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Influence Of Zirconium Diboride (ZrB₂) on the Physio-Mechanical Behavior of AA8011 Alloy base.

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Abstract-

The AA8011 reinforced with 5 to 20 weight percent of zirconium diboride (ZrB₂) were developed via stir casting route. In this current research work, characterization evaluation was conducted on the AA8011 alloy and its composites with the varying composition to investigate the physical and mechanical properties. The results of the mechanical properties obtained revealed an enhanced hardness and strengthening mechanism propagation of the composite in comparison to the base alloy AA8011. The experimental studies show that the addition of ceramic particles into the molten metal alloy resulted in improved properties. Also, an increase in the percentage composition of the particles leads to an increase in the strength value of the composite. Generally, the improvement in the hardening mechanical behavior of the composites can be attributed to the intrinsic properties of the incorporated particulates.

Keywords: ZrB₂; Liquid Metallurgy; AA8011; Metal Matrix Composites; Mechanical properties, Microstructure

1. Introduction

The adoption of aluminium metal matrix composite as a replacement for most structural components that are made up of light aluminium alloy in transportation, construction, food industry and in all-around engineering services has being the major trend due to lightweight, cost-effective, easy fabrication, workability, availability and ever-increasing demands of the modern state of the art technology [1-3].

[1] describe composite material as the mixture of two or more chemically distinctive and insoluble phases which amounted in properties that are more superior to those of the individual constituents. Reinforcing an aluminium alloy with particles of a second phase can improve the physical, mechanical, corrosion and tribological properties of the material or it may result in material savings at the little detriment to the properties desired [2].

Over the years, industrialization has taken a new dimension in which some light alloy materials could not stand the taste of time due to low hardness and strength mechanism, this engineered the researchers to drive their research interest towards the development of composite materials in which the properties needed are enhanced or optimized by the incorporation of hard content, mostly Nano-ceramic particles [3,4]. So many hard particles have been greatly employed for the improvement of aluminium alloy, this includes SiC, Si₃N₄, TiC and lots more which has proven to have influenced the continuous phase of aluminium alloy. The fabrication of composite materials has been successfully possible over time via numerous methods; depending on the type, size, cost, orientation and design of the material desire. Liquid metallurgy technique is one of the most adopted and widely used methods, this was made possible simply because of its countless



advantage over other methods ranging from the ability to fabricate bulk volume of materials, the possibility of avoiding clustering, and segregation with the help of the stirrer to its user-friendly simplicity and flexibility. [1-6].

There has been lots of research work by several authors on the fabrication of AMMCs with Nano-ceramic particles to consolidate on the known behaviour of the primary alloy. Hence, the essence of the present research is, therefore, to evaluate the influence of the addition of 5,10, 15, 20 ZrB₂ wt. % Nano particulates on the physical and mechanical properties of AA8011 (Al-Fe alloy) matrix.

2. Experimental Procedure

2.1 Materials

The materials used in the present study are 100 percent chemically pure Zirconium Diboride (ZrB₂) particles and Aluminum AA8011 alloy which served as the matrix. The composition of the Aluminum 8011 alloy is shown in Table 1.

Table 1: Elemental Composition of the Aluminum Alloy 8011 (AA 8011)

Mg	Si	Mn	Cu	Zn	Ti	Fe	Na	B	Sn	Pb	Al
0.47	0.46	0.09	0.14	0.22	0.01	0.61	0.01	0.01	-	0.01	97.86

2.2 Methods

2.2.1 Liquid Metallurgy Process

The AA8011/xxZrB₂ composites with various weight percent composition (0%, 5%, 10%, 15% and 20%) were developed by liquid metallurgy route. The process started with the preheating process of the Nano Ceramic material at the temperature of 450⁰C and the initial melting of the as-received AA8011 at the temperature of about 700⁰C in a graphite crucible furnace. The preheating purpose on the Nano ZrB₂ particles was done to remove impurities before introducing it into the already melted primary alloy. The preheated particles were incorporated into the melt pool of AA8011 molten and mixed together with the help of mechanical stirrer for about 5 minutes which help to agitate homogeneously and ensure cluster- free composites. The mixed Nanocomposites was then tilted into the mold of dimension 200 mm x 30 mm for solidification. The composites fabricated are machined for various properties test and characterization [5,6].

Table 2: Material Composition of the Composites

AA8011(%)	ZrB ₂
100	0
95	5
90	10
85	15
80	20

2.3 Density Measurement

The density of the materials was carried out to determine the percentage densification as well as the porosity levels of the composites. The density of AA8011-ZrB₂ was estimated both theoretically and experimentally to find its accurate densification. The experimental density of fabricated AA8011-ZrB₂ metal matrix composite was measured by the Archimedes principle, and the theoretical density was measured by the rule of mixture method.

2.4 Hardness Measurement

The hardness of the composites was evaluated in this study using Vicker's hardness tester (FM-800, Japan) with diamond indentation. Prior to testing, the surface of the composite test specimens of sizes 10 mm × 10 mm were made available for the metallographic surface operation to obtain a flat and smooth surface finish. The specimens are then subjected to a test force of 100g force, dwell time of 15 seconds at 3 points indentation.

2.5 Tensile Test

The universal tensile testing machine TQ 1000 was employed according to the ASTM standard procedure to examine the ultimate tensile strength of the samples.

3. Results and Discussion.

3.1 Percentage Porosity and Densification

The results of the percentage porosity and relative density (densification) of the composites are presented in figure 1 a and b. From the figures, the relationship between the porosity, relative density (densification) and percent content of the particles shows that there is a gradual decrease in densification but increase in porosity with increase in ZrB₂ content, this is due to the hardness of ZrB₂ which acts as a boundary against composite mixing thereby preventing the densification of the particles [7]. The low porosity levels and overall high densification are attributed to the process parameters of the two-step stirring process employed for producing the cast.

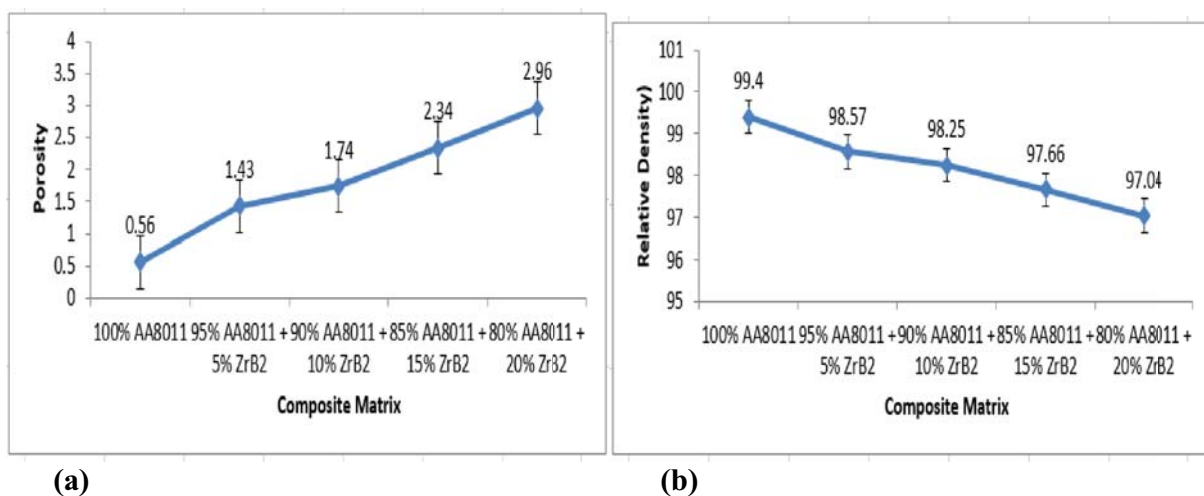


Figure 1: Progression of porosity and Relative Density of Reinforced AA8011 alloy

3.2 Mechanical Properties

3.2.1 Hardness

The microhardness analysis was conducted to observe the degree of resistance by the developed composite to plastic deformation. figure 2 presents the variation of microhardness value with volume percent of ZrB₂. When the reinforcement, is 0% the hardness is 50.48, at 5% the hardness is 57.19 and at 20% reinforcement, the hardness increases to 66.62%. This depicts that the improvement of the material hardness is a function of the increase in the volume fraction of ZrB₂. This improvement in the hardness of AA8011/ZrB₂ is due to an increase in the proportion of the hard ZrB₂ particles in the composites, which invariably increases the resistance of the composite to plastic deformation [6,7]

The improved hardness behavior of composites can also be attributed to the grain refinement of the matrix alloy, wettability between the particulate and the metal matrix, and the uniform distribution of reinforced ZrB₂ particulates [8].

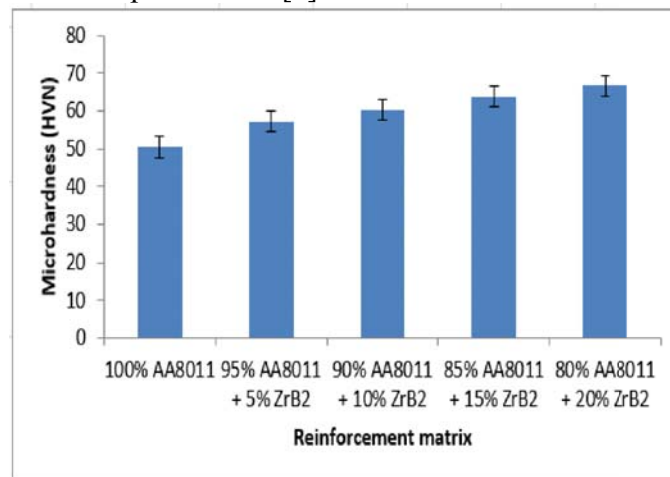


Figure 2: Variation of Microhardness of Reinforced AA8011 Alloy

3.2.2 Tensile Strength and Yield Strength Propagation

Figure 3a and b present the progression of the strengthening mechanism of AMMCs, the tensile analysis was carried out to obtain the optimum results of the tensile strength and yield strength of the developed composites.

From the plots, the ultimate tensile strength and the yield strength of AA8011-ZrB₂ increase with the increase in ZrB₂ addition to the molten metal. Composite with 20% additives was observed to possess better strength with UTS of 221.6 and YS of 172.87 as revealed in figure 5a and b respectively.

Generally, the strengthening mechanism can be ascribed to the higher hardness of Nano ZrB₂ which resulted from the close-packed orientation of the particles that were embedded within the soft aluminium matrix (AA8011) [9,10].

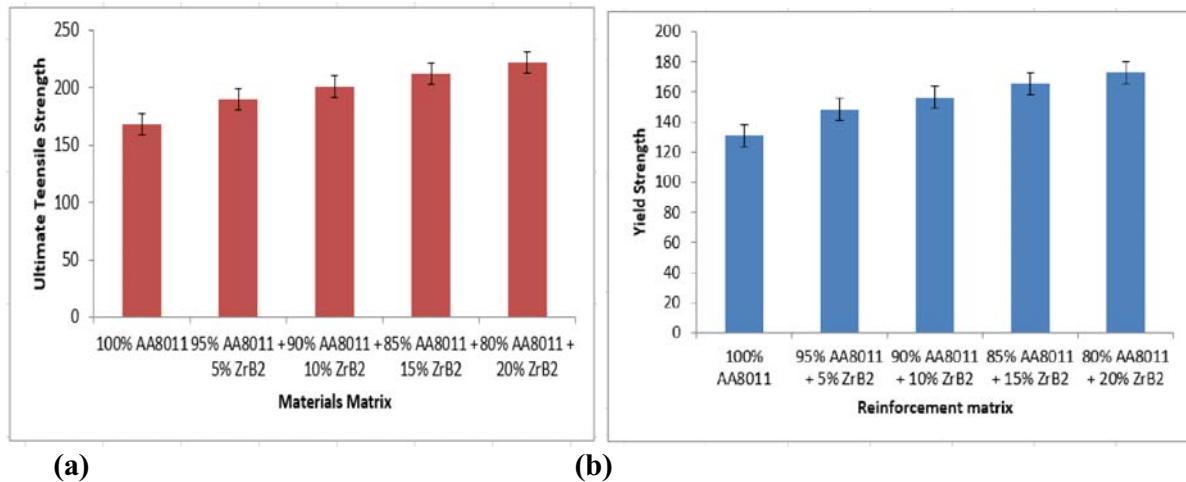


Figure 3 (a and b): Variation of Ultimate Tensile Strength and Yield Strength of AA8011 /xxZrB₂.

4. Conclusions

The AA8011 - ZrB₂ composites were fabricated successfully via liquid metallurgy route with varying ZrB₂ wt. % (5%, 10%, 15%, and 20 %) of reinforcement and the microstructure, physical and mechanical properties were evaluated. The casting of AA8011-ZrB₂ composites via liquid metallurgy route resulted in homogenous dispersion of the Nano particulates embedded in the molten AA8011. The porosity of the composites increases with an increase in the volume fraction of reinforcement. The mechanical behavior of the composites increases linearly with the volume fraction of the particulates and higher mechanical strength was observed in composite with 20 percent volume of ZrB₂.

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