Development of Aluminum Based 'Nanodiamonds & Silicon Carbide' Metal Matrix Composite

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Abstract*----Aluminum matrix composites (AMCs) are gaining importance in the field of aerospace and automobile due to their increased mechanical performance in relation density when compared with aluminum alloys. In the present research, Aluminum alloy has been reinforced with silicon carbide particles of ~25µm in 10wt% loading & Nanodiamonds in 1wt% loading using melt stir casting technique. The melt stir casting is an attractive processing method for producing AMCs as it is relatively inexpensive and offers a wide selection of materials and processing conditions. Stir casting technique also offers better matrix particle bonding due to stirring action of particles into the melts. The dispersion quality was examined by scanning electron microscopy. An increase in the mechanical properties of the composites was observed compared to aluminum alloy without reinforcements.

Keywords—Aluminum matrix composite, melt stir casting, silicon carbide, Nanodiamonds.

I. INTRODUCTION

Aluminum composites are combinations of materials made up of combining two or more materials in such a way that the resulting materials have certain improved properties. Aluminum Silicon carbide alloy composite materials are widely used for a many number of applications like engineering structures, industry and electronic applications, sporting goods and so on. Addition of Nanodiamonds further increases the wear resistances and strength of the alloy composite [1].

Processing methods/techniques are very important in achieving properties that meet the industrial needs. Al-SiC composites can be more easily produced by the stir casting technique due to its good cast ability and relatively inexpensive process. The most convenient and easy method for mass production is the melt stirring method. However, low wettability and particle settling are the main problems encountered for this technique. To improve wettability and particle homogeneity during casting, various method have been used including coating or oxidizing the reinforcement particles, adding some surface active elements (magnesium and lithium) into the matrix, increasing the liquid temperature and stirring of molten matrix alloy for an adequate time period during incorporation [2]. Singla et al. [2009] studied the wear properties of Al-SiC and found that wear rate decreases linearly with increasing SiC content.

Aluminium composites have improved value of coefficient of thermal expansion that is reason they are widely used in electronics industry [3]. Particle reinforced Aluminium matrix composites have considerably improved strength and hardness of Aluminium and its alloys however, at the same time, the plasticity and ductility can substantially reduce. This will severely affect the safety and reliability of components fabricated from Aluminium matrix composites (AMCs) [4]. Purohit et al.[2012] conducted tensile strength experiments by varying mass fraction of SiC (5%, 10%, 15%, and 20%) with Aluminium & obtained maximum tensile strength at 15% SiC ratio [5].

II. PREPARATION OF AL-SIC & NDS COMPOSITE

Amongst the most ancient processes of manufacturing metallic components is casting. The metal matrix composite used in the present work is prepared by the stir casting method. For the preparation of the Aluminum, silicon carbide & Nanodiamonds composite by using stir casting weight ratio of 89:10:1 is taken. The metal ingots are cleaned and melted to the desired super heating temperature of 750^{o}C in graphite crucibles. Pit furnace is used for melting. SiC particulates are preheated to around 500^{o}C for 4 hours and then added to the molten metal and stirred continuously by a mechanical stirrer at 720^{o}C. The stirring time is between 5 and 8 minutes. The super-heated molten metal is purged with nitrogen gas at a temperature of 780^{o}C.

Fig. 1. Al-10 wt% SiC & 1 wt % Nanodiamond Casting

Fig. 2. Solidification of molten AMC into steel mold

Fig. 3. Stir casting Setup

A. *Hardness Test*

Bulk hardness measurements are carried out on the base metal and composite samples by using the standard Vicker's hardness test. The Vicker's hardness measurements are carried out in order to investigate the influence of SiC & Nanodiamonds particulate weight fractions on the matrix hardness. Increased hardness was found in the samples prepared by stir casting.

B. *Microstructure Test*

Metallographic samples are sectioned from the casting. A 0.5 % HF solution was used to etch the samples wherever required. To observe the difference in distribution of SiC & Nanodiamonds particles in the Aluminum matrix, microstructure of samples were taken on Scanning Electron Microscope (SEM). Microstructures of both polished & fractured surfaces were examined. SiC particles were revealed in the micrographs but Nanodiamond particles were not detected due to their decomposition during stir casting process.

III. RESULTS

For the AMC reinforced with SiC & Nanodiamonds with weight ratio of 89:10:1, hardness of Al was found to increase from 51 VPN to 67 VPN. With the help of SEM, microstructure of the Al-SiC-Nds composite was analysed & presence of SiC particles was confirmed. According to research Nanodiamonds are decomposed above 700^{o}C [6]. So Nanodiamonds were not detected in the SEM micrographs.

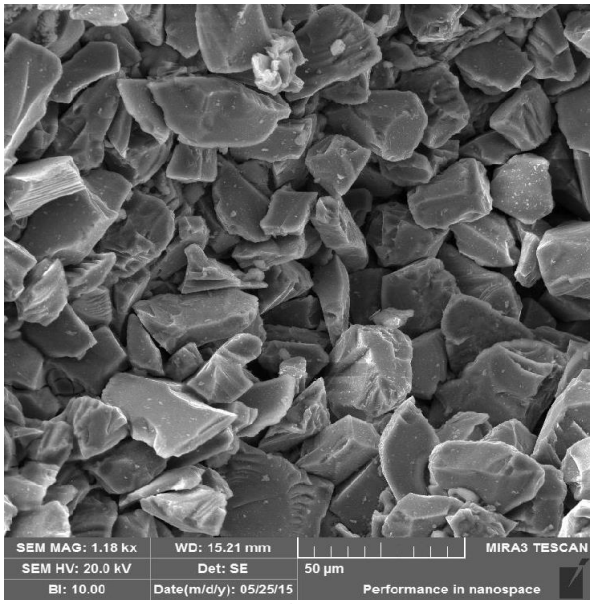

Fig. 4. SEM image of oxidized SiC particles

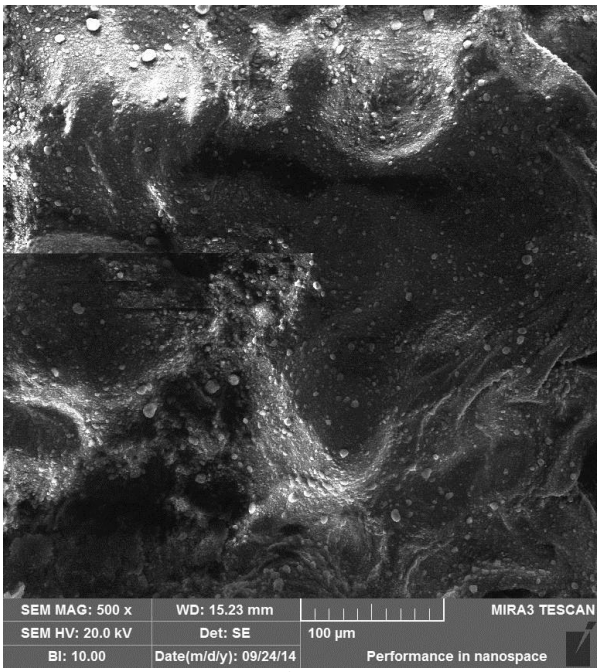

Fig. 5. SEM image of Nanodiamond particles

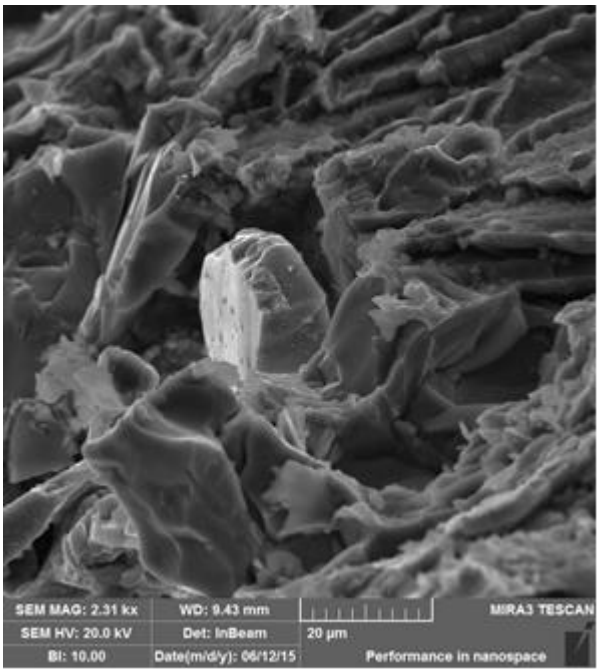

Fig. 6. SiC particle in Al matrix (SEM image of fractured surface)

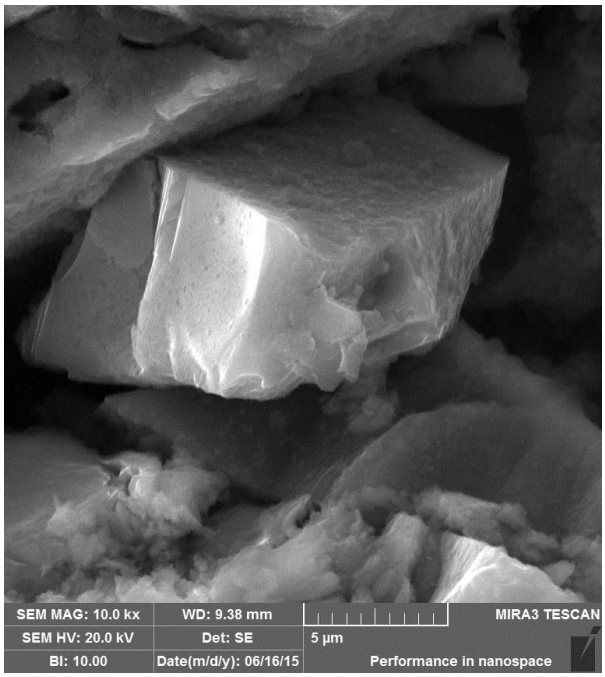

Fig. 7. SiC particles in Al matrix (SEM image of fractured surface)

IV. Conclusion

Silicon carbide & Nanodiamonds particle reinforced aluminum matrix composite (AMCs) were prepared by stir-casting with particle weight fraction of 10% SiC & 1% Nanodiamonds. The following conclusions can be drawn:

- Hardness of 'Al-SiC & Nanodiamonds composite' is much better than the aluminum metal. In case of increased silicon carbide & Nanodiamond content, the hardness, and material toughness are enhanced.
- More uniform distribution of SiC & Nanodiamonds particles can be found if composite is prepared by powder metallurgy than stir casting; however stir casting is more economical."
- Nanodiamond particles start to decompose above 700^{o}C [6]. So these particles can't be seen under SEM after stir casting.

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