Observational Exposition of Metal Matrix Composite Aluminum 6069 (Al) Fraction Variance Strengthened with Molybdenum (Mo) and Coconut Shell Ash (CSA)

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1 Introduction

A composite is a material made up of components generated by physically combining pre-existing elements in order to create a new material with unique qualities that differ from those of a monolithic material. This description distinguishes a composite from other multi-phase materials formed by bulk processes where one or more phases are the products of phase transformation. The word matrix and reinforcement are also used. Composites are classified by (a) phase matrix (b) reinforcement.

Various studies have been published on the use of natural fillers in composites such as coconut shell ash, jute, cotton, and rice husk wood as composite reinforcements. Sasidhar et al. [1] experimented with new aluminum 6069 alloy metal matrix composites (MMCs) fortified amid molybdenum and coconut shells for use in automobiles and found that the strength of the tensile was improved by adding molybdenum and coconut ash grains to the aluminum 6069 alloys. Shireesha Y. et. al., studied the mechanical properties of natural fibre reinforced composites and the factors that affect the mechanical properties of natural fiber composites [2, 3]. A new 6069 aluminum alloy for hot and cold extrusion and forging and observed desirable formability, and carried out systematic tensile and impact tests and measurements of hardness on hot forged aluminum metal matrix composites in order to understand the effect of the alloy material and the shaping process on its mechanical properties [4, 5]. Metal matrix composite (MMC) was successfully manufactured using the

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aluminum plate and molybdenum powder amid friction Stir process (FSP) to create a surface MMC layer on the Al plate in order to increase the mechanical properties of the Al plate being obtained. Also produced aluminum metal matrix hybrid composite reinforced aluminum 7075 alloy beside silicon carbide (SiC) and aluminum oxide (aluminum) by mixing a casting process is less costly and very effective [6, 7]. Sunil et al. [8] provided a detailed overview of the state of the art in the manufacture of magnesium-based composites by friction stir processing and also discussed the effect of the secondary phase particles and grain refining produced by friction stir processing on the properties of these composites. Zaid et al. [9] examined the impact, by pressing the ECAP process at room temperature, of the addition of molybdenum either solo or in the presence of titanium in commercially pure aluminum. Rebba et al. [10] have reported results of an experimental analysis of the mechanical properties in composite samples of aluminum alloy (Al-2024) reinforced with molybdenum disulfide (MOS_2) powders compared to base alloys. Sapuan et al. [11] investigated the tensile and flexural strengths attributed to epoxy composites based on coconut shell filler particles. Many studies have abided toward the use of other innate fillers in composites in the former, and the coconut shell filler is a possible contender for the production of contemporary composites due to their immense strength and modulus properties. On the basis of these considerations, this research has shown that a new composite is effectively prepared with Al-Mo and coconut shell ash by a stir-casting process, and an analysis of mechanical properties just as hardness and compression strength has been carried out.

2 Properties of Materials Used

2.1 Aluminum 6069

Aluminum 6069 is considered to be one of the lightest and strongest alloys in the world. It is cheaper and commonly used in automotive engineering today. The alloy has favorable fatigue, stress-corrosion; moreover, Table 1 shows long-term load-cracking properties by cause of a mixture of structure, high strength, thermal and mechanical treating.

Table 1 Properties of aluminum 6069

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

Table 2 Properties of 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 °C

2.2 Molybdenum

Molybdenum can only be found in different oxidation states in materials. Molybdenum is a silver-gray metal in its pure form. It is the 42nd largest element in the universe. Most high-resistance steel alloys comprise molybdenum from 0.28 to 8%. The following Table 2 contains a list of all molybdenum attributes.

2.3 Coconut Shell Ash

Coconut shell ash is agricultural waste and is commonly available in tropical countries around the world, such as 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. In this work, coconut shell ash having a density of 1.6 g/cm^3 is used, and 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 mechanism by that molten metal is transferred to a mold and can solidify into an object. The resulting entity is also called a casting, see Fig. 1.

Keep the aluminum 6069 alloy in the crucible and heat 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. 1 Image of the stir casting process

3.2 Melting and Streaming

Melting is the preparedness and transition from a solid to a liquid state of the metal into a furnace. In a ladle, it is then forced into the mold region of the foundry and then poured into the molds shown in Fig. 2.

The molds are vibrated after the metal is solidified, which is called a shakeout process where sand is removed from the casting. By stir casting method, the aluminum metal matrix composite has been prepared. We used 4000 gm of commercially available aluminum alloy for this. In the resistance furnace, the commercially pure aluminum 6069 alloy was melted. It increased the temperature of the melt to 700 °C. At an impeller speed of 200 rpm, the stirring was sustained about 5 and 7 min. During the addition of reinforcement materials, the melt temperature was held at 700 °C. The melt was poured into the sand molds prepared earlier with reinforced particulates.

4 Methodology

The main intent of the present work is toward strengthening the aluminum fusion particles by adding molybdenum and coconut shell ash to the liquid base metal. In the first part of the work, an attempt is made to prepare the composites and to classify

Fig. 2 Melting and streaming process for compression test

Fig. 3 Shows **a** specimens before compression test, **b** specimens after compression test

them by identifying the different compounds that have been produced in the matrix. The physical and mechanical properties of the composites are stated in the Sect. 2.

4.1 Experiment on Compression Test

The compression test shall assess the characteristics of the materials under crushing loads. The most widely used compression test is one of all mechanical tests. As per ASTM E-9, the ends of the specimen are fixed to the grips attached to the straining device and to the load measuring device in this test. If the applied load is small enough the compression of any solid body is completely reduced and the solid can return to its original state as soon as the load is removed. However, if the load is too high, the material may be permanently compressed. Specimens before and after compression test were shown in the Fig. 3a and b.

4.2 Experiment on Hardness Test

This test method involves determining the hardness of Brinell metallic materials using the Brinell indentation hardness theory. The Brinell method applies a predetermined test charge to a fixed diameter carbide ball that is retained and removed for a predetermined period of time. The resulting impression is generally measured in at least two diameters at the right angles, and the results are summed. The indent size (see Fig. 4) is optically determined by the calculation of two diagonals of the circular indent with a compact, or integrated, microscope.

Fig. 4 Ball indentations of Brinell hardness test on Al composite specimen

5 Results and Discussions

5.1 Compression Test Results

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

The graphs shown in Fig. 5 and Tables 3 and 4 show that as coconut shell ash increases, compression strength also increases gradually while 1% of molybdenum kept constant. Higher compression strength of 994.274 N/mm^2 was observed at composition 95% Al, 1% Mo, 4% CSA composition compared to other compositions.

The following tabular and photographs will also try to show the effect of molybdenum on the compression strength of aluminum composites.

The graphs shown in Fig. 6 and Tables 3 and 5 show that as molybdenum content increases, compression strength also increases gradually while 1% of coconut shell

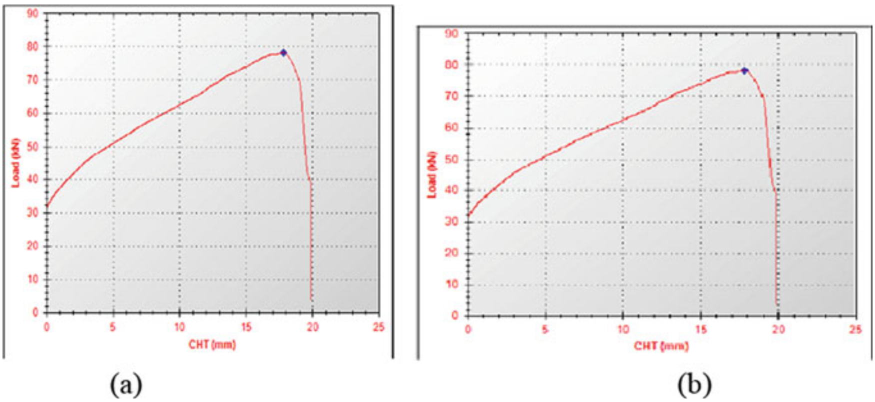

Fig. 5 Graph of load versus elongation **a** at composition (97% Al, 1% Mo, 2% CSA) and **b** at composition (95% Al, 1% Mo, 4% CSA)

Table 3 Input data for Compression test of the different compositions of Al, Mo, and CSA

Input data	
Specimen shape	Solid round
Specimen type	Aluminum
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

Table 4 Shows at 1% Mo the compression strength of different compositions of Al versus CSA

Observations	Composition	
	97% Al, 1% Mo, 2% CSA	95% Al, 1% Mo, 4% CSA
Load at peak (kN)	69.420	78.090
Compression strength (N/mm^2)	883.884	994.274

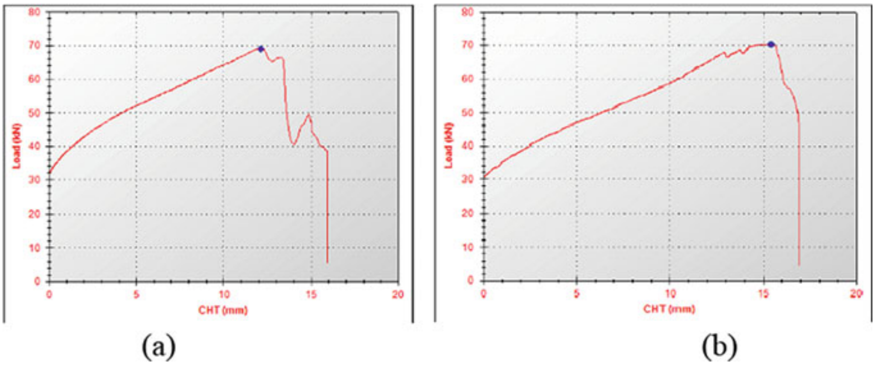

Fig. 6 Graph of load versus elongation, **a** at composition (95% Al, 4% Mo, 1% CSA) and **b** at composition (93% Al, 6% Mo, 1% CSA)

Table 5 Shows at 1% CSA the compression strength of different compositions of Al versus Mo

Observations	Composition		
	97% Al, 2% Mo, 1% CSA	95% Al, 4% Mo, 1% CSA	93% Al, 6% Mo, 1% CSA
Load at peak (kN)	56.910	68.940	70.230
Compression strength (N/mm^2)	724.601	877.772	894.197

Table 6 Shows hardness test results for different compositions and loads

Composite samples	Hardness (BHNs) at 400 kgf Load	Hardness (BHNs) at 600 kgf Load	Hardness (BHNs) at 800 Kgf Load
97% Al + 1% Mo + 2% CSA	23.80	28.51	30.89
95% Al + 1% Mo + 4% CSA	30.5	35.3	38.01
95% Al + 4% Mo + 1% CSA	30.5	28.51	30.89
93% Al + 6% Mo + 1% CSA	27.53	28.51	30.89

ash kept constant. Higher compression strength of 894.197 N/mm^2 was observed at composition 93% Al, 6% Mo, 1% CSA composition compared to other compositions.

5.2 *Hardness Test Results*

The Brinell hardness test machine was used to calculate the hardness. The load applied on Brinell hardness test were 400, 600, and 800 kgf at dwell time 15 s for each sample.

The result of Brinell hardness test for alloy without reinforcement (aluminum 6069) and the wt% variation of reinforcements such as molybdenum and coconut shell ash of various compositions are given in Table 6.

6 Conclusions

MMCs strengthened by molybdenum powder and coconut shell ash particles derived from aluminum 6069 were successfully prepared using the method of stir casting to examine compression strength. The hardness of various composition of aluminum composites specimen were tested and observed that the hardness increases with coconut shell ash content increased. Also, the compression strength of the specimen increased by increasing coconut shell ash and molybdenum percentage to the aluminum alloy. High compression strength is obtained at composition 95% Al, 4% CSA, 1% Mo. The results show that the composite metal matrix with a composition of 95% Al, 1% Mo, 4% CSA is best suited in the automotive industry as the use of aluminum is higher.

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