Experimental Tensile Strength Characterization Of Metal Matrix Composite Aluminum-6069 Percentage Variation Reinforced With Molybdenum And Coconut Shell Ash

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Abstract: Aluminium based matrix composites remain the most explored metal matrix material for the development of metal matrix composites. The present work deals with the fabrication of aluminium-6069 alloy metal matrix composites (MMCs) reinforced with molybdenum and coconut shell. The specimens were prepared by taking into consideration of six different weight fractions of aluminium 6069, molybdenum powder and coconut shell ash by stir casting method. The first three specimens were prepared in such a manner that aluminium 6069 and coconut shell ash weight fraction varies by 2% and molybdenum powder weight fraction kept constant by 1%. The next three specimens were prepared in the same manner, coconut shell kept constant by 1%, molybdenum powder and aluminium 6069 varies by 2%. The main purpose of the paper is to study the properties of Aluminium-6069 alloy reinforced with molybdenum and coconut shell ash composites fabricated by stir casting technique and Tensile test was performed by using equipment's such as Universal testing machine. Based on the results obtained, the tensile strength was improved by adding coconut shell ash particles and molybdenum to aluminum-6069 alloy.

Index Terms: Metal Matrix Composites, Aluminium-6069, Molybdenum powder, Coconut Shell Ash, Stir Casting, Mechanical Properties.

1. INTRODUCTION

Acomposite is a material that consists of constituents produced via a physical combination of pre-existing ingredient materials to obtain a new material with unique properties when compared to the monolithic material properties. This definition distinguishes a composite from other multiphase materials which are produced by bulk processes where one or more phases result from phase transformation. The term matrix and reinforcement are often used. The composites are classified by (a) matrix phase (b) reinforcement.

(a) MATRIX:

The matrix is a percolating "soft" phase in which are embedded the "hard" reinforcements and is completely continuous. In structural applications, the matrix is usually a lighter metal such as aluminium, magnesium or titanium and provides a support for the reinforcement.

(b) REINFORCEMENT:

The reinforcement is embedded into a matrix and it can be continued or discontinued, oriented or disoriented. It does not always serve a purely a structural task but it also used to change physical properties such as wear resistance, friction coefficient or thermal conductivity. It can be worked with standard metal working techniques, such as extrusion, forging, rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling (PCD). The reinforcements used in this present project are molybdenum and coconut shell ash.

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Various works on the application of natural fillers in composites like coconut shell ash, jute, cotton, rice husk wood as the reinforcements in composites have been reported in the literature. P.Rambabu et al. [1] described the alloying and precipitation hardening behaviour, which is the principal strengthening mechanism for Al alloys. Shireesha Y. et al. [2] studied he mechanical properties of composites reinforced by natural fibers and factors which influences the mechanical properties of natural fibre reinforced composites. S.C. Bergsma et al. [3] developed a new 6069 aluminum alloy for application in hot and cold extrusion and forging and observed a favorable formability, with nominal tensile properties after hot or cold extrusion ranging from 394 to 476 MPa UTS, 353 to 448 MPa yield strength, and14–20% elongation. S.Narayan et al. [4] carried out a systematic tensile and impact testing and hardness measurements on hot forged aluminium metal matrix composites to understand the influence of alloying element and forming process on their mechanical properties. A.Arora et al. [5] were successfully fabricated Metal Matrix Composite (MMC) using an Aluminium plate and Molybdenum powder by Friction Stir Process (FSP) to produce a superficial MMC layer on the Al plate in order to increase the mechanical properties of the as received Al plate. Rajesh A.M. et al. [6] also developed aluminium metal matrix hybrid composite by reinforced Aluminium 7075 alloy with silicon carbide (SiC) and aluminium oxide (alumina) by stir casting method which is less expensive and very effective. B.R. Sunil et al. [7] provided a comprehensive summary of the state-of-the-art in fabricating magnesium-based composites by Friction Stir Processing and also discussed the influence of the secondary phase particles and grain refinement resulted from Friction Stir Processing on the properties of these composites. A.I.O. Zaid et al. [8] investigated the effect of addition of molybdenum either alone or in the presence of titanium to commercially pure aluminium on microstructure and mechanical behaviour after pressing by the ECAP process at room temperature. B.Rebba et al. [9] reported the results of an experimental investigation on the mechanical properties of molybdenum disulphide (MOS_2) powders reinforced in aluminium alloy (Al-2024) composite samples and the same are compared with the base alloy. S.M.Sapuan et al. [10] studied about the tensile and flexural properties of epoxy composites based on coconut shell filler particles. Recently hybrid composites are more popular and covers more than one material property. Aluminium matrix composites (AMCs) are a unique class of composite materials that are used for a wide range of applications. Coconut shell is one of the most important natural fillers produced in tropical countries like India, Thailand, and Sri Lanka. Many works have been devoted to use of other natural fillers in composites in the recent past and coconut shell filler is a potential candidate for the development of new composites because of their high strength and modulus properties. On the basis of these considerations, this study has shown that a new composite is effectively prepared with Al-Mo and coconut shell ash by stir casting method and the analysis of mechanical properties like tensile strength and compression strength was carried out.

2 PROPERTIES OF MATERIALS USED

2.1 Aluminium 6069

Aluminum 6069 is known to be one of the lightest and strongest alloys. It is less expensive and very widely used in today's automobile engineering. This alloy also has favorable fatigue, corrosion fatigue, stress-corrosion and sustained load cracking properties due to a combination of composition, high solidification rate, thermal and mechanical processing shown in Table 1.

TABLE 1
PROPERITIES OF ALUMINIUM 6069

Physical properties	Mechanical properties
High strength and less weight	Tensile strength – 400 Mpa
Easily machined and recycled	Compression strength – 495N/mm^2
Excellent corrosion property	Density - 2.72 g/cm^3
Good thermal and electrical conductivity	Melting point – 660 ^{0}C

2.2 Molybdenum

Molybdenum does not occur naturally as a free metal on earth. It is found only in various oxidation states in materials. In the pure form, Molybdenum is a silvery-gray metal. It is the 42nd most abundant element in the universe. Most high strength steel alloys contain 0.28 to 8% Molybdenum.

Physical properties	Mechanical properties
Highest melting temperature	Tensile strength – 324 Mpa
More resistant to corrosion	Compression strength – 400 N/mm^2
Low thermal expansion	Density – 10.22 g/cm^3
Good thermal and electrical conductivity	Melting point – 2623 ^{0}C

2.3 Coconut shell ash

Coconut shell ash is an agricultural waste and is available in very large quantities throughout the tropical countries of the world like India. This waste utilization would not only be economical but may also result in environmental pollution control. In black smithy coconut shell can be used as fuel material in their casting and forging operations.

***Fig. 1**. Preparation of coconut shell ash.*

Coconut shell ash shown in figure 1 having a density of 1.6 gm/cm^3, it is having some good properties like good tensile strength and hardness.

3 FABRICATION OF ALUMINUM-6069 WITH MOLYBDENUM AND COCONUT SHELL ASH REINFORCED

Several steps in aluminum-6069 fabrication have been discussed below.

3.1 Stir Casting

Casting is the process in which molten metal is poured into a mould and allowed to solidify into an object. The object that results from this process is also called a casting, figure 2. Keep the Aluminium-6069 alloy in the crucible heats up to its melting point 650 °C. Add coconut shell and molybdenum reinforcement material to the alloy based on the composition and stir well for uniform distribution of element in the furnace.

***Fig. 2**. Image of the Stir casting process.*

3.2 Die Preparation

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mould. The mould cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mould during the process. Figure 3 shows the dies for tensile test preparation. Multiple specimens can be prepared at one stage.

Fig. 3. *Dies for tensile testing specimens.*

3.3 Melting and Streaming

Melting is the preparation of the metal for casting, and its conversion from a solid to a liquid state in a furnace. It is then transferred in a ladle to the moulding area of the foundry where it is poured into the moulds. After the metal has solidified, the moulds are vibrated to remove the sand from the casting, a process called shakeout as shown in figure 4.

Fig. 4. *Melting and streaming process for tensile test.*

The aluminium metal matrix composite was prepared by stir casting route. For this we took 4000gm of commercially Aluminium alloy. Commercially pure Aluminium-6069 alloy was melted in a resistance furnace. The melt temperature was raised up to 700 ^{0}C. The stirring was maintained between 5 to 7 min at an impeller speed of 200 rpm. The melt temperature was maintained 700 ^{0}C during addition of reinforcement materials. The melt with reinforced particulates were poured into the sand moulds prepared earlier. The pouring temperature was maintained at their levels. The melt was then allowed to solidify in the mould.

3.4 Cleaning

Cleaning generally refers to the removal of all materials that are not part of the finished casting. Rough cleaning is the removal of the gating systems from the casting. Initial finishing removes any residual mould or core sand that remains on the piece after it is free of the mould. Trimming removes any superfluous metal. In the last stages of finishing, the surface of the casting is cleaned for improved appearance. In addition, at this point, the casting is inspected for defects and adherence to quality standards. This inspection may include non-destructive testing to determine whether the part will adequately perform for its intended use. After that work pieces were grinded and finished with emery paper to obtain required shape, dimensions and finish.

3.5 MACHINING

Machining is the broad term used to describe removal of material from a workpiece, it covers several processes, which we usually divide into the following categories: Cutting, generally involving single-point or multipoint cutting tools, each with a clearly defined geometry. Abrasive processes, such as grinding. The term metal cutting is used when the material is metallic. Specimens were prepared for tensile testing on a lathe machine is shown in the figure 5. Machining of these specimens on the machine should be done with good accuracy.

Fig. 5. *Dies for tensile testing specimens.*

4 EXPERIMENTAL METHODOLOGY

The primary objective of the present work is to form reinforcing particles within the Aluminium melt by addition of Molybdenum and Coconut shell ash into the base metal in the liquid state. In the first part of the work attempt is made to prepare the composites and to characterize them by identifying the various compounds that has been formed with in the matrix. In the second part, the physical and mechanical properties of the composites are reported.

4.1 Experiment on Tensile test

These test methods cover the tension testing of metallic materials in any form at room temperature, specifically, and the methods of determination of yield strength, yield point elongation, tensile strength, elongation, and reduction of area. The main product of a tensile test is a load versus elongation curve which is then converted into a stress versus strain curve. Tensile test was conducted on six samples which is shown in figure 6 (a) before and (b) after the test. These samples are prepared by varying composition of molybdenum(Mo) and coconut shell ash (CSA). The data generated during tensile testing is used to determine mechanical properties of materials and provides the Tensile Strength, also known as Ultimate Tensile Strength (UTS) and Yield Strength.

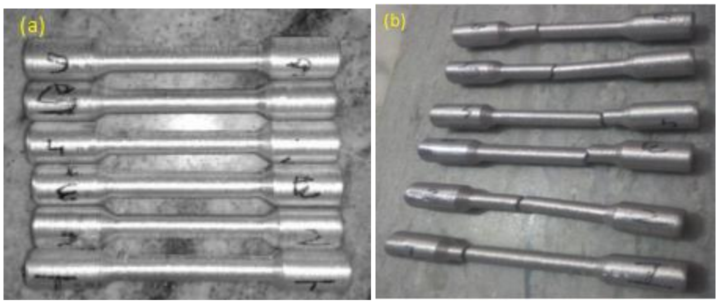


Fig. 6*. Image of the specimens (a) before tensile test (b) after tensile test*

5 RESULTS AND DISCUSSIONS

5.1 Tensile test results

The following tabular and graphical results will show the effect of coconut shell ash on tensile strength of aluminum composite.

TABLE 2

SHOWS THE INPUT DATA FOR TENSILE TEST OF THE DIFFERENT COMPOSITIONS OF AL, MO AND CSA

INPUT DATA	
Specimen shape	Solid round
Specimen type	Aluminium
Specimen diameter	13 mm
Initial guage length for % elongation	62.5 mm
Specimen cross section area	132.73 mm^2
Final specimen diameter	11 mm
Final guage length	70 mm
Final area	95.03 mm^2

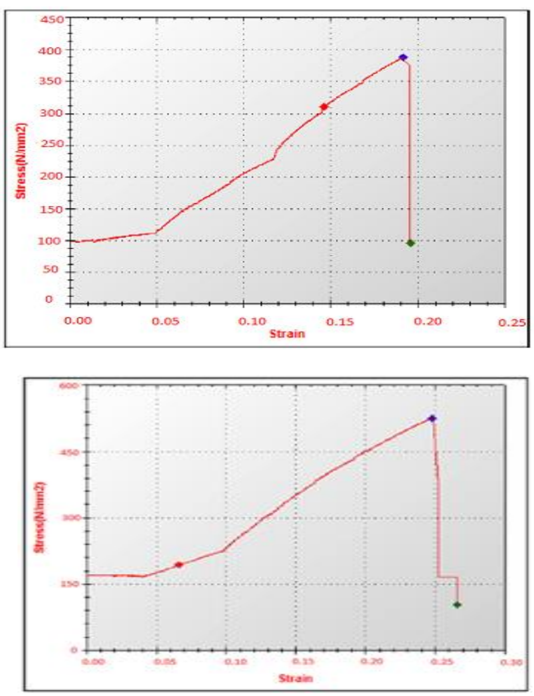
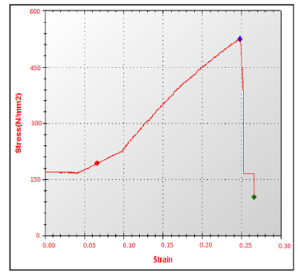
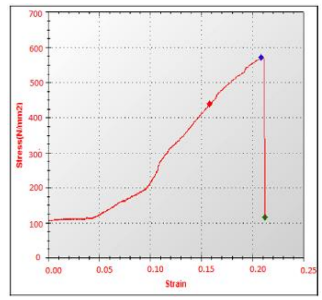


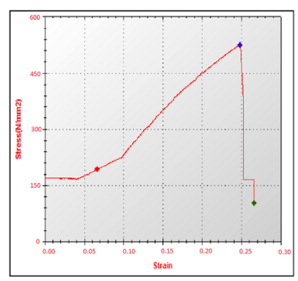
Fig. 7*. Graph of Stress Vs Strain at composition (97%Al, 1%Mo, 2%CSA)*



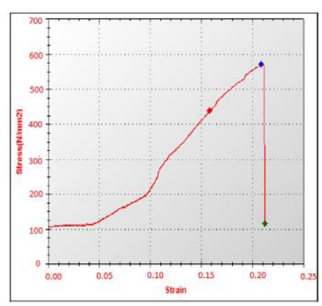
Graph 2 Stress Vs Strain at composition (95%Al, 1%Mo, 4%CSA)



Graph 3 Stress Vs Strain at composition (93%Al, 1%Mo, 6%CSA)



Graph 2 Stress Vs Strain at composition (95%Al, 1%Mo, 4%CSA)



Graph 3 Stress Vs Strain at composition (93%Al, 1%Mo, 6%CSA)

Fig. 8*. Graph of Stress Vs Strain at composition (95%Al, 1%Mo, 4%CSA)*

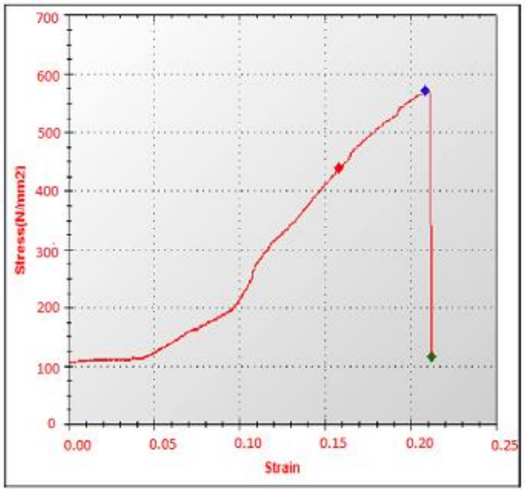


***Fig. 9**. Graph of Stress Vs Strain at composition (93%Al, 1%Mo, 6%CSA)*

TABLE 3

AT 1% MO. THE TENSILE RESULT OF THE DIFFERENT COMPOSITIONS OF AL. VS CSA.

OBSERVATIONS	Composition		
	97%Al, 1%Mo, 2%CSA	95%Al, 1%Mo, 4%CSA	93%Al, 1%Mo, 6%CSA
Yield stress (N/mm^2)	123.632	107.133	63.737
Load at peak (kN)	120.550	17.790	23.190
Elongation at peak (mm)	12.020	13.150	15.550
Tensile strength (N/mm^2)	394.823	554.713	578.029
Load at break (kN)	5.010	5.700	4.530
Elongation at break (mm)	12.250	13.280	16.640
Breaking strength (N/mm^2)	37.745	42.944	34.129
% reduction area	28.40%	28.40%	28.40%
% elongation	16.80%	12%	12%

The graphs shown in Figure 8, Figure 9, Figure 10 and Tables 2 and 3 show that, as Coconut shell ash increases, tensile strength also increases gradually while 1% of Molybdenum kept constant. At composition 93% Al, 1% Mo, 6% CSA tensile strength value was increased when compared to other specimens. Higher tensile strength 578.209 N/mm^2 was observed at composition 93% Al, 1% Mo, 6% CSA composition. The following tabular and photographs will also try to show the effect of molybdenum on the tensile strength of aluminum composites.

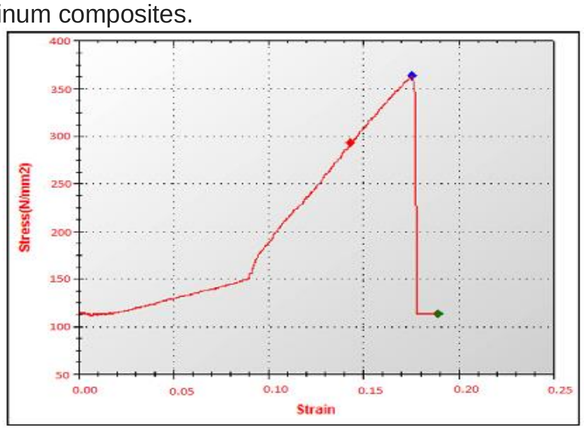


***Fig. 10.** Graph of Stress Vs Strain at composition (97%Al, 2%Mo, 1%CSA)*

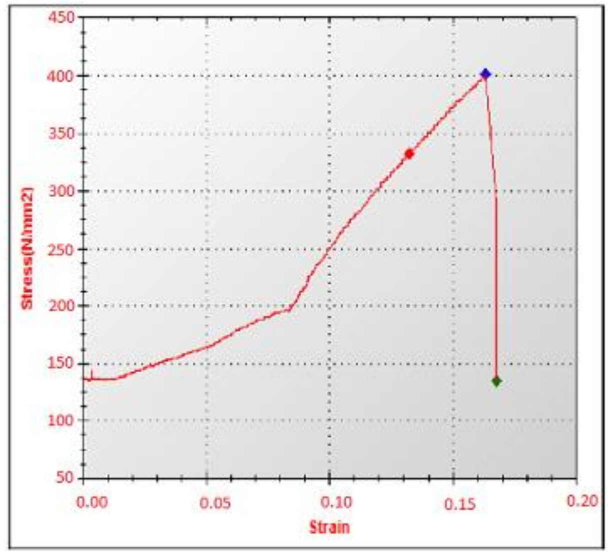


***Fig. 11**. Graph of Stress Vs Strain at composition (97%Al, 4%Mo, 1%CSA)*

The graphs shown in Figure 11, Figure 12, Figure 13 and Tables 2 and 4 show that, as Coconut shell ash increases, tensile strength also increases gradually while 1% of Coconut shell ash kept constant. At composition 93% Al, 6% Mo, 1% CSA the tensile strength quality was improved relative to other samples. Higher tensile strength 550.639 N/mm^2 was observed at composition 93% Al, 6% Mo, 1% CSA composition.

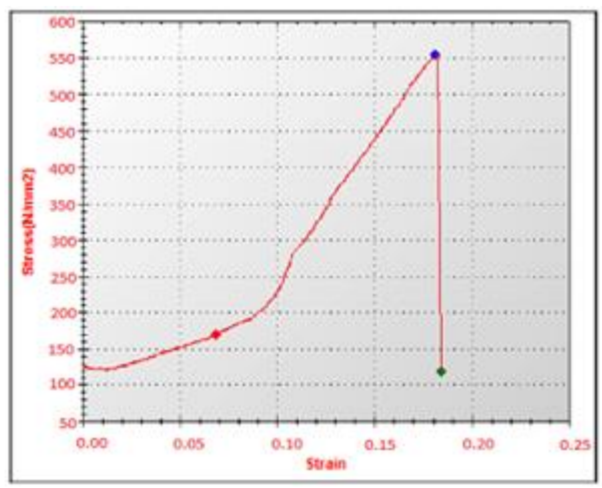


***Fig. 12**. Graph of Stress Vs Strain at composition (97%Al, 6%Mo, 1%CSA)*

TABLE 4

AT 1% CSA. THE TENSILE RESULT OF THE DIFFERENT COMPOSITIONS OF AL. VS MO.

OBSERVATIONS	Composition		
	97%Al, 2%Mo, 1%CSA	95%Al, 4%Mo, 1%CSA	93%Al, 6%Mo, 1%CSA
Yield stress (N/mm^2)	53.793	111.879	111.879
Load at peak (kN)	17.340	18.600	19.290
Elongation at peak (mm)	11.430	10.480	11.030
Tensile strength (N/mm^2)	375.330	400.132	550.639
Load at break (N)	5.820	4.470	5.970
Elongation at break (mm)	11.510	10.480	11.830

Breaking strength (N/mm^2)		33.677	44.978
% reduction area	28.40%	28.40%	28.40%
% elongation	8.80%	12%	8.80%

The table 5 shows that the introduction of Molybdenum and Coconut shell ash particles into the Aluminum matrix induces a reasonable and fair increase in tensile strength at composition. 93% Al,1% Mo,6% CSA. The strengthening of the composite can be due to dispersion strengthening as well as due to particle reinforcement.

***TABLE 5** SUMMARY OF TENSILE TEST RESULTS.*

Composition	Tensile Strength (N/mm^2)
97%Al+1%Mo+2%CSA	394.823
95%Al+1%Mo+4%CSA	554.713
93%Al+1%Mo+6%CSA	578.029
97%Al+2%Mo+1%CSA	375.330
95%Al+4%Mo+1%CSA	400.132
93%Al+6%Mo+1%CSA	550.639

Figure 14 illustrates the variability in tensile strenth for the different compositions of aluminium, molybdenum and coconut shell ash graphically..

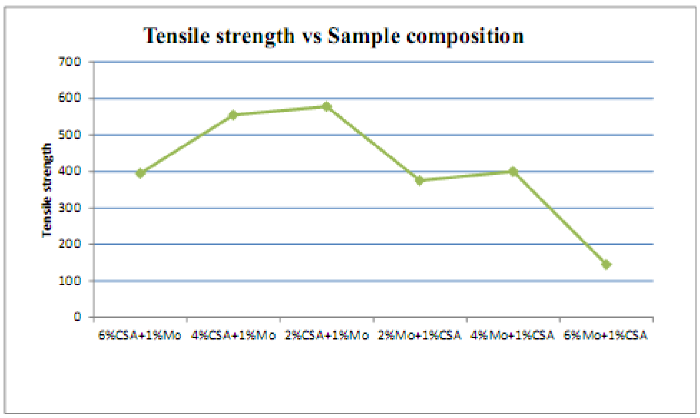


***Fig. 14**. Graph between sample composition and tensile strength.*

6 CONCLUSIONS

Aluminum-6069 derived MMCs reinforced with molybdenum powder and coconut shell ash particles have been successfully prepared using the stir-casting process for the study of tensile strength. The tensile strength of the specimen increased by increasing Coconut shell ash and Molybdenum percentage to the aluminium alloy. High tensile strength is obtained at composition 93% Al, 6% CSA, 1% Mo. The results show that the composite metal matrix with a composition of 93 per cent Al, 1 per cent Mo, 6 per cent CSA is best suited in the automotive industry as the use of aluminum is higher.

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