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An Investigation into the Microstructure and Mechanical behavior of Aluminium Hybrid Metal Matrix Nanocomposite

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Abstract. The present study, examines microstructure characterization and mechanical behavior of fabricated Aluminums Hybrid Metal Matrix nanocomposites through electromagnetic stir casting process. Aluminum Hybrid Metal Matrix nanocomposites are made-up of Aluminum alloy as the primary phase and nano titanium diorites (TiB2) and nano graphite (Gr) reinforced materials as the secondary phase. Al7075 alloy matrix reinforced with varying weight percentage of TiB2 (0, 2.5, 5, 7.5, 10 and 12.5 wt. %) and 8wt. % Gr hybrid nanocomposites. Micro structural examination illustrations that compare to unreinforced alloy the hybrid reinforcement nanoparticles are homogeneously dispersed in the matrix alloy using optical images, Scanning Electron Micrographs (SEM), Energy Dispersive X-ray Spectrum (EDAS) and X-ray Diffraction (XRD). Several experiments are carried out to examine the mechanical behavior of fabricated nanocomposites. The samples were taken and mechanical behaviors of the nanocomposites were tested by conducting tensile and compression tests. The result revealed the presence of TiB2 hard ceramic nanoparticles in the matrix strengthened the produced nanocomposites and increased their tensile and compression strength when compared to the matrix alloy.

Keywords: Aluminum Hybrid metal matrix, Electromagnetic stirs casting, Optical images, SEM, EDAS, XRD, Mechanical behavior.

1. Introduction

Aluminium metal matrix nanocomposites have been widely applicable in marine, automotive, defense owing to significant mechanical properties like high specific strength, modulus and good wear resistance [1, 2]. The size, quantity and distribution of reinforcement as well as the morphology and bonding strength amongst the phase and matrix, controls the mechanical properties of composites [3, 4]. Uniform dispersal of ceramic particles in matrix can be achieved with various methods such as mechanical alloying [5, 6], Squeeze casting [7,8], powder metallurgy [9,10] and stir casting [11-13]. Ceramic nanoparticles were utilized as reinforcements in reinforced metal matrix composites. To improve mechanical properties of matrix alloy, various types of ceramic nanoparticles like Al2O3, SiC, TiC, TiB2 etc. were preferred. TiB2 and Gr are the most commonly utlised reinforcements in aluminium-based matrix composites because light-weight materials of high specific strength and modulus, strong wear resistance and grain refinement effects are required in automotive applications [12, 14, 15]. Kumar et al. [16] used the fabrication process stir casting procedure to create a Aluminium hybrid composite with reinforced SiC and TiC. Authors discovered, as amount of SiC and TiC particles increased, hardness increases. Uppada Rama et al. [17] employed Al 7075 as the matrix, fly ash at a fixed weight percentage, and SiCat various weight percentages, all of which were manufactured utilizing the stir casting process. Microstructure investigations revealed homogenous dispersal of reinforced SiC and fly ash particles over Al alloy, while Electron Backscatter Diffraction study revealed grain size reinforcement. T. Gunasekaran et al. [18] studied the mechanical behavior and wear resistance of Al7075 reinforced ZrO2 of varied weight percentages, manufactured using the compo casting techniques. Result shows, hardness and ultimate tensile strength have increased owing to the homogenous dispersal of ZrO2 in the matrix,In the current study, the percentages of of TiB2 and Gr reinforcements are varied and their impacts are assessed using mechanical behavior such as tensile and compressive strength. Optical microscopy, Scanning Electron Microscopy (SEM) with Energy Dispersve X-ray Spectroscopy, and X-ray diffraction analysis are used to assess the dispersal of reinforced particles and the existence of compounds and elements over the matrix alloy, respectively.

2. Material and methods

The raw materials used in this study were titanium diorite powder, graphite powder with an particle size of 80-100nm and Al7075. The chemical composition of Al7075, element wt. % are Mg -2.6, Fe-0.5, Si-0.4, Cu-1.6, Mn -0.3, Zn-6.1, Ti-0.2, Cr-0.15 and remaining is Al. Al7075 alloy based TiB2 and Gr nanoparticles reinforced composites was fabricated by Electromagnetic-stir casting process. Al7075 alloy were melted in a graphite crucible using an electric furnace with a threephase AC power of temperature above 800 ˚C with induction motor stator, vortex is generated. Then TiB2 and Gr powder were added gradually to molten matrix alloy as it melted. For improvement of wettability of TiB2 and Gr with Al7075 alloy at the temperature below 800 ˚C, K2TiF6 flux is added. The created vortex disperses the particles in the melts, resulting in a homogeneous reinforcement distribution of the reinforcements. By this, Al7075/TiB2/Gr hybrid nanocomposites are cast. The cast composite was poured into the mould cavity and allowed to solidify at room temperature.

Castings were taken by varying weight percentage of (0, 2.5. 5, 7.5, 10 and12.5 wt %) TiB2 and constant weight percentage of (8 wt%) Gr. The similar procedure was repeated for all the other hybrid composites.Optical Microscopy, Scanning Electron Microscopy (SEM) with Energy Dispersive X-ray Spectroscopy used to investigate distribution of the reinforcements in matrix. For the study of the microstructure, Standard Metallurgical methods was utilized, polishing of the composite specimens, and Keller's reagent was used as etchant. Tensile test samples was preformed via Universal Testing Machine with the standard ASTM E08-08. Compressive test samples are machined to ASTM E09-09 specifications and performed test on a Universal Testing Machine. These composite samples were machined of cylindrical shape to meet the criteria of tensile and compressive testing standards. At room temperature, the tests were run at a minimum cross head speed of 0.5mm/min. To acquire tensile and compressive test results, four samples were examined for each category,

3. Results and discussions

Microstructure Evaluation of hybrid nanocomposites Optical micrographs of the Al7075 alloy and Al7075/TiB2/8wt%Gr hybrid nanocomposites of various weight percentage of TiB2 are shown in figures 1 (a-f). In Figure 1 (a), common defects as porosity, shrinkage, slag inclusion were present and the matrix had large grain size.

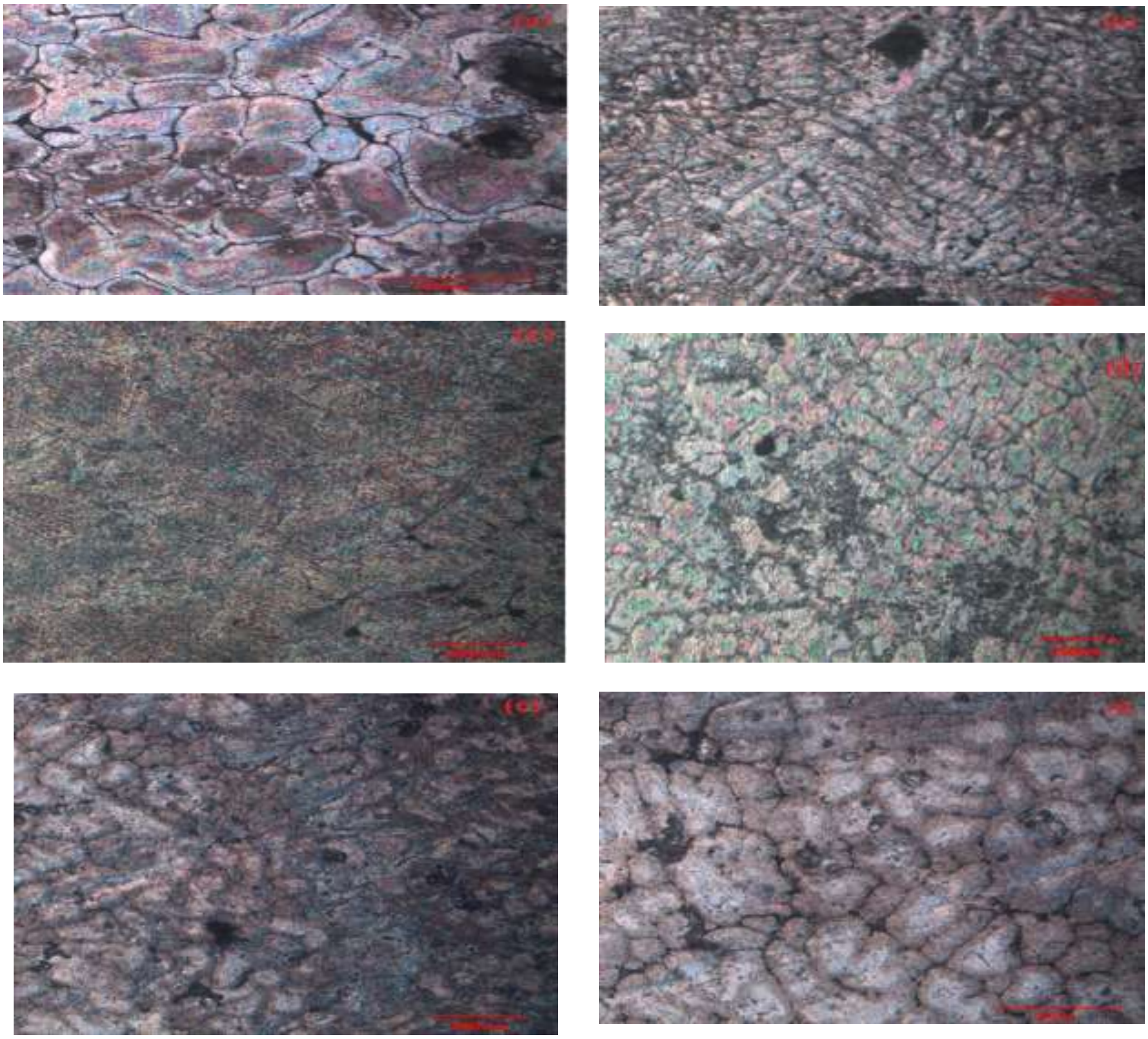


FIGURE 1. Optical images of (a) Al7075 alloy, (b) Al7075/ 2.5wt%TiB2/8wt%Gr, (c) Al7075/ 5wt%TiB2/8wt%Gr, (d) Al7075/ 7.5wt%TiB2/8wt%Gr, (e) Al7075/ 10wt%TiB2/8wt%Gr, (f) Al7075/ 12.5wt%TiB2/8wt%Gr,

From Figure 1(b-f) it was observed that these defects are decreased as the percentage of TiB2 started to increase and correspondingly grain size starts to decrease. Thisfigures shows uniform dispersal of reinforcements in the matrix which might have enhance the strength. Figure 1(f) observes the formation of no uniform dispersal of reinforced particles over the matrix alloy with more grain size, so it results in decreased mechanical properties.

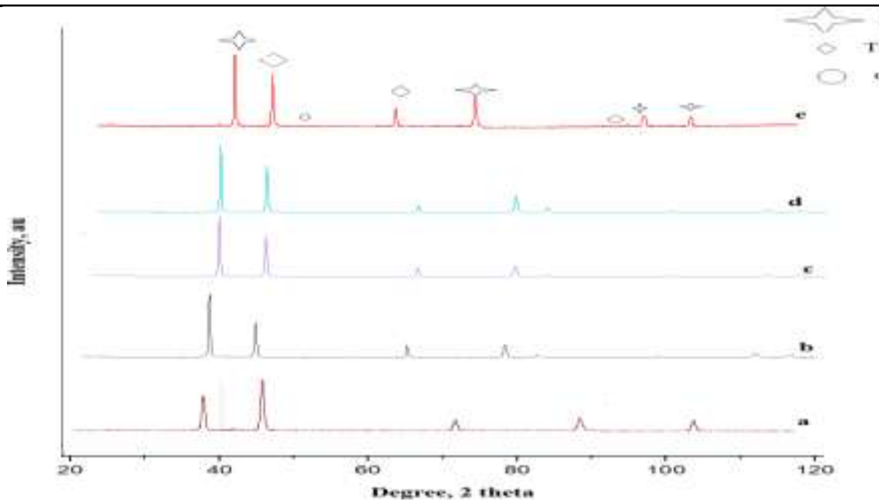


FIGURE 2. XRD of (a) Al7075 alloy, (b) Al7075/ 2.5 wt% TiB2/8wt%Gr, (c) Al7075/ 5 wt% TiB2/8 wt% Gr, (d) Al7075/7.5 wt% TiB2/8 wt% Gr,(e) Al7075/12.5 wt% TiB2/8 wt% Gr.

X-ray diffraction were used for the detection of the reinforced particles and matrix presence in the cast composites. X-ray diffraction analysis of cast composites with varying amounts of TiB2 and Gr in Al7075 alloy shown in Figure. 2. The presence of Al, TiB2 and Gr in the form of carbon are conformed by their respective peaks. Al shows the higher peaks owing to the presence of large amount of Al followed by the TiB2 and Gr. The peak intensities of TiB2 are distinctly visible and they increase with increases in the TiB2 content.Scanning Electron Microstructure micrographs (SEM) with Energy Dispersive X-ray Spectrum (EDAS) patterns of cast composites were shown in figure 3(a-d). SEM image with EDAS of Al7075 alloy are shown in figure 3(a). Figure 3 (b-d) indicates the SEM image and EDAS of various composites. The fundamental elements peaks such as magnesium, aluminium, silicon, manganese and zinc were recognized with high-intensity peaks whereas surplus elements such as carbon, nitrogen, ferrous, titanium, carbon etc. were found as low-intensity peaks. Topographical SEM images confirms the presence of TiB2 and Gr, there is no agglomeration of the TiB2 and Gr in the matrix. Most common casting defects like porosity, shrinkage, slag were not found in the SEM images. Mechanical properties Evaluation of hybrid nanocomposites: Figure 4 depicts the graphical representation of the composites tensile strength. Comparing the composite samples with the matrix alloy, the tensile strength has increased for all the composites samples. The inclusion of TiB2 nanoparticles in the composites improves the tensile strength primarily by the stress transfer from matrix alloy to reinforced TiB2 nanoparticles, whereas the addition of Gr usually reduces [19] the strength. However, at 12.5wt% TiB2 the tensile strength has slightly decreased.Figure 5 shows that as TiB2 increases, the compressive strength increases. Compressive strength of reinforced hybrid nanocomposites are superior to that of matrix alloy. It is well known that the inclusion of graphite reduces mechanical strength; therefore in order to increase the strength hard ceramic particles TiB2 were added. With adding of TiB2, the compressive strength was improved by 11% over that of the matrix, because the hybrid composites grew tougher as the TiB2 nanoparticles were added. With addition of TiB2 nanoparticles, the hybrid composites were more durable.

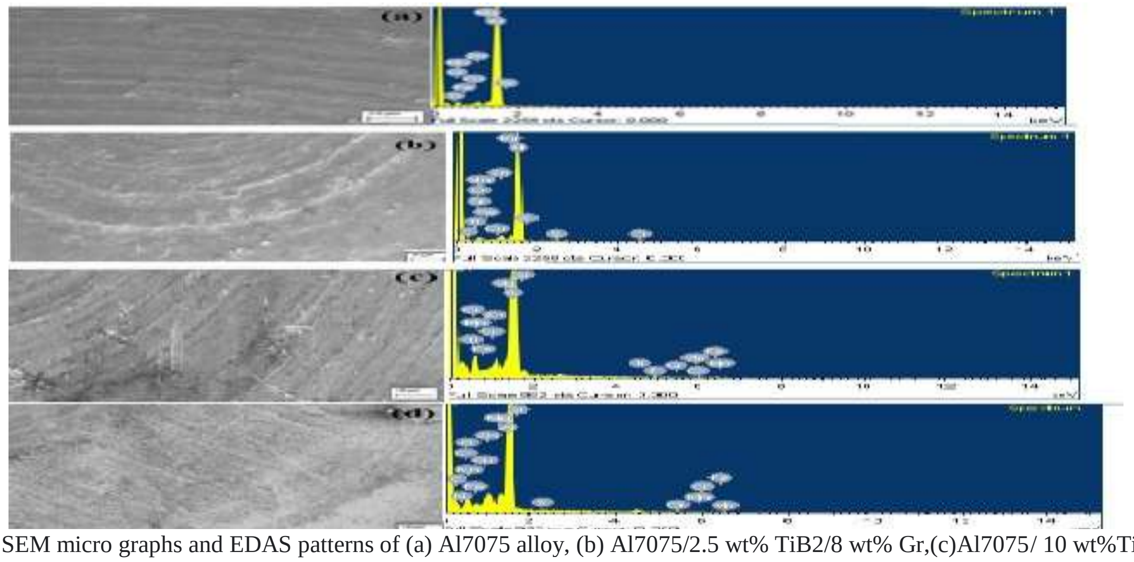
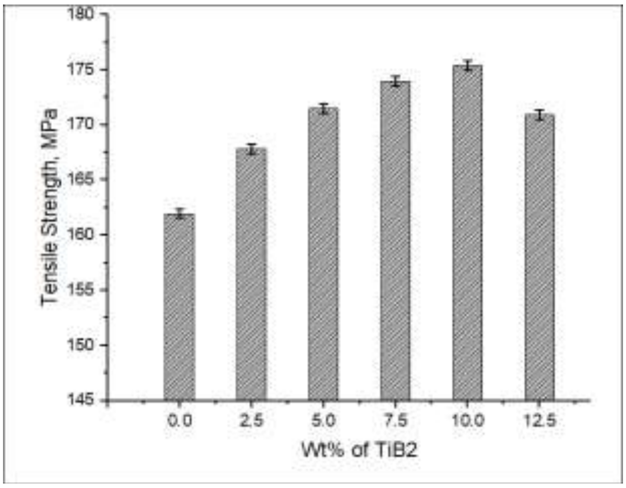


FIGURE 3. SEM micro graphs and EDAS patterns of (a) Al7075 alloy, (b) Al7075/2.5 wt% TiB2/8 wt% Gr,(c)Al7075/ 10 wt%TiB2/8 wt% Gr,(d) Al7075/12.5 wt% TiB2/8 wt% Gr



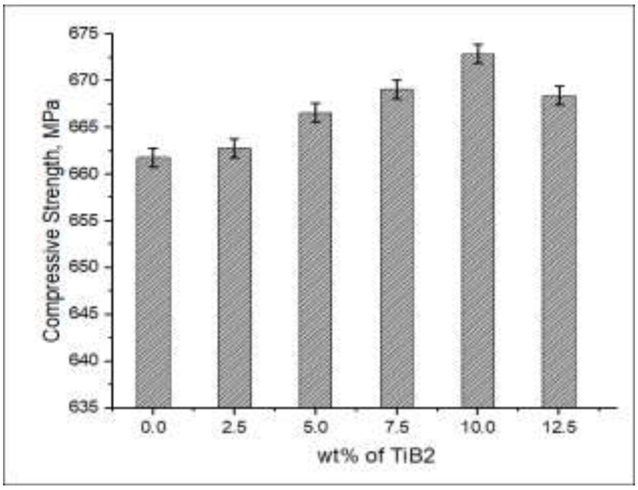


FIGURE 4. Tensile strength with varying wt% TiB2 and 8wt% Gr in Al7075 alloy; **FIGURE 5.** Compressive strength with varying wt% TiB2 and 8wt% Grin Al7075 alloy.

4. Conclusion

The Aluminium based hybrid metal matrix nanocomposites were fabricated through electromagnetic-stir casting process. The present study investigate the influence of reinforcing TiB2 and Gr in Al7075 and the following conclusions were drawn.In the Al7075 alloy matrix, Optical microstructure and SEM images demonstrate a homogenous distribution of TiB2 and Gr nanoparticles reinforcements. The existence of reinforced particles in the composites is confirmed by EDAS and XRD patterns.It is well known that adding Gr particles to Aluminium alloy reduces tensile and compressive strength, however this was overcome by using TiB2 particles in the hybrid composites. The inclusion of TiB2 particles initially enhanced the tensile strength and compressive strength of the hybrid composites, but after 12.5wt% of TiB2 particles was added, the tensile strength and compressive strength of the hybrid composites decreased, however observed higher strength to that of the matrix alloy.

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