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Investigation on Mechanical Properties of Aluminium Matrix Composites with SiC & MoS_2 Reinforcements

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Abstract: Aluminum alloy has superior property such as low weight, high strength superior malleability, excellent corrosion resistance and good thermal and electrical conductivity. It has high strength to weight ratio. Different alloying elements can be used based on the properties requirements. For automobile parts, the alloying material should improve strength with low density so as to give fatigue resistance and better fuel economy. Silicon carbide and molybdenum disulfide particles reinforced with aluminum metal matrix composite are synthesized using stir casting method. This method distributes silicon carbide particles homogeneously in the aluminum microstructure by forming vortex in molten metal. Molybdenum disulfide is added in the aluminum silicon carbide combination to provide high strength and wear resistance. Aluminum based alloy containing 20% weight of silicon carbide and molybdenum disulfide particles of three different samples for hardness, impact strength, material toughness and wear resistance are investigated and evaluated. Under stir casting, the silicon carbide as uniformly distributed in the aluminum and well bonded with aluminum matrix as seen in scanning electron microscope. Metal matrix composite gives an improved property of high compressive strength, good corrosion resistance, high compact strength, high specific stiffness, and high specific strength, a controlled co efficient of thermal expansion, increased fatigue and excellent wear resistance. These properties along with good strength and wear resistance make them good materials for many engineering applications especially in automobile parts like gears, seals, guide, bearings, brakes and clutches.
Keywords: Aluminum alloy, corrosion, electrical and thermal conductivity, molybdenum, Silicon carbide.

I. INTRODUCTION

Aluminum and its alloys possess excellent properties such as low density, good plasticity and ductility, and good corrosion resistance. They find extensive applications in aeronautics, astronautics, and automobile and high speed train. However, low hardness and poor impact resistance results in their limited application in heavy duty environments. It is important to develop processing and technology for improvement of mechanical properties.

Silicon Carbide is the chemical compound of carbon and silicon. It is produced by a high temperature electro-chemical reaction[1] of sand and carbon. Silicon carbide is an excellent abrasive made into grinding wheels and other abrasive products for over hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractories, ceramics, and numerous high-performance applications. The material can also be made as an electrical conductor and has applications in resistance heating, flame igniters and electronic components. Structural and wear applications are constantly developing.

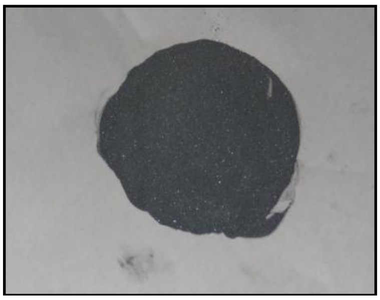


Fig 1.1. Silicon Carbide

Molybdenum disulfide is an organic compound MoS_2. This black crystalline sulfide[2] of molybdenum occurs as the mineral molybdenum. It is the principal ore from which molybdenum metal is extracted. MoS_2 is relatively unreactive, being unaffected by dilute acids and oxygen. In its appearance and feel, molybdenum disulfide is similar to graphite. Indeed like graphite, it is widely used as a lubricant because of its low friction properties. Molybdenum disulfide, simply molybdenum powder, is a purified form of molybdenite.

Fig 1.2.Molybdenum

II. METHODOLOGY

The present study deals with investigations relating to dry sliding wear behavior of the Al 2219 alloy reinforced[3] with SiC particles in 0–15 wt. % in three steps. Un-lubricated pin-on disc tests were conducted to examine the wear behavior of the aluminum alloy and its composites. The tests were conducted at varying loads, from 0 to 60 N and sliding speeds of 1.53 m/s, 3 m/s, 4.6 m/s, and 6.1 m/s for a constant sliding distance of 5000 m. The results showed that the wear rates of the composites are lower than that of the matrix alloy and further decrease with increasing SiC content. As the load increases, cracking of SiC particles occur and a combination of abrasion, delamination, and adhesive wear is observed. The samples were examined using scanning electronic microscopy after wear testing.

The liquid metallurgy technique was used to fabricate the composite specimen. This method is the most economical route to obtain composites with discontinuous fibers or particulates. In this process, the matrix alloy was first superheated above its melting temperature to create a vortex in the melt using a stainless steel mechanical stirrer. At this stage, the preheated SiC particles are introduced into the slurry and the temperature of the composite slurry was increased until it is in a full liquid state, and the stirring is continued for about five minutes at an average stirring speed of 300–350 rpm.

Nitrogen is subsequently passed to degas this melt. The melt is then superheated above the liquidus temperature (7000ºC) and finally poured into a permanent cast iron mould of 10 mm in diameter and 50 mm hight.

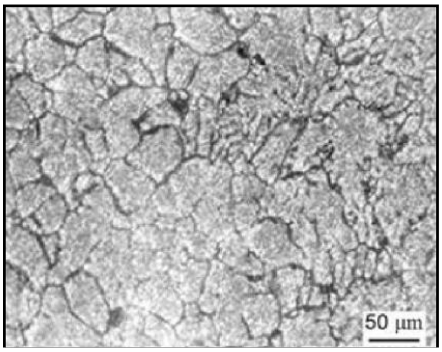


Fig.2.1. Micrographs of Al 2219-15%SiC

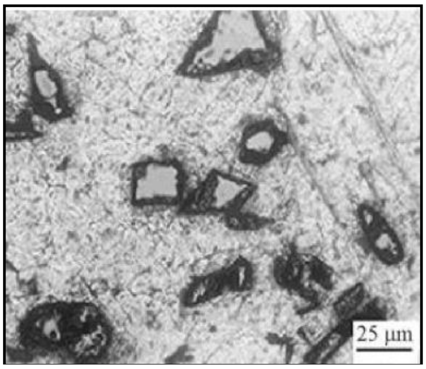


Fig.2.2. Micrographs of Al 2219–10% SiC

Conventional materials[4] like Steel, Brass, Aluminum, etc. will fail without any indication. Cracks initiation, propagation will take place within a short span. To overcome this problem, conventional materials are replaced by Aluminum alloy materials. Aluminum alloy materials are found to be alternatives with these unique properties. Tensile strength experiments have been conducted by varying mass fraction of SiC (5%, 10%, 15%, and 20%) with Aluminum. The maximum tensile strength is obtained at 15% SiC. Mechanical and Corrosion behavior of Aluminum Silicon Carbide alloys are also studied.

Fig.2.3. Specimen 5 % SiC with Al

Fig.2.4. Specimen 10 % SiC with Al

Fig.2.4. Specimen 15 % SiC with Al

Fig.2.5 Specimen 20 % SiC with Al

Aluminum Silicon carbide alloy composites are widely used for applications like engineering structures, aerospace and marine application, automotive bumpers and sporting goods. Based on test results it is found that the weight to strength ratio for Aluminum silicon carbide is about three times that of mild steel tensile test. Aluminum silicon carbide alloy composite is two times less in weight. In these maximum 15% silicon carbide is maximum used to reinforce aluminum alloy to obtain the maximum strength and fatigue resistance.

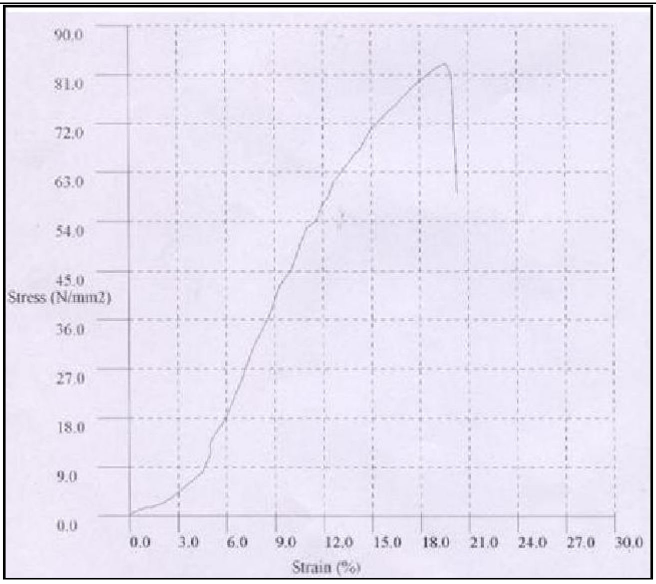


Fig.2.6. Stress–Strain curve for 15%SiC
Tensile strength: 94.2N/mm²,
%Elongation: 5.57%.

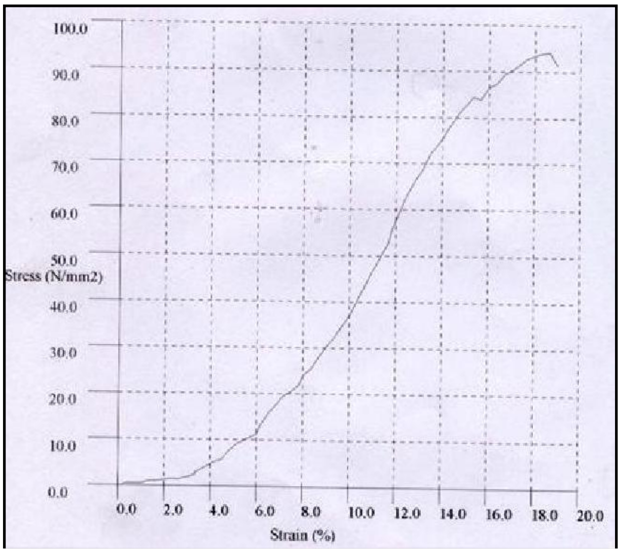


Fig.2.6. Stress–Strain curve for 20% SiC
Tensile strength: 83 N/mm²,
%Elongation: 6.87%.

III. STIR CASTING PROCESS

Liquid state fabrication of metal matrix composite involves incorporation of dispersed phase into a molten matrix metal[5], followed by its solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix is required.

Wetting improvement is achieved by coating of dispersed phase particles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix. The simplest and the most cost effective method of liquid state fabrication is stir casting.

STIR CASTING:

Stir casting is a liquid state method of composite material fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten metal matrix by means of mechanical stirring. The liquid composite material is then cast by conventional metal forming technologies.

i. Content of dispersed phase is limited (usually not more than 30 %).

ii. Distribution of dispersed phase throughout is matrix is not perfectly homogeneous. High viscosity of the semi-solid matrix material enables better mixing of dispersed phase.
iii. There are local clouds (clusters) of the dispersed particles (fibers).
iv. There is gravity segregation of the dispersed phase due to a difference of densities of the dispersed and matrix phase.
v. The technology is relatively simple and cost effective.

Fig.3.1 Stir casting

STEPS INVOLVED:

i. The weights of Al alloy &SiC& MoS_2 for different compositions are calculated.
ii. Material is preheated
iii. Aluminum alloy is melted and thoroughly stirred
iv. Molten metal poured into the die.

IV. CALCULATION

DENSITY CALCULATION:

Density of Al (ρAl)= 2.7 g/cm^3
Density of SiC(ρSiC)= 3.21 g/cm^3
Density of MoS_2 (ρ MoS_2)= 5.06 g/cm^3
Total mass = 550g
80 % of Al in total mass = 440g
12.5 % of SiC in total mass=68.75g
7.5 % of MoS_2 in total mass= 41.25g

$$\text{Volume} = \frac{Mass}{Density} = \frac{m}{\rho}$$

Volume of Al= $\frac{40}{2.7} = 162.96\,cm^3$

Volume of SiC= $\frac{68.75}{3.21} = 21.41\,cm^3$

Volume of MoS_2= $\frac{41.25}{5.06} = 8.15\,cm^3$

Total volume=V= 162.96 +21.41+8.15
V= 192.52 cm^3

$$Density(\rho) = \frac{Mass}{\text{Volume}} = \frac{m}{V}$$

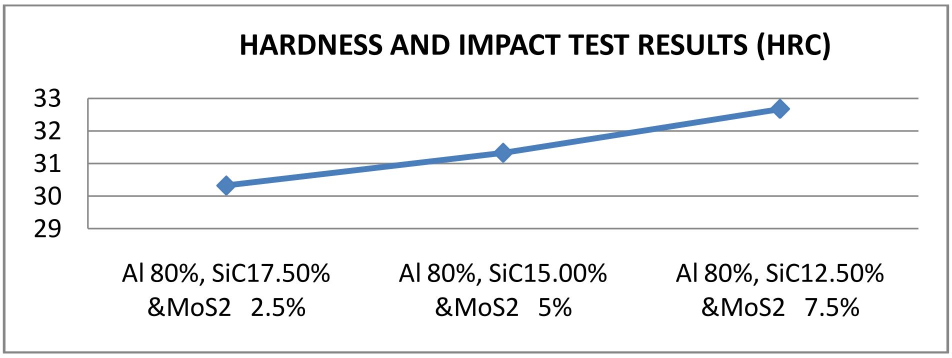
$$\rho = \frac{m}{V} = \frac{550}{192.52} = 2.85g/cm^3$$

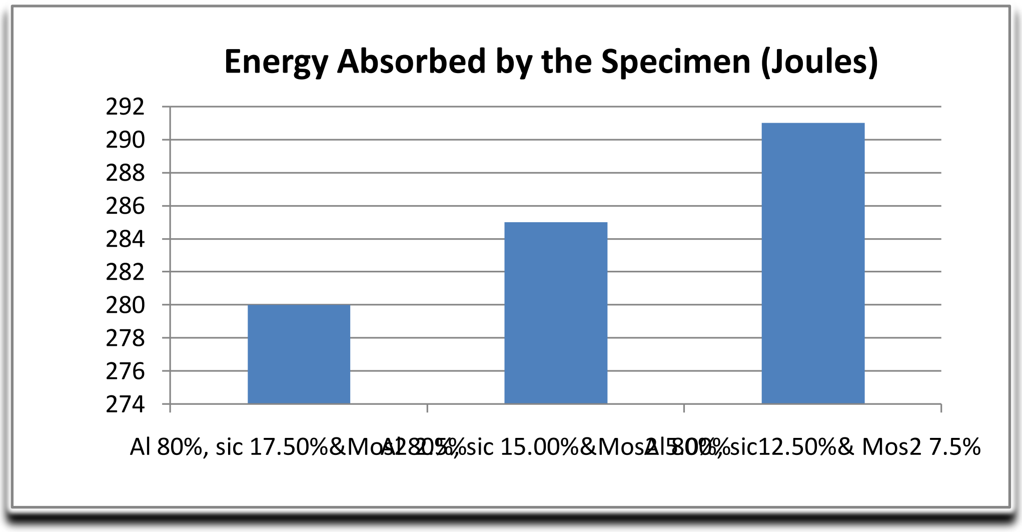
V. TESTING

The following tests results are conducted:

i. Rockwell hardness test
ii. Charpy test
iii. Pin on disc test
iv. Scanning electron
v. Microscopy (sem) test

HARDNESS AND IMPACT TEST RESULTS





VI. SEM RESULTS

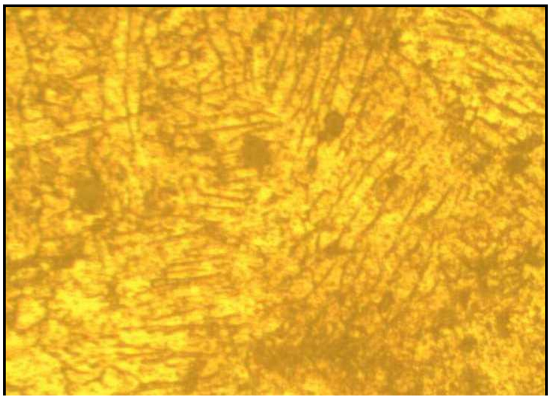
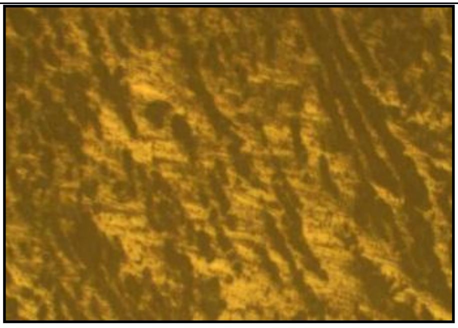


Fig.6.1.Compound A



6.2. Compound B

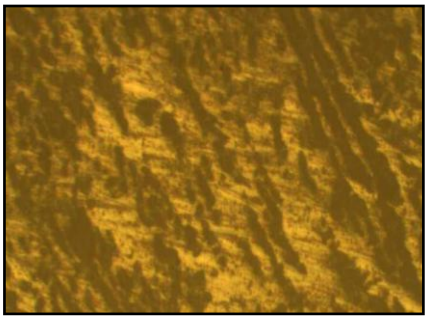


Fig.5.3. Compound C

VII. CONCLUSION

i. Test results shows that composite material with three different composition of Al alloy+SiC+MoS_2 is having more hardness than aluminum. Increase in area fraction of reinforcement in matrix resulted in improved hardness.
ii. The composite material absorbed more impact energy than aluminum as revealed by the Charpy test.
iii. The SEM images revealed that both SiC and MoS_2 particles are well dispersed in aluminum alloy matrix.
iv. This composite material is more suitable for sliding and rolling contact bearing.

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