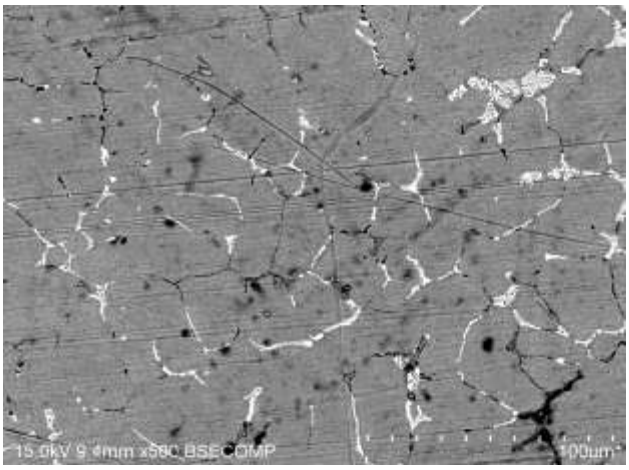

Fig. 11. SEM image of sample 4

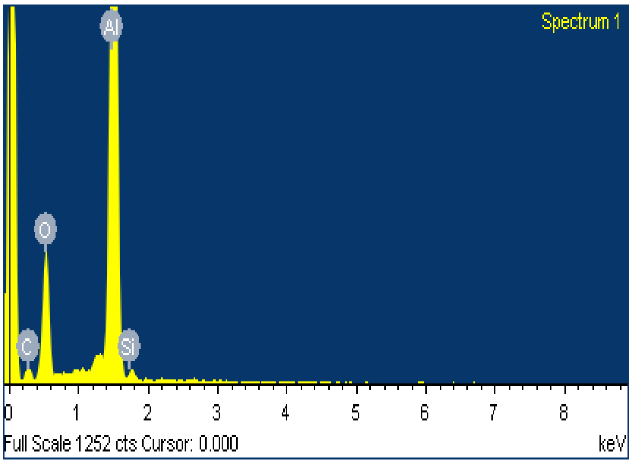

Fig. 12. EDS spectrum of Al6061

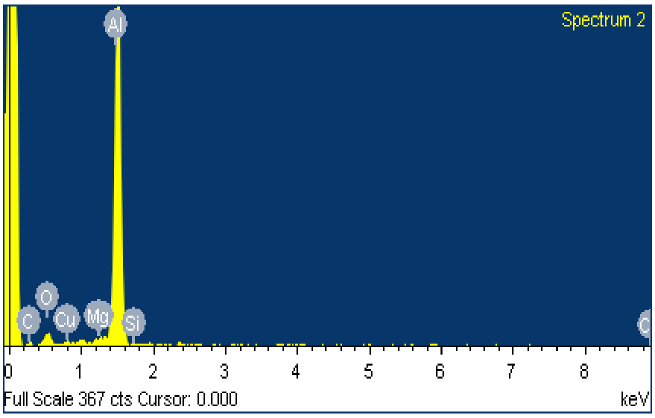

Fig. 13. EDS spectrum of Al 6061 reinforced with 1% CSA

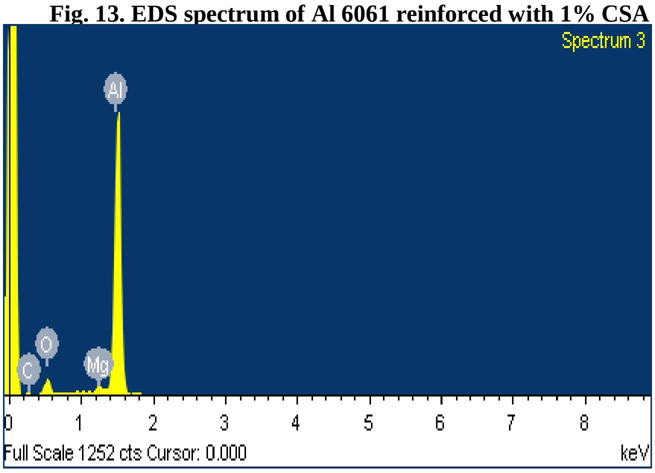

Fig. 14. EDS spectrum of Al 6061 reinforced with 3% CSA

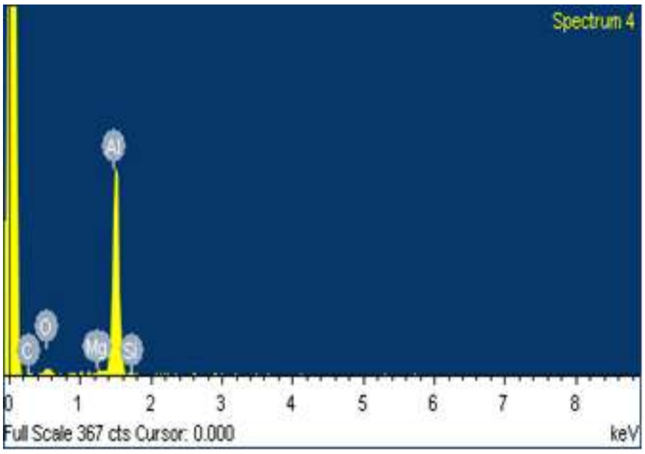

Fig. 15. EDS spectrum of Al 6061 reinforced with 5% CSA

IV. Conclusion

The following conclusions have been drawn:

1. Al 6061-CSA Composites manufactured by the Stir Casting with different compositions(0 to 5 wt. %).
2. The optimum parameters considered are Melt temperature-750ºC, Mold temperature - 350ºC, Stirrer speed - 650 rev/min, the reinforcement discharge rate was 4g/min.
3. The density of the CSA reinforced composites showed the decreasing trend with the increase of reinforcements.
4. The hardness increases with the increase of the reinforcement when compared with alloy.
5. The Ultimate Tensile Strength of the composites increased with gradual increase of wt% of Coconut Shell Ash.

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