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Tensile and Hardness behaviour of AlMg1SiCu alloy reinforced with SiC/ MoS_2 metal matrix composite

Ragupathy *K*[1], Anand *T*[1], Vishvanathperumal *S*[2], Arun *M* [1],

[1] Agni college of Technology, Chennai, Tamilnadu,India.
[2] S.A. Engineering College, Chennai,Tamilnadu,India.

Abstract. The current work examines the AlMg1SiCu alloy material through the stir casting process, where the Molybdenum Disulphide (MoS2) using three different variations of weight percentage (3 MoS_2%, 6% MoS_2, 9% MoS_2) and 10% uniform proportion silicon carbide (SiC). The distribution of reinforcements such as Hard particle Silicon Carbide (SiC) and Soft particleMolybdenum Disulphide in the matrix was studied by looking at the microstructure of the composites before Tensile and Hardness test using Backscattered Secondary Electron image (BSE). A Brinell hardness tester was employed to determine the hardness of samples made of AlMg1SiCu alloy and hybrid metal matrix composites. Tensile test carried out using a Universal test Machine for AlMg1SiCu alloy and HMMC Samples. With an increase in MoS_2 particle percentage, hybrid composites' tensile strength improves. With a AlMg1SiCu hybrid composite containing 10% SiC and 9% MoS2, the maximum tensile strength has been achieved.

1 Introduction

Modern composites are additionally growing in the hybrid metal matrix area, where the base AlMg1SiCu metal which may be aluminum is combined with non-ceramic reinforcements such as Boron Carbide ,Aluminium oxide , Titanium carbide, and Silicon Carbide . A composite material is produced when ceramic material is added to a metal matrix. The result exhibits an appealing blend of mechanical and physical properties that wouldn't be possible with a solid alloy [1]. In the term "Hybrid matrix" implies, in order to improve the composite's qualities, solid lubricants such as the graphite(Gr) or MoS2 non-ceramic materials are also added to supplement the base metal. The wear-resistant and anti-frictional characteristics of the composite would be improved by adding soft lubricants within the metal matrix. When specific reinforcement is blended through a hybrid composite material, physical and mechanical properties improve along with the composite's tribological behaviours [2]. A variety of methods, including a liquid infiltration, squeeze casting, stir casting, the use of powder metallurgy, diffusion bonding, and laser composite surfacing, were used to create these hybrid metal matrix composites [3]. The most technically sophisticated method for casting the HMMC from all of the above is stir the casting process, and it provides the material the right characteristics. Molybdenum Disulphide addition improves component density and improves compressibility; 3% of Molybdenum Disulphide will result in optimal dry sliding wear behaviour, and the volume percentages in excess of 5% lower the composite's hardness.

* Corresponding author: ragupathy86@gmail.com

According to Maivizhi Selvi et al. [4], MoS2 improved the mechanical characteristics of the Al6061 alloy composites, AA 6061-6% aluminium(III) oxide and Al6061-6% aluminium(III) oxide -2% Molybdenum Disulphide. These characteristics included flexural strength , toughness, and hardness values. Major improvements have been

made on various mechanical characteristics, such as the hardness and tensile properties. Singh J et al.'s investigation [5] on the mechanical characteristics of stir-cast T1 temper 6063 alloy reinforced with Molybdenum Disulphide revealed that the composite's density had increased and the reinforcement particles had been evenly distributed. It has been noticed compared to the extensive literature which there is a lack of reporting on the impact of adding reinforcing materials, such as Molybdenum Disulphide, to the aluminium matrix. It is commonly known that because aluminium alloy is mainly utilised to be a structural material, its tribological properties are not a design function. Few studies have examined the impact of Silicon Carbide and Molybdenum Disulphide particles on the tribological characteristics and mechanical characteristics of aluminium matrix composites. Tensile strength and hardness of hybrid composite materials raised with increasing molybdenum disulphide material.

2.1 Materials and methods

2.1.1 Materials

AlMg1SiCu alloy was chosen as the matrix material in the present study, and Silicon carbide and molybdenum disulphide, or MoS2 particles were considered as reinforcement. Using a spectrometer, the theoretical chemical composition of the AlMg1SiCu alloy was determined

Sample Number	**Fabrication of composites Sample**
1	AlMg1SiCu alloy + 10 wt.% SiC+ 3% MoS_2
2	AlMg1SiCu alloy + 10 wt.% SiC +6 % MoS_2
3	AlMg1SiCu alloy + 10 wt.% SiC +9% MoS_2

to be (wt.%).97.57 aluminium,0.63 Silicon ,0.89 Magnesium,0.24 Copper, 0.16 Iron; 0.48 Mn;0.014 Ti; 0.007 Zn; and 0.003 Cr. Particles of reinforcements have an average size of 75 microns.

Table 1. Fabrication of composites Sample

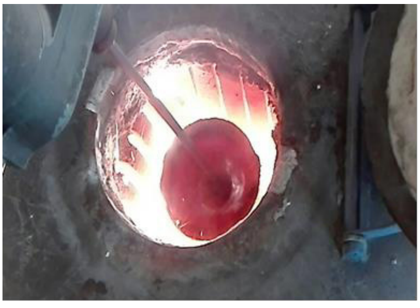

Fig. 1. Stir casting setup

2.1.2 Microstructural Analysis

The distribution of reinforcement particles in the matrix was studied by looking at the microstructure of the composites before wear test using Backscattered Secondary Electron image (BSE). The SEM images were taken for all the materials tested under specified conditions after the experiments. These SEM images were used to explain the surface morphology of the wear specimen. For the purpose of to show the boundaries that surround the grains inside the HMMC composite at the micron size level, the specimens were etchant-treated with Keller's reagent. For examining the microstructure, a JOEL SEM (Model: JSM 6390) had been utilised.

2.1.3 Tensile Test

Stir-cast aluminium AlMg1SiCu MMC has been manufactured with the incorporation of powdered SiC and MoS2 composites. Stir cast metal matrix composite castings have been produced using a variety of various combinations that had been prepared. After processing these stir-cast composites, the required ASTM E8 / ASTM E8M standard samples were created. For tensile test, 20 mm diameter and 110 mm length specimens were fabricated as show in Figure 3. Table 1 shows the composition of specimens used in tensile tests. The load-displacement data are obtained in the system attached to the tensile tester, and a plot of stress vs strain for each specimen is obtained. The tensile testing machine used for the experiments is shown in Figure 4.According to ASTM E8 standard, Figure 2 shows the standard specimen size for a test. Using a computer-controlled servo system, the tensile examination was performed at room temperature on the test specimens with an outer Bore size of 10 mm and a length of the gauge size of 36 mm.

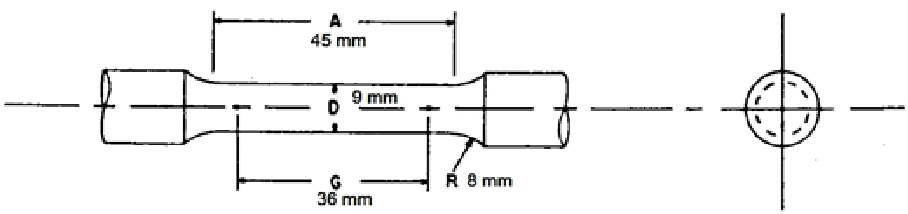

Fig. 2 The standard spécimen size for Tensile test

Fig. 3. Tensile test samples

Fig.4 Tensile testing machin

2.1.4 Brinell Hardness Test

The samples made of HMMC had been polished with standard grit (400–1000) rough sheets. A Brinell hardness tester has been utilised to determine the hardness of samples made of single and hybrid metal matrix composites. As indicated in Figure 5, a trial applied force of

550 kg was used with a carbide ball indenter over a duration of 15 s at 5 distinct locations on the samples' layer in accordance with ASTM E10-18.

Fig. 5 Hardness test samples reinforced composites

2.1.5 Microstructural Analysis

The figures 6–8 display the line EDS, which is results for the AlMg1SiCu/silicon carbide/MoS_2 composite specimens. The element aluminium(al), magnesium(mg), manganese(mn), silicon(si), along with iron are among the functional elements of aluminium that exhibit high intensity peaks. Low peaks are observed for other impurities like nitrogen, oxygen, and carbon,. The elements molybdenum, silicon, aluminium, and sulphur are confirmed with the EDS elemental plot.

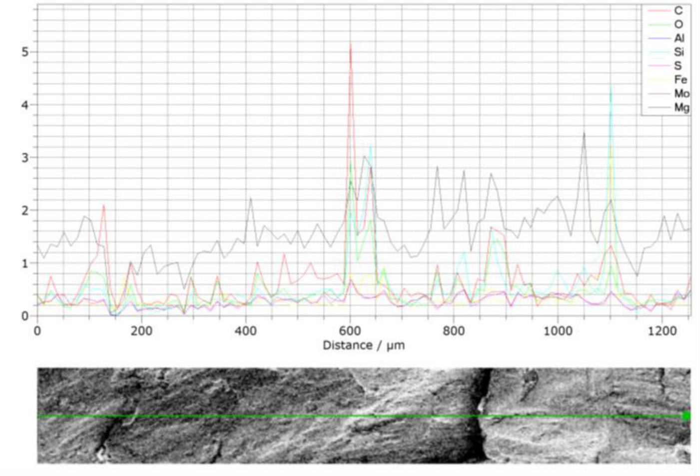

Fig. 6 Line surface EDS of 3 wt.% MoS_2 Sample

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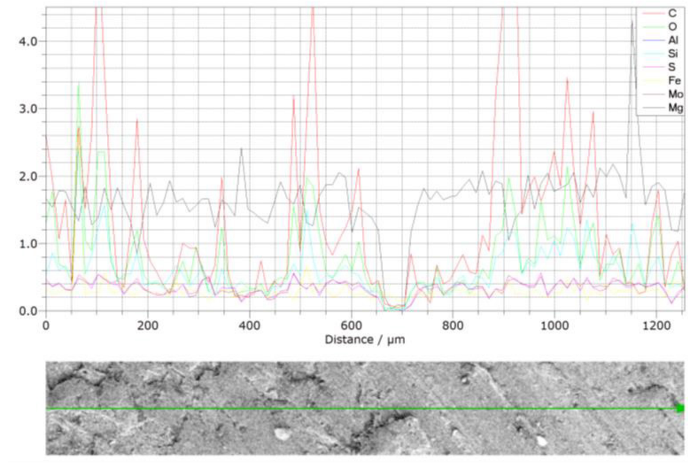

Fig.7 Line surface EDS of 6 wt.% MoS2 Sample

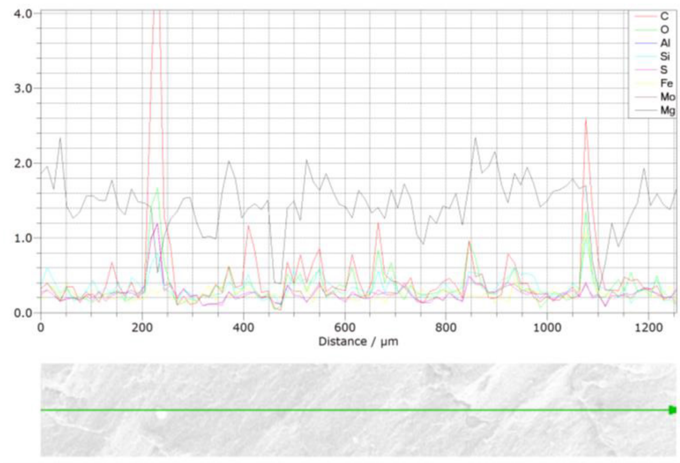

Fig. 8 Line surface EDS of 9 wt.% MoS_2 Sample

2.1.6 Hardness of as cast composites

Results of the Brinell Hardness Test are displayed in Figure 9. as-cast composites with varying reinforcement content. Due to the thermal mismatch during the solidification of the molten metal, the hardness values of AlMg1SiCu alloy composites increase with the addition of SiC particles (Habibur Rahman 2014).The increased dislocation density is due to the differing thermal expansion of the AlMg1SiCu alloy and the silicon carbide particles. As dislocation density increases, dislocation movement is blocked, leading to an increase in hardness values. The presence of hard Silicon carbide particles also resists dislocation motion, increasing the composite's hardness (Dora Siva Prasad 2014).

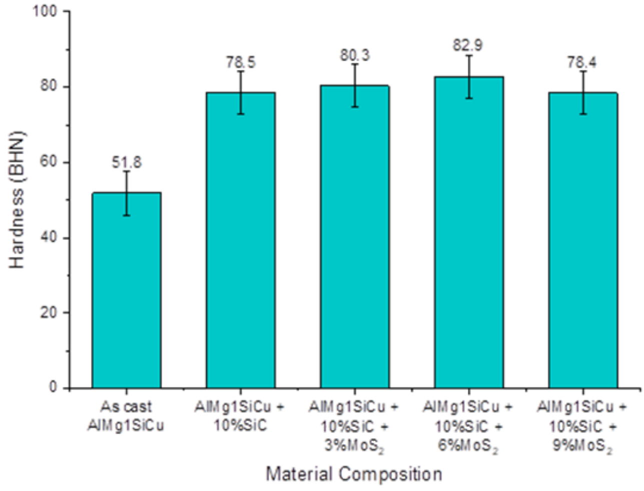

Fig. 9 Hardness Values of hybrid MMC composites

The effect of the weight percentage of reinforcements on the Hardness of the various AlMg1SiCu composite samples appears in Figure 9. The hardness of the reinforced AlMg1SiCu HMMC composites is found to be higher than that of the base AlMg1SiCu alloy, and it rises gradually when additional reinforcement particles are added, to a maximum a weight percentage of 6 wt%. of MoS_2 and additionally declines with the incorporation of Molybdenum Disulphide particles; however, the composite specimens' strain value progressively rises to be the Molybdenum Disulphide added additionally . The incorporation of reinforcement is what gives the lubricating property. According to Rebba and Ramanaiah (2014), Molybdenum Disulphide particles promote rapid grain shifting along direction of the slip planes, Permitting the specimens of HMMC composite to move and deform under the pressure of the indenter.

2.1.6 Tensile studies

Stress Vs strain curves are used to interpret the, ultimate stress, and tensile stress variation elongation of As cast AlMg1SiCu alloy, AlMg1SiCu +10% Silicon Carbide Composite, AlMg1SiCu +10%SiC +3% Molybdenum Disulphide , AlMg1SiCu 10 % Silicon Carbide +6 % Molybdenum Disulphide and AlMg1SiCu +10% Silicon Carbide + 9% Molybdenum Disulphide hybrid composites. Figure 10 shows the tensile strength of the AlMg1SiCu alloy reinforced HMMC composites . The graphical representation indicates evident that when the weight percentage of MoS_2 Reinforcement increases, correspondingly increases the tensile strength Values of AlMg1SiCu alloy Reinforced HMMC composites. contrasted with more refined particles, SEM images of the worn-out surfaces show that the bond that exists among coarse fragments in deeper thin craters possesses strengthened. As the number of sliding grooves and shallow craters increases, the hybrid composites' elastic modulus gradually decreases, increasing their tensile strength in comparison to as-cast AlMg1SiCu alloy. To identify the hybrid composite consisting of 10% SiC and 9% Molybdenum Disulphide, the optimum tensile strength was achieved.

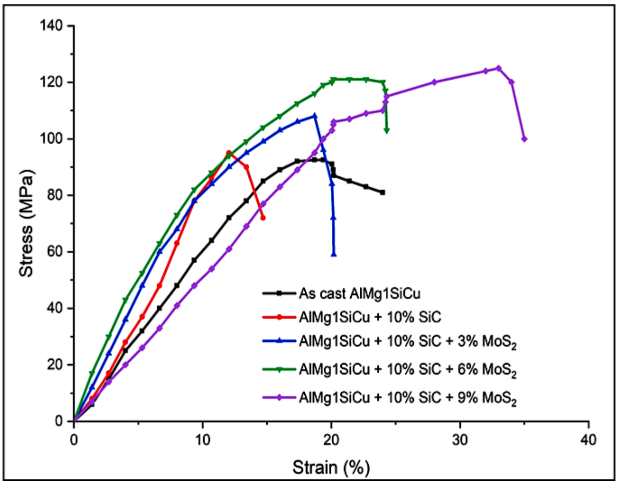

Fig. 10 Stress strain curves of hybrid composites

The theoretical Young's modulus was evaluated according to Callister (2007), which reported that the rule of mixture equation predicts that Youngs Modulus. The modulus of elasticity for AlMg1SiCu , SiC , and MoS_2 are 68, 90 and 250 GPa, respectively. Predicted Theoretical Young's modulus is calculated based on Equation 1. Predicted Youngs Modulus vaule are listed in Table 2.

Theoretical Young's modulus

$$E_C = E_{Al}V_{Al} + E_{SiC}V_{SiC} + E_{Mo}V_{Mo} \quad (1)$$

Table 2 Density and Young's modulus of hybrid composites

S.No	**Composition**	**Density (g/cm^3)**	**Youngs Modulus Gpa**
1	As cast AlMg1SiCu	2.700	68
2	AlMg1SiCu +10%SiC	2.931	70.2
3	AlMg1SiCu +10%SiC +3%MoS2	2.851	75.66
4	AlMg1SiCu +10%SiC +6%MoS2	2.886	81.12
5	AlMg1SiCu +10%SiC +9%MoS2	2.927	86.58

3.Conclusion

The major conclusions drawn from the present study on experimental investigations on the Tensile and Hardness behaviour of stir casted AlMg1SiCu hybrid aluminium composites are summarized.The Back scattered electron micrograph reveals a shows that the AlMg1SiCu matrix has been covered within a homogeneous blend of AlMg1SiCu alloy , Hard particles of SiC and soft particles of MoS2. silicon, molybdenum, sulphur and Aluminium, have been confirmed by the EDS line surface elemental plot. The results of the hardness test values, which HMMC AlMg1SiCu composites increased with an increase in MoS2 content up to 6 weight percent, at which point further addition slightly decreased the hardness. The lubricating property can be obtained by the incorporation of molybdenum disulphide (MoS2) particles. MoS2(molybdenum disulphide) particles promote rapid rapid grain shifting along direction of the slip planes, Permitting the specimens of HMMC composite to move and deform under the pressure of the indenter. It is clear that the presence of MoS2 reinforcement particles increases the tensile strength. 129.76 MPa maximum value of tensile strength has been reached for hybrid composites containing 10% silicon carbide and 9% molybdenum disulphide. Also, adding solid molybdenum disulphide (MoS2) lubricant increased the maximum strain.

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