*Grenze International Journal of Engineering and Technology, July 2017*

# A Review on Microstructural and Mechanical Characteristics of Stir Cast Aluminium Hybrid Metal Matrix Composites (AHMMCs)

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***Abstract*—Aluminium Hybrid Metal Matrix Composites (AHMMCs)have evoked a keen interest in recent times for potential applications in aerospace and automotive industries owing to their superior strength to weight ratio and high temperature resistance. In the past few years the global need for low cost, high performance and good quality materials has caused a shift in research from monolithic to composite materials. Reinforcements like particulate alumina, silicon carbide, graphite, fly ash, rice husk ash (RHA)etc can easily be incorporated in the melt using cheap and widely available stir casting method. The present review deals with the characterization of aluminium based hybrid composites developed by stir casting for advanced applications. The potential of a wide range of secondary reinforcements has been explored for the development of Aluminium Hybrid Metal Matrix Composites (AHMMCs) and the application area of these composites has been proposed. The focus is on the optimization of parameters for various properties of composites. Further, the influence of reinforcement's type and contents on the material properties has also been reviewed and discussed.**

***Index Terms*— Aluminium Hybrid Metal Matrix Composites (AHMMCs), stir casting.**

## I. INTRODUCTION

The different reinforcing materials used in the development of AHMMCs can be classified into three broad groups, which are synthetic ceramic particulates, industrial wastes and agro waste derivatives. The final properties of the hybrid reinforcement depend on individual properties of the reinforcement selected and the matrix alloy [1-4]. Moreover, the processing route adopted for synthesizing AHMMCs depends on the nature of the matrix alloy and reinforcing materials which also influence the final properties of AHMMCs. This is because most of the parameters put into consideration during the design of AHMMCs are linked with the reinforcing materials. A few of such parameters are reinforcement type, size, shape, modulus of elasticity, hardness, distribution in the matrix among others [1,5]. Based on the published articles studied, the discussion on the combinations of reinforcement used in the synthesis of AHMMCs is divided into three broad groups. These are AHMMCs with two synthetic ceramic materials; an agro waste derivative combined with synthetic ceramic materials; and industrial waste combined with synthetic reinforcement [6-8].

*Grenze ID: 01.GIJET.3.3.26*

The present study deals with the characterization of aluminium based hybrid composites developed by stir casting foradvanced applications. The potential of a wide range of secondaryreinforcements [6, 9-12] has been explored for the developmentof AHMMCs and the application area of these composites hasbeen proposed. The focus is on the optimization of parametersfor various properties of composites. Further, the influence ofreinforcement's type and contents on the material propertieshas also been reviewed and discussed.

II. Manufacturing And Characterization

Boopathi et al. [2]have studied the microstructures of aluminium alloy (Al 2024) reinforced with different compositions of fly ash, SiC and their mixtures. It has been observed that theparticles were not uniformly distributed in single reinforcedcomposites and segregation of particles was clearly visible.This was attributed to the gravity-regulated segregation ofthe particles in the melt. But, the micrographs of Al/SiC/flyash hybrid composites indicate uniform distribution of particlesat various concentrations Figure.1(a) and (b).

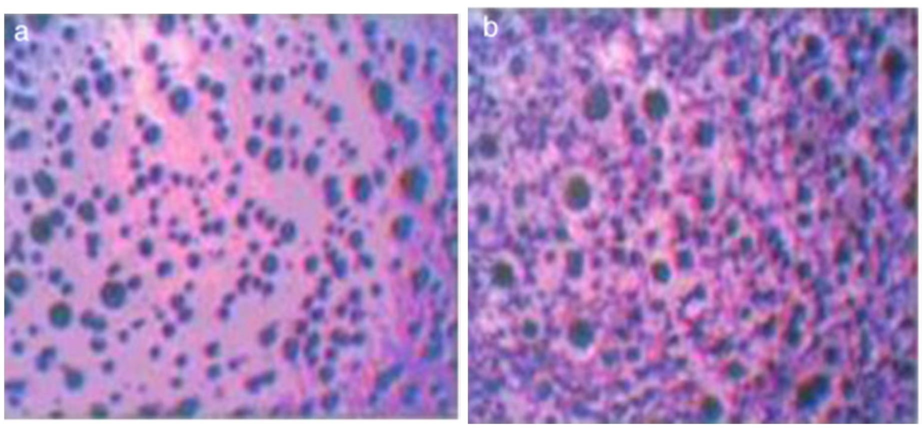


Figure 1.Optical micrograph of Al 2024/ (10%SiC + 10% fly ash) (a) before etching and (b) after etching (Boopathi et al. [2])

According to Rajmohanet al. [3], the hybrid reinforcements SiC and micaparticles were uniformly distributed in Al356 alloyFigure 2(a). The aluminum,carbon, silicon and oxygen particles were clearlyvisible in the energy dispersive X-ray spectroscopy (EDS) profileFigure. 2(b). The scanning electron micrograph (SEM) imagesof composites are the evidence of successful incorporation ofhybrid reinforcements in the Al-matrix. The clustering of SiCparticles in matrix was attributed to their lower thermal conductivityand heat diffusivity than the alloy melt. The hotterSiC particles heats up the surrounding melt and delays thesolidification process. Generally, the SiC particles are accumulatedin the interdendritic regions and geometrical trapping by dendrites is not observed in the micrographs. This suggeststhat SiC particles are always pushed by dendrite fronts duringsolidification process.

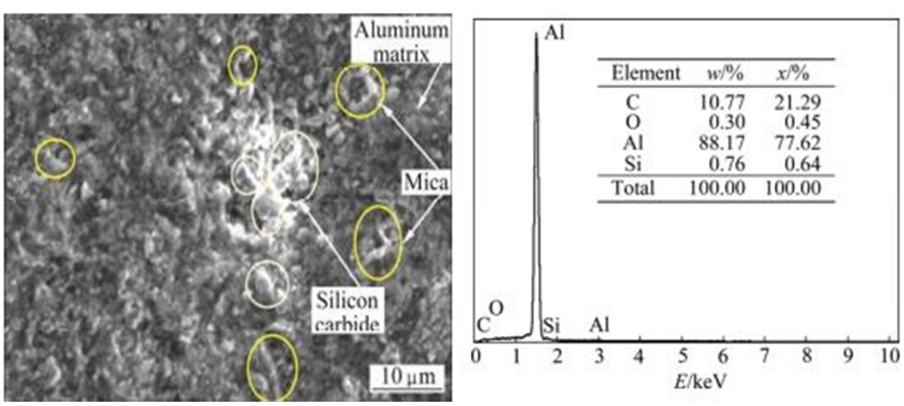


Figure 2.(a) SEM image of Al/10SiC-3mica composite(b)EDS spectrum of Al/10SiC-3mica composites (Rajmohanet al. [3])

Prasad and Shobha[4]observed the microstructuralcharacteristics of hybrid composites reinforced by SiC andrice husk ash (RHA) particles. The uniform distribution ofreinforcing particles was revealed during the examination.The presence of RHA and SiC particles was also confirmed inthe micrographs of hybrid composites (Figure. 3). The results ofabove studies indicate that it is possible to obtain nearly uniformdistribution of particles in the hybrid composites. But,various parameters need to be controlled and optimized duringfabrication process. However, the successful incorporationof reinforcing particles shows that it is possible to obtain thehybrid composites with isotropic set of properties.

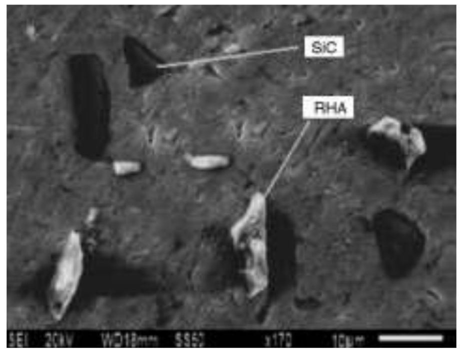


Figure3. Scanning electron micrograph of hybrid composite. (Prasad and Shobha[4])

Deravaju et al. [5] studied the influence of SiC/Gr and SiC/$Al_2O_3$ on the wear properties of friction stir processed Al 6061-T6 hybrid composites. The authors reported uniform distribution of the reinforcing materials in the nugget zone of the AHMMCs as shown inFigure. 4(a) and (b).

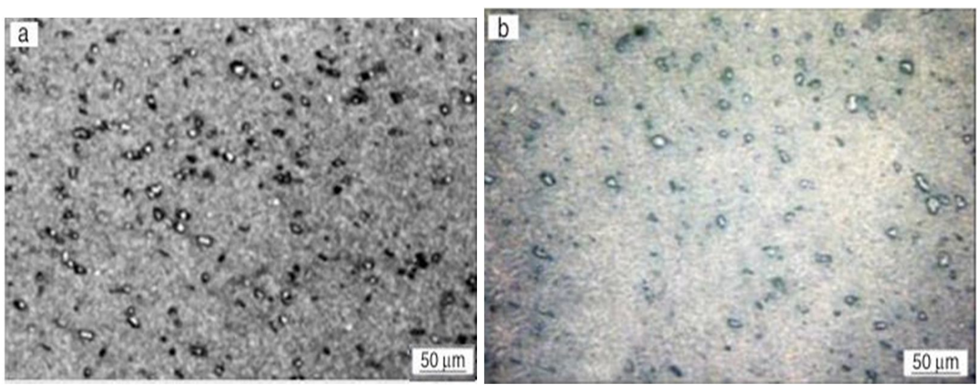


Figure4.Microstructure of surface hybrid composites (a) Al-SiC/Gr; (b) Al-SiC/$Al_2O_3$ (Deravaju et al. [5])

Suryakumari et.al.[11] studiedAl7075 hybrid metal matrix composites (Al7075+ SiC + $Al_2O_3$) was produced via stir castingtechniques. Al7075 is a matrix material and SiC , $Al_2O_3$ are the reinforcing elements. The Al7075aluminium alloy with 2.5, 5 and 7.5 W% of SiC and 2.5, 5 and 7.5 W% of $Al_2O_3$ was produced viastir casting.

## III. Mechanical Properties

The mechanical properties of a composite depend on many factors such type of reinforcement, quantity ofreinforcement, shape, size etc. The proper understanding of the mechanical behaviour is thus essential as they areemployed in different areas.

### *A. Hardness*

Boopathi et al. [2] have reported an increasing trend in the hardnessFigure 5(a) of composite with increase in weight fraction of reinforcements. They observed maximum hardness for Al/10 wt.%SiC/10 wt.%fly ash hybrid composites. This shows that incorporation of fly ash particles significantly improves hardness of the Al-matrix. In another study, Rajmohan et al.[3] have evaluated the hardness of the hybrid composites reinforced with different mass fractions of mica particles (for fixed 10 wt.% SiC). The result shows that the hardness value Figure.6(a) of Al/10 wt.%SiC/6wt.%mica composite is less as compared to Al/10 wt.%SiC/3 wt.%mica composite. Low values of hardness and strength are favourable for improving machinability of composites. The results show that hardness of the AHMMCs increased more or less linearly with the fraction of mica particles.Prasad and Shoba [4] have observed that the hardnessof the hybrid composites (A356.2/x%RHA/x%SiC) was higher than the pure A356.2 alloy. The hardness of the alloy increases with addition of hybrid reinforcements and the increase in hardness may be due to presence of relatively hard ceramic particles in the composite. It has also been reported that the addition of reinforcement (up to 8 wt. %) increases the hardness value by more than 50%.

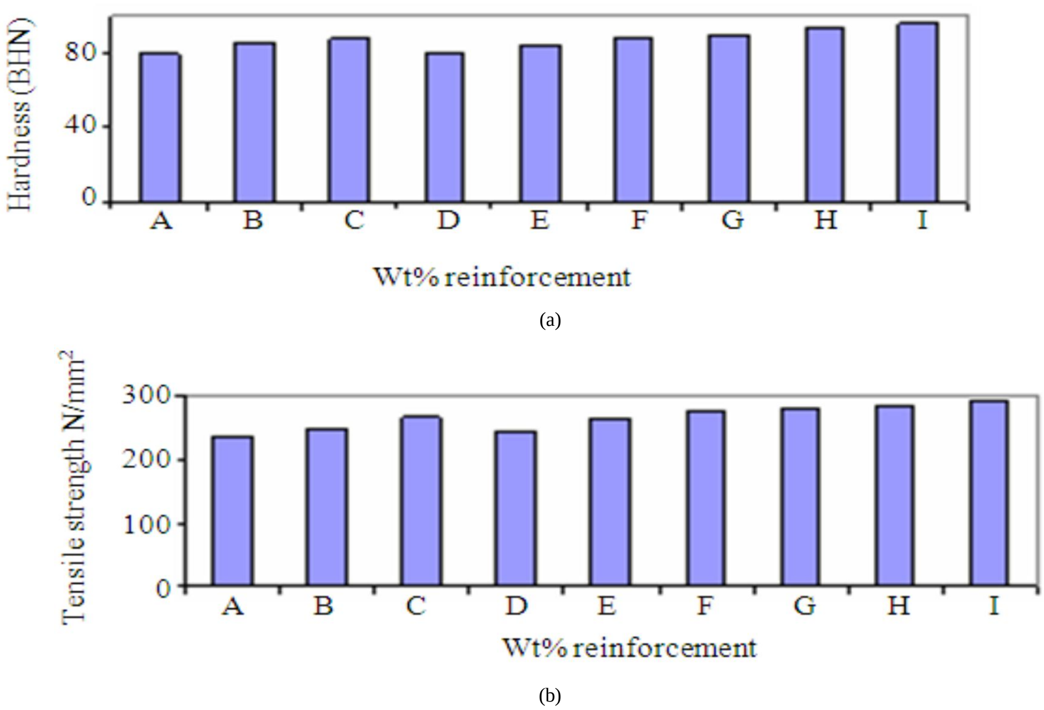


Figure5.Graph showing variation in (a) hardness and (b) tensile strengths with different composition (A = Al, B = Al +5% SiC, C = Al +10% SiC, D = Al +5%fly ash, E = Al +10% fly ash, F = Al +5% SiC +5% fly ash, G = Al +5% SiC +10% fly ash, H = Al +10% SiC +5% fly ash, I= Al +10% SiC +10% fly ash) of hybrid MMCs (Boopathi et al. [2])

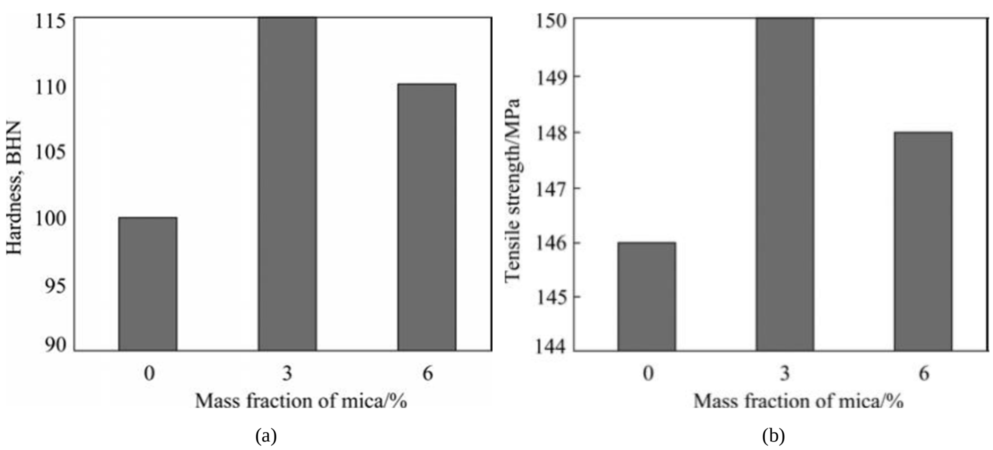


Figure 6. (a) Hardness (b) tensile strength of composite with different percentage of mica (Rajmohan et al.[3])

Suryakumari et.al [11] have performed Brinell hardness on the cast Al 7075 hybrid metal matrix composites with four trials. The effects on the hardness of Al 7075 hybrid metal matrix composites with the addition ofSiC and $Al_2O_3$ achieved from hardness testsare shown in Figure7. The increases in thehardness of the hybrid metal matrix composites were observed by addition of SiC and $Al_2O_3$initially and the maximum hardness was achieved at 2.5%W $Al_2O_3$ of and 5%W of SiC. The moreaddition of reinforcement of SiC and $Al_2O_3$ leads to decreases in the hardness. Up to certain limitthe addition of hard ceramic particles results in significant increase in the hardness of aluminiumalloy. The hardness decreases with high weight percentage of SiC and $Al_2O_3$ in the hybrid metalmatrix because of formation of more clustering of particles and settling down.

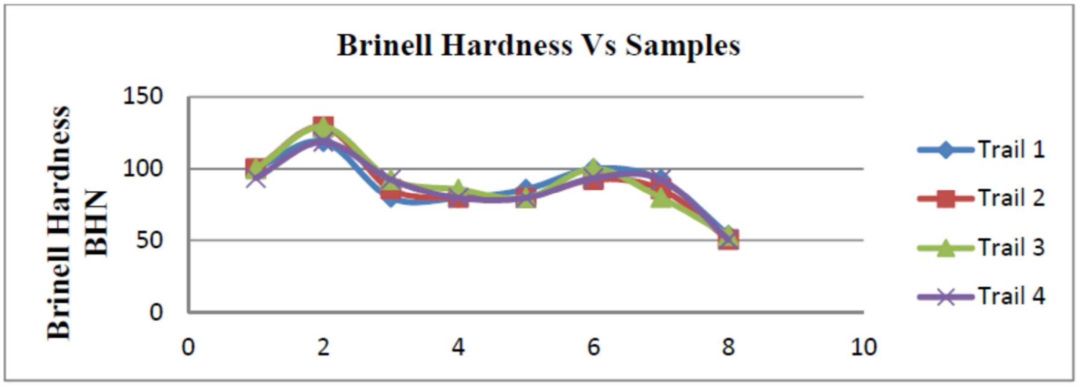


Figure 7.Brinell hardness test for Al 7075 hybrid metal matrix composites (Suryakumari et.al [11])

*B. Tensile strength*

Boopathi et al. Have reported the graph of the experimental tensile strength of the composites according to the SiC, fly ash and their mixtures is shown in Figure. 5(b). Results show that the tensile strength of composites is higher than that obtained for the unreinforced Al. Tensile strength of unreinforced Al is 236 $N/mm^2$ and this value increases to 265 $N/mm^2$ for Al/(10%SiC), 263 $N/mm^2$ for Al/(10%fly ash) and 293 $N/mm^2$for Al/(10%SiC+10%fly ash) composite, which is about 57% improvement over that of the unreinforced Al matrix.

Rajmohan et al.[3] observed the tensile tests of mica reinforced composites are shown in Figure. 6.(b). The Figureure indicates that the composites reinforced with 10% SiC and 3% mica particle have the highest tensile strength of 150 $N/mm^2$. At the same time, the tensile strength of composite with 10% SiC and 6% mica particle is found to be 148 $N/mm^2$. The results indicate that with the increasein mass fraction of mica, the tensile strength of the composites increases up to certain value and then reduce. In the present investigation, addition of 3% mica shows better tensile strength than the 6% mica addition.

## IV. CONCLUSIONS

This paper reviews the different combination of reinforcements used in the synthesis of AHMMCsand how it influences its performance. The double synthetic ceramics reinforced AHMMCsdespite showing good mechanical and tribological properties over the unreinforced alloys still need to be subjected to test under different corrosion media to ascertain its corrosion behaviour. Furthermore, comparison should be made between the hybrid composites with the single reinforced grades in order to determine how much improvement is obtained when hybrid reinforcement is used. More agro waste should be investigated and further studies should be concentrated on how to optimize the production process to determine the optimum processing parameters.

The stir casting method is found to be suitable to fabricate the aluminium hybridmetal matrix composites.Mica reinforced composites exhibits less wear loss and higher density compared with the ceramic reinforced composites.The addition of SiC and $Al_2O_3$ on the hardness of AHMMCs results in increases initially and decreases with more addition of weight fraction of $Al_2O_3$ and SiC. The high hardness value obtained with the addition of 2.5 % W of $Al_2O_3$ and 5% W of SiC.

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