Mechanical Characterization of Aluminum-TiB_2 Metal Matrix Composites by In-Situ Method

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ABSTRACT: In the current day engineering design and development activates many Scientists, Researchers and Engineers are striving hard to develop new and better engineering materials, which accomplish high strength, low weight and energy efficient materials since the problems of environment and energy are major threshold areas. The development of new materials is growing day by day to replace the conventional materials in aerospace, marine engineering, automobile engineering industries etc., hence, composite materials are found to be an alternative.

In this paper attempts are made to develop Al 6061-Mg-TiB_2 composite materials for light weight applications using In-situ salt reaction stir casting process by varying the weight percentage of TiB_2 (0,3,6,9 and 12 wt %).Microstructure and Mechanical characterization was carried out as per ASTM Standard which includes SEM, XRD analysis, micro hardness, tensile strength and ductility tests. It was noticed that the composites developed exhibit greater properties when compared with matrix alloy.

Keywords*: Al6061, TiB_2, Halide salts, Microstructure and Mechanical properties.*

1. INTRODUCTION

Composite materials are the mixture of two or more materials which are different in its form and chemical composition. These materials are widely used in many engineering applications generally composites are classified based on the matrix and reinforcement [1, 2, 3]. Aluminum based metal matrix composites have good specific modulus, strength, wear and fatigue characteristics so that these composites play very significant role in the field automobile, aerospace, chemical and transportation industries [4, 5, 6].Aluminum 6061 is the mainly used 6xxx series which offering good mechanical, corrosion resistance, and workability [7, 8, 9].

Among various reinforcements titanium diboride is an exceptional ceramic material due to its high strength, hardness, superior wear resistance and good thermal stability and more prominently it does not react with molten aluminum [10, 11, 12]. The aluminum 6061 embedded with different ceramic particles can be synthesized using various manufacturing methods like stir casting, in situation stir casting process, powder metallurgy, squeeze casting etc.,[14,15,16]. In situation stir casting process has been found to be one of the most essential techniques in the fabrication of aluminum reinforced with TiB_2 due to the fact that this process is thermodynamically stable, uniform distribution of reinforcement in the matrix and economical. [17, 18, 19]. Composites are synthesized using an exothermic reaction route with addition of inorganic salts like K_2TiF_6 and KBF_4 [21, 22].

2. EXPERIMENTAL PROCEDURE

Al 6061 alloy reinforced with TiB_2 by varying different wt fractions are used to prepare composite material to study the mechanical characteristics of the composite materials developed using In-situ technique.
In this process, the reinforcement phase is formed in situation, by adding halide salts to form required combination of composites.

Table.1 Chemical Composition of Al 6061 alloy

Element	Mg	Fe	Si	Cu	Mn	V	Ti	Al
Weight %	1.08	0.17	0.63	0.32	0.52	0.01	0.02	Balance

Al 6061 rods were weighed and placed in a coated graphite crucible and heated using an electrical furnace up to 850°C. The chemical composition of Al 6061 aluminum alloy is presented in Table 1. A coating was applied inside the crucible to avoid contamination. The temperature of the molten aluminum was maintained at 850^{0}C. The measured quantities of inorganic salts like K_2TiF_6 and KBF_4 were added into the molten aluminum and thoroughly stirred using a graphite stirrer at intervals of every 10 minutes. A total reaction holding time for about 45 min to 1 hr to form titanium diboride and then 1.5 Wt % of magnesium was added and stirring was continued so that the TiB_2 and Mg particles are completely dispersed in to the molten alloy [15, 16, 18, 22].

After solidification process castings were obtained as shown in Figure 4. Machining of the composites was carried out as per different ASTM standards to conduct morphological study and various mechanical tests.

Aluminum 6061 reinforced with TiB_2 particulates were successfully synthesize by the in situation salt metal reaction of K_2TiF_6 and KBF_4 salts. During in-situ reaction process, the elements Ti and B are introduced from the two salts into the molten aluminum and made to react within it [18, 19,22].

As the salts are mixed stoichiometrically to form TiB_2, TiB_2 is the only intermetallic phase to be formed by the reaction which is given below [15, 23].

$$3K_2TiF_6+13Al \leftrightarrow 3Al_3Ti+3KAlF_4+K_3AlF_6 \quad (3.1)$$
$$2KBF_4+6Al \leftrightarrow 4AlB_2+2KAlF_4 \quad (3.2)$$
$$Al_3Ti+ AlB_2 \leftrightarrow TiB_2+4Al \quad (3.3)$$

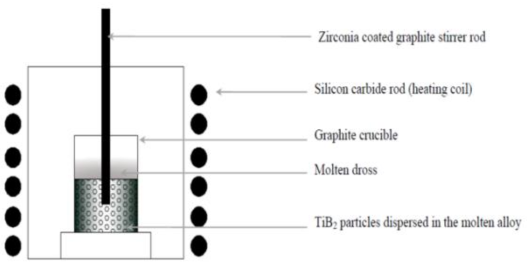


Fig 1: Schematic Setup for Composite preparation

Fig. 2 Aluminum Rods

Fig. 3 Metal Mould

Fig.4 Molten metal in the Mould

3. RESULTS AND DISCUSSION

Microstructure

The SEM images of the composites developed are shown in Figure.5 (a-e). It is noticed from the micrographs the castings are free from severe defect such as porosity, shrinkages and slag inclusion which shows the quality of castings. Solidification process dictates the uniform distribution of TiB_2 particles in the matrix [17] .The in situ formed TiB_2 particles are distributed homogeneously in the aluminum matrix. The in situ formed TiB_2 particles are distributed homogeneously in the composites which are an important requirement to achieve better mechanical properties. It is evident from the images that TiB_2 particles appear to be distributed uniformly in the composites developed Figure.5 (a-e). Further it is noticed that porosity in the composites having weight fraction less than 6% of TiB_2 and 1.5% Mg is less thus enhancing the bonding between the matrix and particulates. Beyond 6 wt. % of TiB_2 clustering of particles is noticed and it indicates the formation of hard and brittle Al_3Ti intermetallic phase which decreases the ductility of the composites. It is evident from the images that in situ formed TiB_2 particles exhibit various shapes. [18, 19, 27].

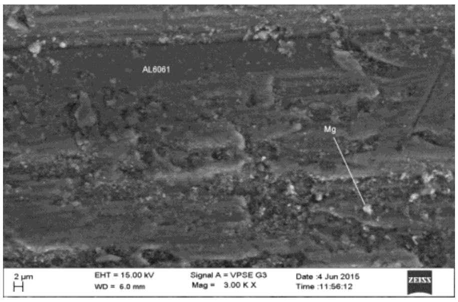


Fig:5(a)

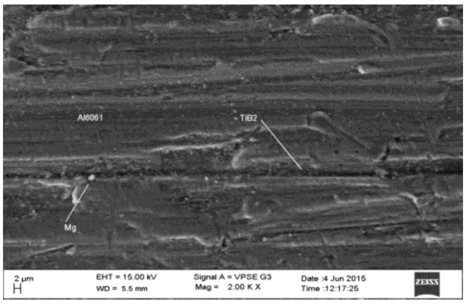


Fig:5(b)

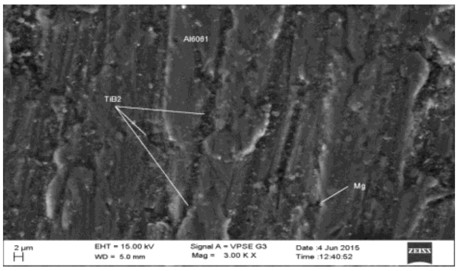


Fig:5(c)

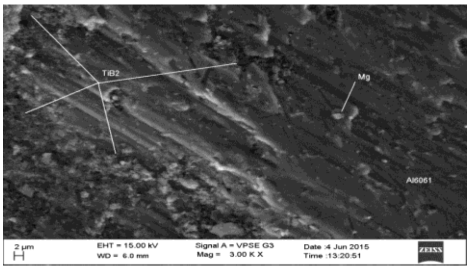


Fig:5(d)

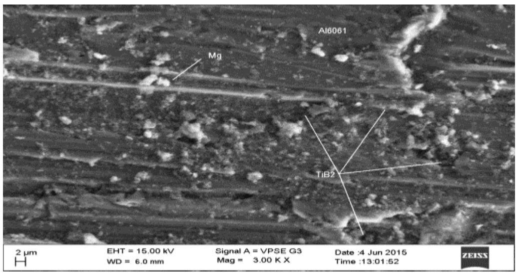


Fig: 5(e)

Fig: 5 (a-e) Microstructure of Al 6061-Mg -TiB_2 Composites

X-ray Diffraction Analysis

XRD pattern of the composites shows the characteristic peaks in the XRD pattern were consistent with JCPDS files. Figure.6 shows the XRD results of the developed composites with their intensity peaks confirms the formation of TiB_2 in the matrix. [17]

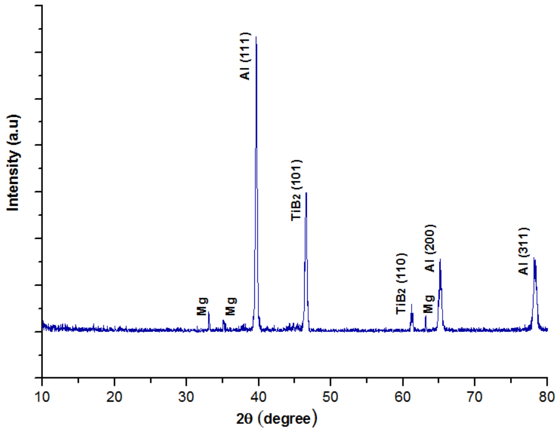
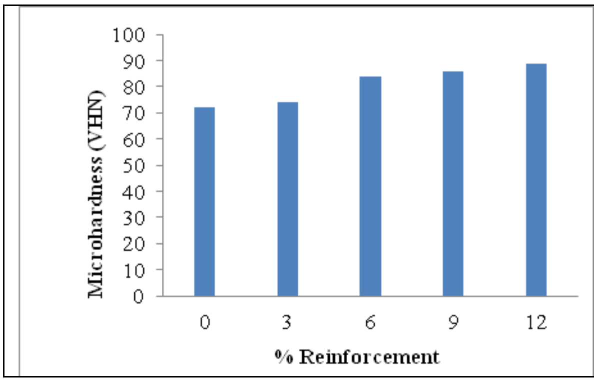


Fig 6: XRD pattern of Al 6061 -6% TiB_2

Micro hardness

Hardness tests were conducted as per ASTM E-384 to determine the hardness of the composites developed.



Description	Micro hardness (VHN)
0	72
3	74
6	84
9	86
12	89

Fig.7: Variation of Micro hardness

Table.2 Micro hardness Test Results

Fig 7 shows the hardness number of different Wt % of TiB_2 reinforcement. A significant raise in hardness of the alloy matrix can be seen with addition of TiB_2 particles. Higher value of hardness is comprehensible indication of the fact that the presences of particulates in the matrix have enhanced the overall hardness of the composites. This is true due to the fact that whenever a hard reinforcement is added in to a soft ductile matrix, the hardness of the material is enhanced [7, 8 10].The hardness of the composites is influenced by grain improvement of matrix and quality of the reinforcement fused. It is also reported that fabrication process and soundness of the castings are greatly influences the hardness of MMC's [14, 17]

Tensile Strength

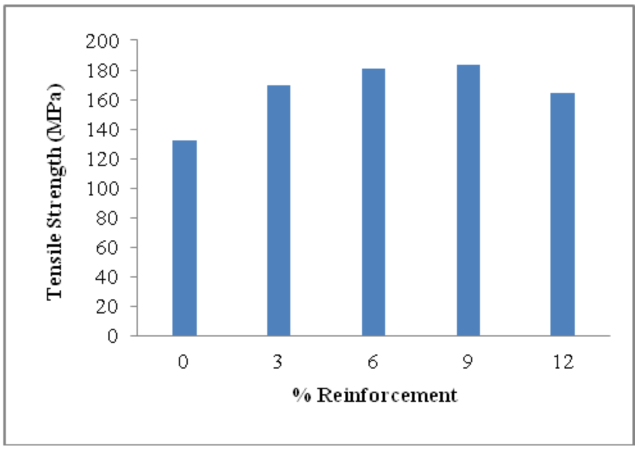


Fig 8: Variation of Tensile strength

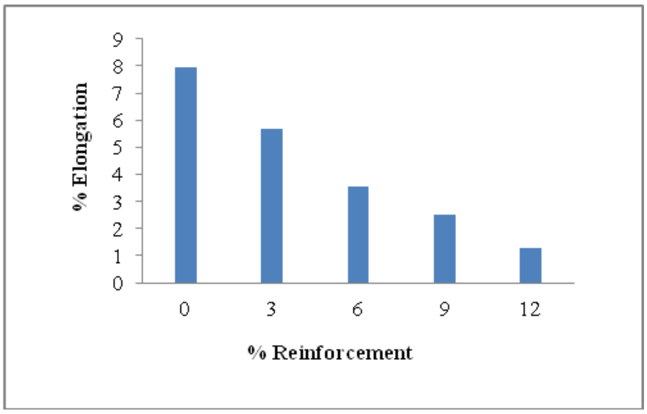


Fig 9: Percentage Elongation.

Table.3 Tensile Test Results

Description	Tensile Strength MPa	Ductility %
0	132.14	7.96
3	169.16	5.68
6	181.3	3.56
9	183.08	2.5
12	164.5	1.3

Table 3 shows the tensile strength of different wt. % of TiB_2 reinforced composites. It is observed from the Figure 8 that tensile strength increases with the increase in the addition of TiB_2. Further, it is evident that tensile strength of 3, 6, 9 and 12 wt. % of TiB_2 are increased as compared to the base alloy. Tensile strength of the composites is decreased with the addition of TiB_2 reinforcement beyond 9 wt. % this is attributed to the clustering of particles at the interface, TiB_2 particles interact with each other leads to decrease in the density of melt which reduces grain size of aluminium alloy thereby lowering the tensile strength.[7,8]

However, the composites synthesized exhibited lesser elongation than that of base material. It is clear that plastic deformation of the mixed soft metal matrix and the non-deformable reinforcement is more difficult than the base metal [15, 22] As a result, the ductility of the composite materials decreases when compared to that of unreinforced alloy.

4. CONCLUSIONS

The mechanical characterization of Aluminum 6061 alloy composites reinforced with Mg and different weight % of TiB_2 particles was successfully synthesized by In-situ reaction process using halide salts. The study reveals that SEM images and XRD patterns clearly shows the presence of TiB_2 particles with a good bond between the matrix and the reinforcement. The in-situ stir casting TiB_2 particles are distributed homogeneously in the composites which are an important requirement to attain improved mechanical properties.

From the result, it is observed that addition of the TiB_2 particles enhances the load carrying capacity of 3, 6, 9 and 12 wt. % of TiB_2 as compared to the base alloy. Improvement in the load carrying capacity is due to the uniform distribution of TiB_2 particles, fine size of TiB_2 particles formed during in situ process.

Tensile strength of the composite was significantly higher than matrix alloy. However, composites exhibited lower ductility when compared to the matrix alloy.

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