

## INVESTIGATIONS OF MECHANICAL PROPERTIES OF HYBRID ALUMINIUM METAL MATRIX COMPOSITES

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### ABSTRACT

Aluminum MMCs are preferred to other conventional materials in the fields of aerospace, automotive and marine applications owing to their improved properties like high strength, low density, good hardness etc. In the present work an attempt has been made to synthesize metal matrix composite using Al356 as matrix material reinforced with ceramic Al<sub>2</sub>O<sub>3</sub> particulates using stir casting technique. The mechanical properties of hybrid aluminium metal matrix composites were investigated. Mica and Alumina ceramic particles were reinforced into Al356 alloy by stir-casting route. Microstructures of the samples were considered using Scanning Electron Microscope (SEM). The investigation indicate that the better density and hardness are achieved with Al/Al<sub>2</sub>O<sub>3</sub>-mica composites.

**Key words:** hybrid metal matrix composites; Al 356 alloy; Alumina; mica; stir casting

### 1. Introduction

The increased demand of lightweight materials with high specific strength in the aerospace and automotive industries has led to the improvement and use of Al alloy-based composites (mainly Al alloy/Al<sub>2</sub>O<sub>3</sub> composites). The metal matrix composites (MMCs) are slowly replacing the general light metal alloys such as aluminium alloy in different industrial applications where

hardness, low density and energy savings are the most important norms. The combination of various properties like chemical, mechanical, and even electrical can be achieved by the use of different types of reinforcements, i.e., continuous, discontinuous, short, whiskers, etc., with the MMCs [1]. The MMCs are smart materials for use in structural applications because they combine favourable mechanical

properties, good wear resistance, and low thermal expansion [2]. Particle-reinforced metal matrix composites (PMMCs) are very promising varied materials for structural applications due to their isotropic material properties, low cost, and ability to be formed using conventional metal forming processes such as rolling, forging, extrusion and forging to produce the finished products. But, the indentation characteristics of varied material systems in various forms of composites, precipitation-hardened alloys, and dispersion-strengthened alloys are not known well. Their macroscopic depression responses are affected by the mechanical properties of the matrix material and reinforcement as well as the type, shape, dimension, geometric arrangement, and volume fraction of the reinforcement [3]. Particulate-reinforced metal matrix composites have smooth a new path to produce high strength and high wear-resistant materials by introducing hard ceramic particles and solid lubricant in the metal matrix [4]. Addition of ceramic reinforcements such as SiC, Al<sub>2</sub>O<sub>3</sub>, TiC, B<sub>4</sub>C, and ZrO<sub>2</sub> to metal matrix develops hardness and thermal shock resistance [5].

Hybrid metal matrix composites (HMMCs) are second-generation composites wherever more than one type, shape, and sizes of reinforcements are used to achieve better properties [6]. Hybrid composites have better properties compared with single reinforced composites as they combine the advantages of their fundamental reinforcements [7]. PRASAD and ASTHANA [8] described that reinforcement of aluminium alloys with graphite solid lubricants and hard ceramic particles were used in automotive applications. DEONATH and ROHATGI [9] exposed that cast aluminium–mica particulate composites and copper-coated ground mica particles have sufficient strength and they are used as bearings in several applications.

JHA et al [10] reported that the adding of talc particles in the composite increases the wear resistance in the range of 22%–30% compared with the matrix alloy. RAJMOHAN and PALANIKUMAR [11,12] found that hybrid aluminium/ceramic–mica composites indicated better machinability in terms of reduced thrust force, tool wear and burr height compared with aluminium/ceramic

composites. 10% (volume fraction) SiCp/Al–Mg composites with different Mg contents were effectively fabricated by semi-solid mechanical stirring technique under optimum processing conditions. The effects of Mg content on microstructure and mechanical properties were studied by scanning electron microscopy (SEM) [13]. Vencl A et al.,(2010) [14] reported a number of materials such as SiC, Al<sub>2</sub>O<sub>3</sub>, B<sub>4</sub>C, TiB<sub>2</sub>, ZrO<sub>2</sub>, SiO<sub>2</sub> and graphite are being used as reinforcements to increase the properties of 6061Al alloy. But, the applications of Al<sub>2</sub>O<sub>3</sub> or SiC particle reinforced aluminum alloy matrix composites in the automotive and aircraft industries is gradually increasing for cylinder heads, pistons, connecting rods etc.

Bharath V et al.,(2014) [15], The hardness of the prepared composites increases with increasing wt% of Al<sub>2</sub>O<sub>3</sub> particulates and Strength of prepared composites both tensile and yield was higher in case of composites, while ductility of composites was less when compared to as cast 6061Al. Further, with increasing wt% of Al<sub>2</sub>O<sub>3</sub>, the tensile strength an increasing trend. S.A. Sajjadi et al., (2011) [16] found that another problem is distribution of reinforcement particles in molten matrix.

Due to density difference between matrix and reinforcement, these particles tend to float or settle in the molten matrix as a result agglomeration and clustering of the particles will occur It has been reported that injection of particles with inert carrier gas is helpful in improving the distribution. WANG Yi-qi, SONG Jung-il [17] is essential to develop a method for producing Al-MMC's taking account of incorporation and distribution reinforcing particles in the molten matrix. The squeeze cast Al/SiC composite materials find massive applications in industry. Al<sub>2</sub>O<sub>3</sub> fiber (Al<sub>2</sub>O<sub>3</sub>f) and SiC particle (SiCp) hybrid metal matrix composites (MMCs) are made-up by squeeze casting method. The similarity of reinforcement and tensile properties increase with reducing the stirring temperature and increasing the stirring time [18].

The review of literature left the scope for the researcher to study the mechanical properties of ceramic–mica reinforced hybrid composites. Also, suitable investigations have not been carried out to find the mechanical properties of hybrid Al/Al<sub>2</sub>O<sub>3</sub>–mica composites. In this study, Al<sub>2</sub>O<sub>3</sub> reinforcement is added to the

Al356/mica composite to form stronger hybrid Al/Al<sub>2</sub>O<sub>3</sub>-mica composites. The mechanical properties of Al356/Al<sub>2</sub>O<sub>3</sub>-mica composites are studied and presented in detail.

## 2. Experimental Details

The alumina particles with grain size of 125µm and mica with average grain size of 45µm were used as the reinforcement materials. The composites were fabricated with the mica particles of 2%, 4% and 6% in mass fraction and a fixed quantity of 10% of Al<sub>2</sub>O<sub>3</sub>. The composites were fabricated by stir casting method to ensure even distribution of the reinforcements. The Al 356 alloy, which was in the form of ingot,

was cut into small pieces to accommodate in the silica crucible. Initially Aluminum alloy was melted in an electric furnace in 750°C. Mica and Al<sub>2</sub>O<sub>3</sub>, preheated to a temperature of about 600 °C, were added to the molten metal at 900°C and stirred continuously.

The stirring was carried out at 600 r/min for 4–6 min. Magnesium was added in a small quantity through the stirring to rise the wetting. The melt with reinforcement was transferred into a permanent metallic mould.

Cu	Si	Mg	Mn	Fe	Ti	Zn	Al
<0.0005	7.27	0.45	<0.002	0.12	0.08	0.005	Bal.

**Table1 Composition of Al 356 alloy (mass fraction, %)**

**Table2 Composition of Mica (mass fraction, %)**

SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	Fe <sub>2</sub> O <sub>3</sub>	Na <sub>2</sub> O	TiO <sub>2</sub>	CaO	MgO
45.57	33.10	9.87	2.48	0.62	Traces	0.21	0.38

**Table 3 Mechanical properties of Al 356 alloy**

Density/ (g·cm <sup>-3</sup> )	Ultimate tensile strength/MPa	Yield tensile strength/MPa	Elongation/%	Modulus of elasticity/ GPa	Poisson ratio
2.67	234	165	3.5	72.4	0.33

### 3. RESULTS AND DISCUSSION

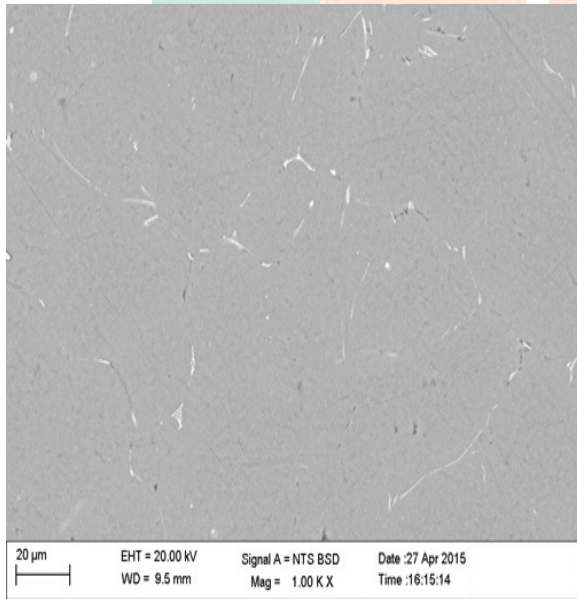
#### 3.1 Microstructure

The SEM micrographs of Al/Al<sub>2</sub>O<sub>3</sub>-mica composites. The distribution of the Al<sub>2</sub>O<sub>3</sub> and mica particles in the aluminum matrix is noticeably uniform. Further, these figures reveal the homogeneity of the cast composites. Homogeneous distribution of

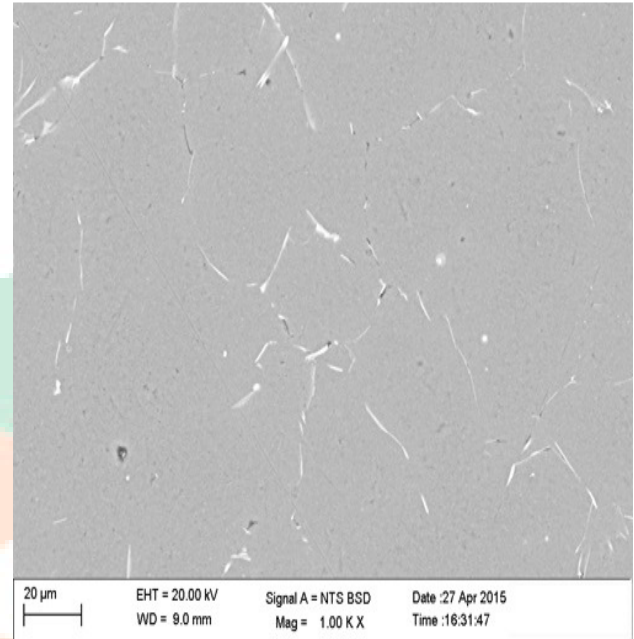
the reinforcement in the matrix is essential to form a composite with uniform mechanical properties. The produced cast composites show some degree of porosity and sites of mica particles clustering. There is no large agglomeration of particles. Porosity may be due to improper casting or particles pulled out during grinding and polishing.



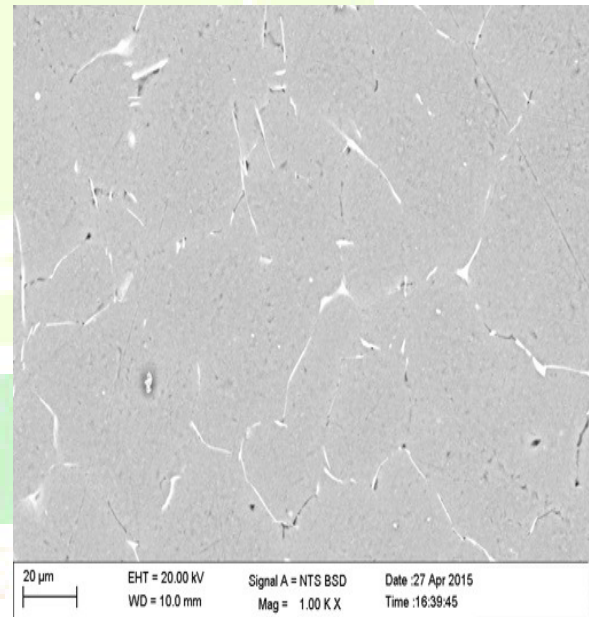
Therefore, these SEM structures are evidence of successful incorporation of hybrid Al/Al<sub>2</sub>O<sub>3</sub>-mica composites. The clusters of Al<sub>2</sub>O<sub>3</sub> particles in the primary Al seem to be finer. As a result, the temperature of the particles is higher than that of the liquid alloy. The hotter particles may heat up the liquid in their immediate surroundings, and thus delay solidification of the surrounding liquid alloy. The Al<sub>2</sub>O<sub>3</sub> particles generally observed are accumulated in the interdendritic regions and geometrical trapping by dendrites is rarely observed.



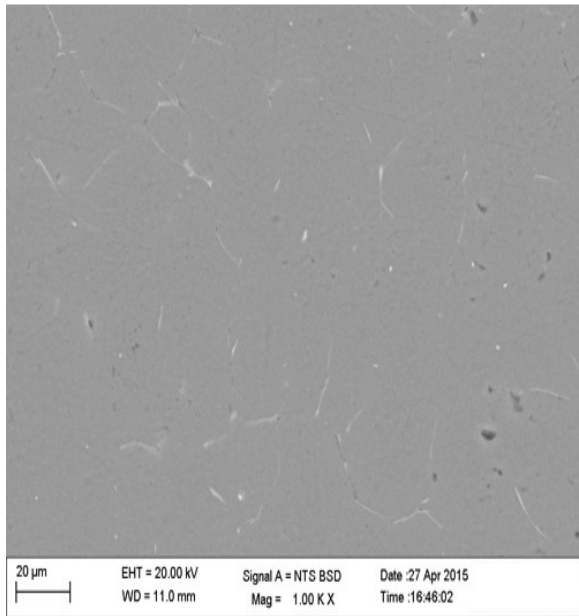
**Fig.1 Sample 1: Al 356 alloy + Al<sub>2</sub>O<sub>3</sub>**



**Fig.2 Sample 2: Al 356 alloy + Al<sub>2</sub>O<sub>3</sub> + Mica(2%)**



**Fig.3 Sample 3: Al 356 alloy + Al<sub>2</sub>O<sub>3</sub> + Mica (4%)**



**Fig.4 Sample 4: Al 356 alloy + Al<sub>2</sub>O<sub>3</sub> + Mica (6%)**

### 3.2 Hardness

The results of hardness of the composites reinforced with different mass fractions of mica particles are shown in Table 4. The hardness value of Al/Al<sub>2</sub>O<sub>3</sub> composite is higher compared with Al/Al<sub>2</sub>O<sub>3</sub>-mica composite. High values of hardness are favourable for reducing machinability, include for very ductile materials, which may reduce a built-up edge, burr, and poor finish. Higher value of hardness is clear indication of the fact that the presences of particulates in the matrix have improved the overall hardness of the composites. This istrue due to the fact that

aluminium is a soft material and the reinforced particle especially ceramics material being hard, contributes positively to the hardness of the composites. The presence of stiffer and harder Al<sub>2</sub>O<sub>3</sub> and mica reinforcement leads to the increase in constraint to plastic deformation of the matrix during the hardness test. Thus increase of hardness of composites could be attributed to the relatively high hardness of Al<sub>2</sub>O<sub>3</sub> and mica itself.

**Table 4 Hardness of composites with different contents of mica**

Sample Name	Hardness Value ( Hv )
Al+ Al <sub>2</sub> O <sub>3</sub>	409.2
Al+ Al <sub>2</sub> O <sub>3</sub> + Mica (2%)	447
Al+ Al <sub>2</sub> O <sub>3</sub> + Mica (4%)	464.8
Al+ Al <sub>2</sub> O <sub>3</sub> + Mica (6%)	485

### 3.3 Density

The results of density of the composites reinforced with different mass fractions of mica particles are shown in Table 5. The result shows that the densities of mica reinforced composites are higher than Al/Al<sub>2</sub>O<sub>3</sub> reinforced composites. The

results are in that the density increased with increasing the volume fraction of particulates. The increase in density indicates that particle breakage may not have any significant influence on the composites. It is believed to achieve an improvement of the bonding between the particle and matrix.

**Table 5 Density of composites with different contents of mica**

Sample Name	Value ( g/cc )
Al+ Al <sub>2</sub> O <sub>3</sub>	3.59
Al+ Al <sub>2</sub> O <sub>3</sub> + Mica (2%)	3.78
Al+ Al <sub>2</sub> O <sub>3</sub> + Mica (4%)	3.84
Al+ Al <sub>2</sub> O <sub>3</sub> + Mica (6%)	4.01

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## 4. Conclusions

The present work on preparation of Al356/Al<sub>2</sub>O<sub>3</sub>-mica metal matrix composite by stir casting and investigation of mechanical properties has led to following conclusions: The stir casting method is found to be suitable to fabricate the hybrid aluminium-mica reinforced metal matrix composites. The higher density and higher hardness will be achieved from Al356/Al<sub>2</sub>O<sub>3</sub>-mica composites compared to Al/Al<sub>2</sub>O<sub>3</sub> composites. The optical micrographs of composites produced by stir casting method shows fairly uniform distribution of Al<sub>2</sub>O<sub>3</sub> and mica particulates in the Al356 metal matrix.

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