INVESTIGATION OF MECHANICAL PROPERTIES IN ALUMINIUM SILICON CARBIDE MICA HYBRID METAL MATRIX COMPOSITE

P Saravanan[1], M Shanmuga Priyan[2], R Raghuram[3], S Sharath Kumar[4], T Anand[5]

[1]*Student, Mechanical Engineering, SriMuthukumaran Institute of Technology, Tamil nadu, India,* ***saravchanselvam@gmail.com***
[2]*Student, Mechanical Engineering, SriMuthukumaran Institute of Technology, Tamil nadu, India,* ***glorioussun.m21@gmail.com***
[3]*Student, Mechanical Engineering, SriMuthukumaran Institute of Technology, Tamil nadu, India,* ***raghuramsmilecan@gmail.com***
[4]*Student, Mechanical Engineering, SriMuthukumaran Institute of Technology, Tamil nadu, India,* ***sharathk69@gmail.com***
[5]*Associate professor, Mechanical Engineering, SriMuthukumaran Institute of Technology, Tamil nadu, India,* ***tanandresearch@gmail.com***

Abstract

The wide range of availability of aluminium has made it an important material for manufacturing many components. An aluminium alloy which has low tensile strength and hardness is been composited with other materials to improve its properties and reduce its drawbacks. Aluminium is been composited with silicon carbide that drastically increases the properties. Our study involves fabrication of aluminium silicon carbide with mica in stir casting method to obtain a hybrid metal matrix composite. Maintaining a constant amount of aluminium and silicon carbide, mica is varied to obtain a three different compositions of (AlSiCM) composites. The mechanical properties such tensile strength, flexural strength, impact and hardness are studied. The dispersion of mica and silicon carbide particles are observed by viewing the microstructure photographs obtained using Scanning Electron Microscope (SEM).

Index Terms: *Aluminium metal matrix composite, silicon carbide, mica, mechanical properties, stir casting.*

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1. INTRODUCTION

Aluminium is the third most abundant material available in nature. It has replaced the ferrous element in wide range of applications due to its specific properties like low density, corrosion resistance due to passivation, light in weight etc. Aluminium also has defective properties which prevent it from being applied in other fields. In order to overcome the defects of pure aluminium alloys, a new material called aluminium composite was discovered. Aluminium composites are also called as aluminium metal matrix composites. A metal matrix composite is a combination of two distinct metals to obtain a compounded material known as reinforced material. In metal matrix, matrix is the continuous material in which the reinforcing material is added in whiskers, fabrics and particulates. The reinforcement may be continuous or discontinuous. When more than one reinforcement is added with the matrix it is said to be a Hybrid metal matrix composite.

The aluminium alloy components are replaced with metal matrix aluminium composites (MMC). The MMCs play a vital role in our modern day today life. Graphite or steel with high carbide contents or tungsten carbides or metallic binders also come under this category. It is mainly used when a conventional material does not achieve the required standards or specific demands. Reinforcement of the metal matrix is chosen based on the required property to be achieved with a base metal. Such a MMC's are called as particulate metal matrix composites (PMMCs). The PMMCs lead to obtain a high strength and high wear resistive material by introduction of hard particles such as silicon carbide, boron carbide etc.., Hybrid metal matrix composites are modern day composites where more than one type of material of different shapes and sizes are used to improve the properties. They are still advantageous than PMMCs as it involves with advantages more than two materials.

Metal matrix composites such as cobalt matrix with tungsten carbide particles is used to manufacture carbide drills, steel reinforced with boron nitride is used in tank armours, in power electronic modules aluminium graphite composites are used because of their high thermal conductivity. These composites have wide range of application space systems because of their wide range of operating temperatures and resistance to absorb moisture etc.

[1]Anthony Macke, B.F. Schultz, PradeepRohatgi in their journal have described about the opportunity in reduction of weight and increase in performance of auto mobiles using MMCs. [2]T.Rajmohan, K.Palanikumar, S.Ranganathan have discussed about the mechanical and wear properties of aluminium silicon carbide mica hybrid composites and their results showed that the mica composite had good strength and hardness. Cast aluminium alloy composites containing ground mica particles coated by copper a journal published by [3]Deona T H, Rohatgi P K revealed that the ground mica coated with copper found to have good strength and used for bearing applications.

2. EXPERIMENTAL PROCEDURE

2.1 MATERIALS

The matrix that has been used here is 6061. The alloy composition and mechanical properties of Al6061 is tabulated. A micron size of 4µm black silicon carbide is used as the first reinforcement and muscovite a type of mica of 26 µm is taken as the 2nd reinforcement. Three different compositions, taking 1%, 2% and 3% of mica and 4% SiC as a constant required composites are fabricated. The Table-1 shows the composition In which the material is fabricated.

The fabrication of composites are done by stir casting method, Due to its suitability in producing uniformly distributed reinforcements. Aluminium6061 was purchased in the form of rods and then were cut into pieces to as per requirement of the crucible. Muscovite a type of mica was obtained for study from Micafab industries. Table -2&3 shows the composition of Al6061 alloy and its mechanical properties respectively.

Table-1: Compositions of AlSiC-Mica

COMPOSITIONS	SiC %	Mica %
1	4	1
2	4	2
3	4	3

Table-2: Composition of Al6061

Cu	Si	Mg	Mn	Fe	Ti	Zn	Al
0.15-0.4	0.4-0.8	0.8-1.2	Max 0.15	Max0.7	Max0.15	Max 0.25	Bal

Table-3: Chemical properties of mica (mass fraction %)

SiO2	Al2O3	K20	Fe2O3	Na2O	TiO2	CaO	MgO
45.57	33.10	9.87	2.48	0.642	Traces	0.21	0.38

Table-4: Mechanical properties of Al6061

Density gcm-3	Ultimate Tensile strength MPa	Yield tensile strength MPa	Elongation %	Modulus of elasticity Gpa	Poisson ratio
2.7	310	276	12	68.9	0.33

Metallic moulds of required shapes are used to obtain the specimens for tests. The molten metal of aluminium obtained by stir casting is poured into the moulds.

2.2 SPECIMEN FABRICATION

The cylindrical rods are cut into required sizes and placed into the crucible. SiC and Mica are taken in separate vessels and preheated along with the crucible in the furnace up to a temperature of 850°C. The metallic moulds of required shapes are placed in the preheated and heated up to a temperature of 500°C. After 850°C is reached the molten aluminium is taken out and 5 grams of degasser is added to remove the impurities and small amount of coverall is added to prevent oxidation. For a good wettability a small amount of magnesium is added. The heated SiC and Mica are added to the crucible and placed again into the furnace. The furnace is once again heated up to a temperature of 850°C. The crucible is placed perpendicular to the stirrer and the stirrer is inserted into the crucible. The stirrer is made to stir at a speed of 300 rpm.

The preheated metal moulds are placed over river sand. The crucible with melt is poured into the mould. The melt is poured until the metal rises from the riser. The mould is then allowed to cooled and then the metal of the mould shape is obtained which is then later cut into require dimensions of the specimen.

2.3 SPECIMEN TESTING

2.3.1 TENSILE

Tensile strength is one of the important parameters which is used to determine the applications of a material.

Fig-1: Tensile test specimen

The ASTM standard that has been applied for tensile test is E8. The cylindrical rod casted by stir casting method is machined with respect to standard. A dumbbell shaped specimen was fixed at the ends of the universal testing machine. Tensile load was applied until the break point and the corresponding values were recorded.

2.3.2 FLEXURAL

For flexural testing, rectangular specimen was casted which was later machined into standard specimen. The specimen was placed over the universal testing machine and then a vertical load is applied until breakeven point and the value are recorded.

Fig-2: Flexural test specimen

2.3.3 IMPACT

The method of impact test that has been applied here is charpy impact test. A standard test piece of required dimension is machined and then the test was carried out.

Fig-3:Impact test specimen

2.3.4 HARDNESS

Brinell hardness test was carried out with a finely polished plate surfce. The surface was placed below diamond indentor and three sets of impressions were made and on a average the Brinell Hardness Number (BHN) was obtained

Fig-4:Hardness test specimen

2.3.5 SEM SPECIMEN

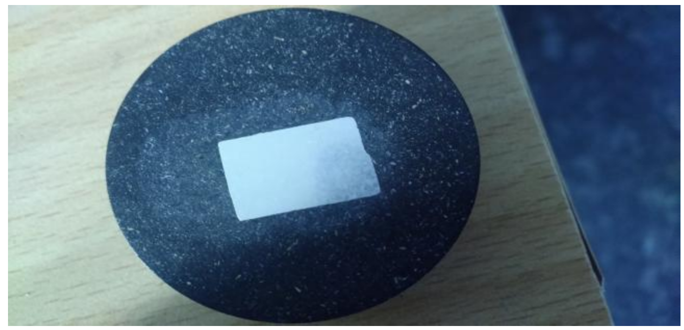


Fig-5:SEM specimen

Scanning Electron Microscopy (SEM) is the device used to view the particles and grain size of the specimen. The specimen is prepared by polishing 10*10*10 mm cube. 5% of volume of HF etchant is used to etch the surface of the sample and it is washed in distilled water before carrying out SEM.

3. RESULTS AND DISCUSSIONS

3.1 MICROSTRUCTURE

The micrographs obtained by scanning electron microscopy show the dispersion of the reinforcement particles in the matrix. The SiC particles were evenly distributed and mica was clogged at some places. There is an agglomeration of particles. Appearances of small pits are due to oxidation of surface by the etchants or may be by the grinding of the surface. Thread like grain boundaries are due to fine particles of reinforcements added with matrix.

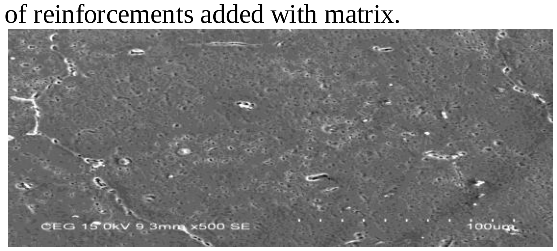


Fig-6:SEM micrograph of Mica 1% composition

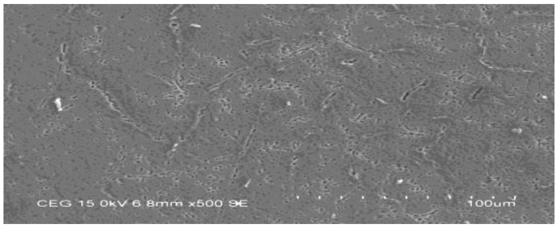


Fig-7:SEM micrograph of Mica 2% composition

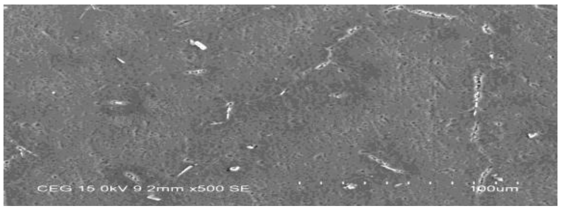


Fig-8:SEM micrograph of Mica 3% composition

The SEM photographs acts as evidence for the proper distribution of silicon carbide and mica particle in the aluminium matrix.

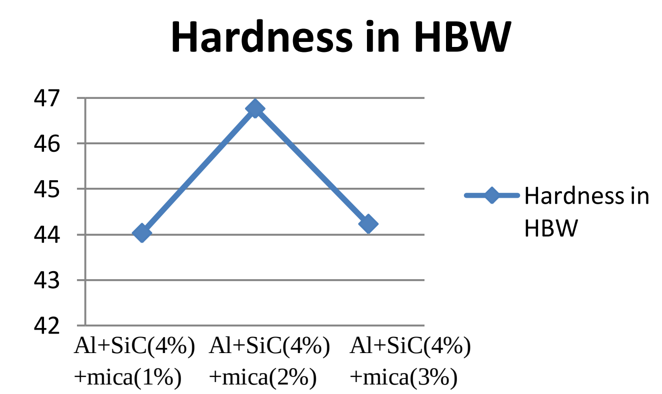
3.2 MECHANICAL PROPERTIES

3.2.1 HARDNESS

Table-5: variation of hardness in each composition

s.no	compositions	Hardness in HBW
1	Al+SiC(4%)+mica(1%)	44.03
2	Al+SiC(4%)+mica(2%)	46.76
3	Al+SiC(4%)+mica(3%)	44.23

Three impressions were made on the specimen of each composition in different places so as to get the aggregate value of hardness of the sample.



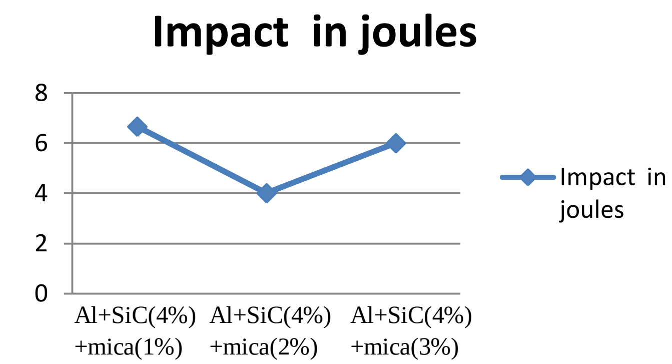
Graph-1: Hardness variation in each composition

The hardness result obtained by Brinell Hardness Test shows that the composition with 2% of mica has a higher hardness than other two compositions. It shows that on increasing mica, the hardness of aluminium silicon carbide decreases. As the decrease in hardness improves the machinability of the composite, this proves mica a good substitute for AlSiC composite as a hardness reducing agent. Mica will be a good substitute for graphite because of its ductile nature.

3.2.2 IMPACT

Table-6: variation of impact strength in each composition

s.no	compositions	Impact in joules
1	Al+SiC(4%)+mica(1%)	6.66
2	Al+SiC(4%)+mica(2%)	4
3	Al+SiC(4%)+mica(3%)	6



Graph-2: Impact load variations in each composition

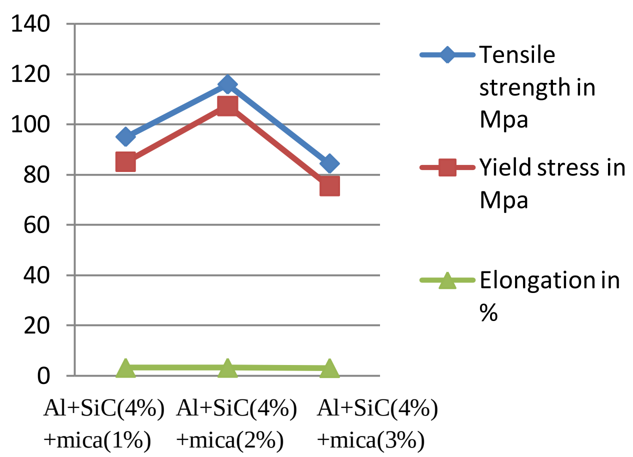
The impact of the composites obtained through charpy impact test shows that the toughness of the composite decreases at first and then increases. The yield strength of the composite decreases as the composition of mica increases.

3.2.3 TENSILE

Table-7: variation of tensile properties in each composition

s.no	compositions	Tensile strength in Mpa	Yield stress in Mpa	Elongation in %
1	Al+SiC(4%)+mica(1%)	94.96	85.09	3.2
2	Al+SiC(4%)+mica(2%)	115.845	107.28	3.2
3	Al+SiC(4%)+mica(3%)	84.32	75.425	3.1

The figure shows the relationship between tensile strength, yield stress and elongation percentage of the compositions. The tensile strength specimen increases from 1% of mica composite to 2% of it. Above 3% of mica the tensile strength is observed to be decreased . This shows that 2% mica composition is the threshold region of Aluminium silicon carbide Mica composite. The elongation percentage of all the three composition remained constant.The consistency in elongation percentage is due to constant silicon carbide 4%.The brittleness increse with in crese in SiC and there by it is observable that 2% mica constituent is good.

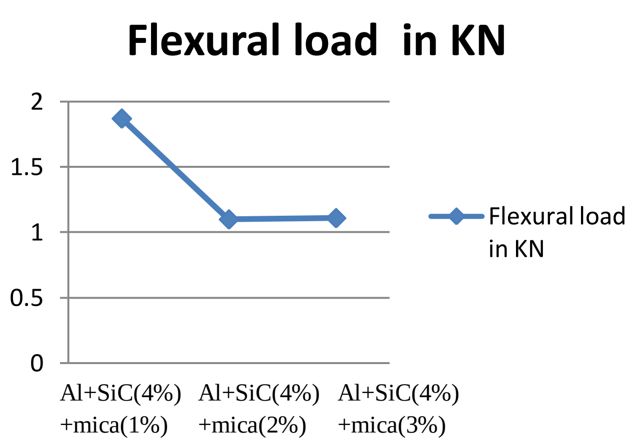


Graph-3: Tensile properties variation in each compositon

3.2.4 FLEXURAL

Table-8: variation of flexural strength in each composition

s.no	compositions	Flexural load in KN
1	Al+SiC(4%)+mica(1%)	1.87
2	Al+SiC(4%)+mica(2%)	1.1
3	Al+SiC(4%)+mica(3%)	1.11



Graph-4: Flexural load variation in each composition

The flexural test is made to know the load at which a material starts to bend. The figure shows that the 1% mica composite higher bending load than the other composites. Therefore on increasing mica the bending load gets decreased at greater difference at first and followed minimal differences.

3. CONCLUSION

Aluminium reinforced with silicon carbide is the vital composite with less machinability. In order to improve the properties of such a composite various materials are reinforced by researchers around the world. The above results show that mica could be a good substitute to soften the AlSiC composite. It is observed that fabrication of Aluminium silicon carbide mica composite can be done using stir casting method. The micrographs obtained from SEM prove that the dispersion reinforcement particles are finer with stir casting method. The grain boundaries show the mixing of particles with little clusters of particles.

- The hardness of the compositions first increases and then decreases with higher hardness in 2%mica composition.
- The toughness of the composition first decreases and then increases.
- The tensile strength of the composition increases from 1% to 2% mica composition followed by a fall in 3% mica composition.
- The flexural load for bending first decrease followed by increase.
- The 2% composition of mica is the better reinforcement that showed a effective properties.

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