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Microstructure and Mechanical Properties of Al7075-TiB_2 in-situ composite

R.Keshavamurthy[1], Sadananda Mageri[2], Ganesh Raj[2], B.Naveenkumar[2], Prashant M Kadakol[2] and K.Vasu[2]
[1]Department of Mechanical Engineering, Dayananda Sagar College of Engineering, Bangalore, Karnataka, INDIA
[2]Department of Mechanical Engineering, Government Engineering College, Ramanagaram, Karnataka, INDIA

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Abstract

Al7075-TiB_2 in-situ composite was processed by stir casting technique using commercially available Al-10%Ti and Al-3%Br master alloys. Both matrix alloy and composite were subjected to microstructure analysis, microhardness test, grain size studies and tensile test. Microstructure shows fairly uniform distribution of TiB_2 particles in matrix alloy. Average grain size of the composite was lower than unreinforced alloy. Microhardness, yield strength and ultimate tensile strength of Al7075-TiB_2 composite are considerably higher when compared with unreinforced alloy. However, the ductility of the composite was decreased when compared with unreinforced alloy.

Keywords: Metal matrix composite, In-situ reaction, Al7075, Titanium di-boride.

Introduction

Aluminum based metal matrix composites are most promising materials owing to their excellent properties, low cost and ability to be formed using conventional metal processing techniques[1-2]. Combining ductility and toughness of the soft matrix material and strength, hardness and modulus of hard reinforcement material, excellent mechanical and tribological properties can be obtained in composite materials[3-4]. However, there still exist challenges in producing high quality metal matrix composites, the major issues are achieving excellent bond between matrix and reinforcement and reducing interfacial reaction between reinforced particles and matrix alloy[5-7]. The above problems that are associated with metal matrix composites can be addressed by adopting in-situ method of fabricating metal matrix composites. In-situ technique involves production of reinforcing particles inside the matrix material. Reduced size and even distribution of reinforced particles in matrix material – are the other advantages of in-situ composites over ex-situ techniques[8-9]. In the light of the above, the present investigation has been focused on development of Al7075-TiB_2 composites and its characterization by optical microscopy and X-ray diffraction technique. Its tensile properties, hardness and grain size were also evaluated and compared with matrix alloy.

Al-10%Ti and Al-3%Br master alloys were used along with Al7075 matrix material to fabricate Al7075-TiB_2 composites. The chemical composition of master alloys used in the present study is reported in the table-1. Both matrix material and master alloys were procured from M/s Fen fee Metallurgicals, Bangalore, India.

Material and Methods

Material and composite preparation: Al7075 alloy was used as matrix material in the present study. Table-2 shows the chemical composition of Al7075 alloy used in this study.

Table-1
Chemical compositions of master alloys

Al–10%Ti master alloy		**Al–3%B master alloy**	
Element	Percentage	Element	Percentage
Ti	10.27	B	2.94
Fe	0.37	Fe	0.32
Others	0.11	Others	0.10
Al	Balance	Al	Balance

Table-2
Chemical composition of Al7075 alloy

Element	**Cu**	**Cr**	**Mn**	**Mg**	**Si**	**Ti**	**Zn**	**Fe**	**Al**
Percentage	1.8	0.2	0.4	1.9	0.5	0.15	3.25	0.5	Balance

Stir casting technique was adopted to fabricate Al7075-TiB_2 composites owing to its low cost and ease of manufacturing. 2kgs of Al 7075 alloy with 10wt% of Al-Ti alloy and 20wt% of Al-3% Br master alloys were melted in the 6kw electrical resistance furnace to a temperature of 810°C. The liquid alloy was agitated by use of mechanical stirrer / blade rotating at a speed of 200 rpm for duration of 20 minutes. The temperature of composite melt maintained at 810°C was then poured in to metallic moulds. The percentage of TiB_2 formation in the composite was estimated by dissolving known quantity of sample in hydrochloric acid[10]. The matrix was disintegrated in the acid and leaving TiB_2 / Al_3Ti particles. The separated particles were dried, cleaned and weighed. The difference in the weight of the composite and separated particles was considered for estimating percentage of TiB_2 and Al_3Ti particles. The percentage of TiB_2 in the separated particles was measured by comparing the ratios of peak intensities of TiB_2 and Al_3Ti obtained from x-ray diffraction analysis.

XRD, microstructure, microhardness and Tensile properties: Both matrixes material and composite were subjected to optical microstructure studies. Standard metallographic procedure was adopted to polish the samples. Polished surfaces were etched with kellers' reagent (5ml HNO_3, 3ml HCl, 2ml HF and 190ml H_2O). Microphotographs were captured using NIKON metallurgical microscope (Model: ECLSE LV 150). Grain size studies were performed as per ASTM E112 standard test method at Advanced Metallurgical Laboratory, Peenya, Bangalore, India, using Clemex Image analyzer software.

Microhardness studies were performed on metallographically polished samples of unreinforced alloy and composite, by applying 100 grams of load for a period of 10 seconds using Vickers micro hardness tester (Model: MRB 250). The test was performed at four different regions in order to contradict the probability of indentor resting on the hard TiB_2 particles. The mean of all the four readings was considered as hardness of sample. X-ray diffraction patterns were recorded using Philips X-ray diffractometer, at Indian institute of Science, Bangalore.

Tensile properties of unreinforced alloy and developed composite were evaluated using TUE-C –400 tensile testing machine as per ASTM A370 standards at M/s. Advanced Metallurgical Laboratory, Peenya, Bangalore, India. Yield strength, Ultimate tensile strength and ductility were evaluated. An average of three results was taken as strength of each material.

Results and Discussion

X-ray diffraction analysis: Figure-1 shows the X-ray patterns of extracted TiB_2 and Al_3Ti. The X-ray diffraction pattern clearly indicates presence of TiB_2 and Al_3Ti particles. Based on the relative fractions of the intensity of the peaks TiB_2 particles were calculated. From the XRD pattern, the relative fractions of TiB_2 particle are found to be 8.5% approximately.

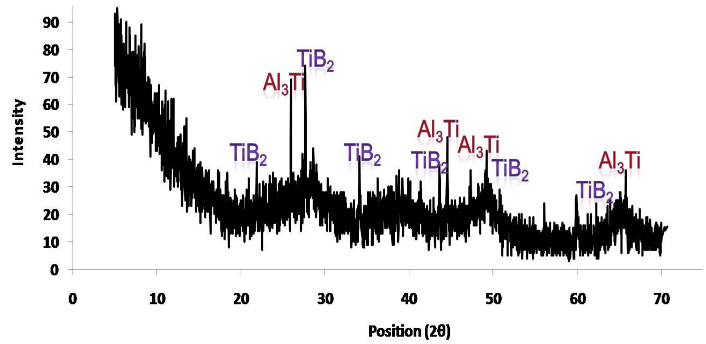
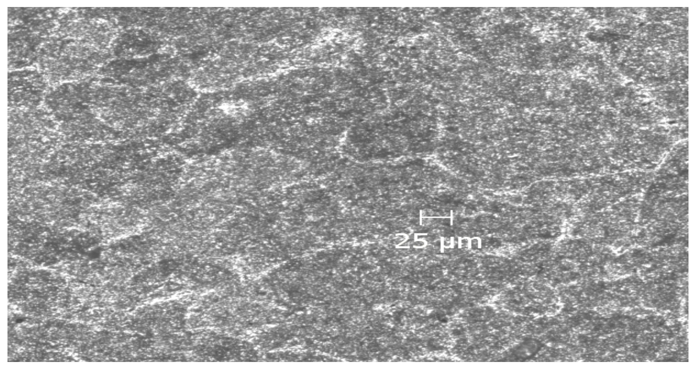
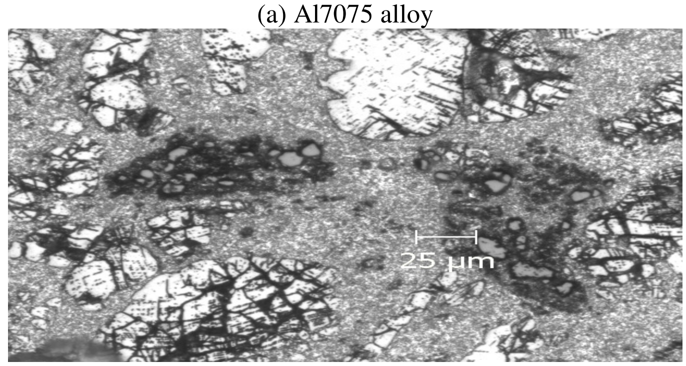


Figure-1
X-ray diffraction pattern of extracted TiB_2 and Al_3Ti

Optical Micrograph studies: Figure-2 (a-b) shows the optical micrographs of Al7075 alloy and Al7075-8.5wt% TiB_2 composite. It is observed that the fine TiB_2 particles are distributed evenly throughout the matrix alloy. In addition to TiB_2, $AlTi_3$ particles were also seen in the composites.

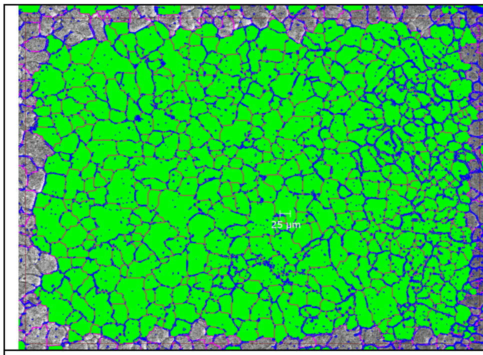


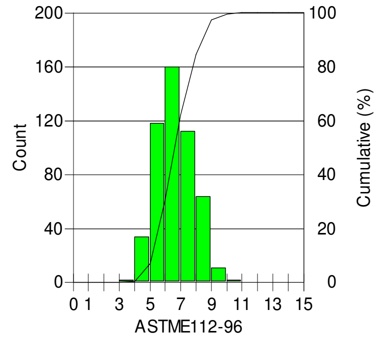
(a) Al7075 alloy



(b) Al7075-8.5wt%TiB_2 composite
Figure-2 (a-b)
Optical microphotographs of Al7075 alloy and Al7075-8.5wt%TiB_2 composite

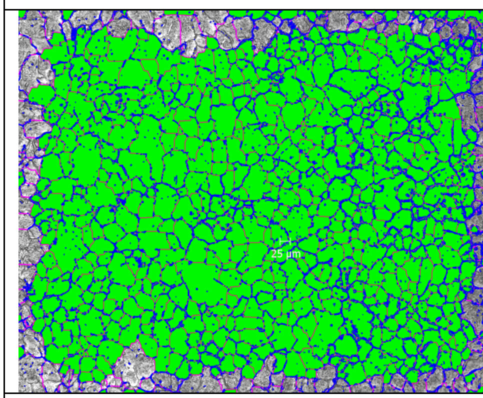
Grain size analysis: Figure-3(a-b) shows the details of grain size analysis of Al7075 alloy Al7075-8.5wt% TiB_2 composite. The grain rating of the composite is lower than the Al7075 alloy which indicates that the average grain size of the composite is lower than the matrix alloy. The decrease in the grain size of the composite may be attributed to presence of fine TiB_2 particles. Further, the solute boron content also helps in grain refinement[11].

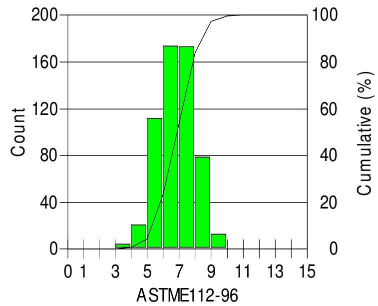




Rating #:6.12

a) Al7075 alloy





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b) Al7075-8.5wt%TiB_2 composite

Figure-3
(a-b) Details of grain size analysis of Al7075 alloy Al7075-8.5wt%TiB_2 composite

Microhardness: Figure-4 shows the variation of microhardness of Al7075 alloy and Al7075-TiB_2 composite. It is observed that there is a remarkable improvement in the microhardness of the composite when compared with unreinforced alloy. An improvement of 32.5% is observed in the hardness of the composite when compared with the unreinforced alloy.

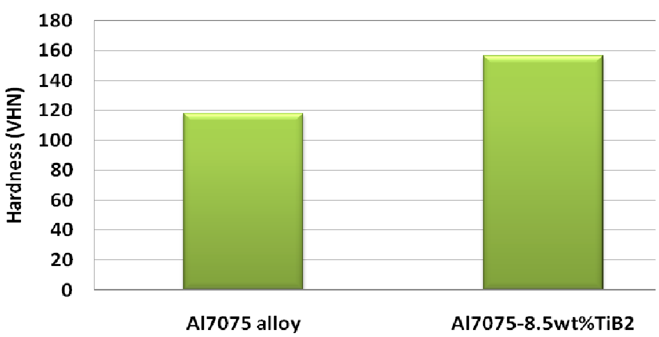

Figure-4
Hardness of Al7075 alloy and Al7075-TiB_2 composite

TiB_2 being a hard reinforcement, it renders the inherent property of hardness to the matrix material, thereby enhancing its resistance to deformation. It is an experimentally proven fact that addition of hard reinforcement into a soft ductile matrix material like aluminum alloy, the hardness of the matrix material can be improved significantly[12]. The hardness behavior of composite is also affected by grain refinement of matrix alloy and fine and even distribution of reinforced particles. Reduction in grain size always enhances the hardness of the composites. Smaller the grain size, higher will be the obstructions for dislocation motion, thereby improving the resistance to plastic deformation resulting in increased hardness[13].

Tensile Properties: Variation of ultimate yield strength and ultimate tensile strength of Al7075 alloy and in-situ Al7075-TiB_2 composite is shown in figure-5 and figure-6 respectively. It is observed that composite shows higher ultimate tensile strength and yield strength when compared with unreinforced alloy. A maximum improvement of 33.9% and 13.55% has been observed in tensile strength and yield strength of the composite. Basically tensile properties of composite material are a strong function of nature and properties of reinforced particles and matrix alloy. The excellent interfacial bond between matrix and reinforcement played a important role in improving the tensile properties of composites. The fine size and shape of the reinforcement also contributed to the improvement in the ultimate tensile strength and yield strength of composite. The improved ultimate tensile strength and yield strength of the composite can also be attributed to higher hardness of the composite and superior mechanical properties of TiB_2 particles.

Improved ultimate tensile strength of the developed composite can also be attributed to the interaction between TiB_2 particles and dislocations when composite experience the load. Increased dislocations are introduced during composite processing due to variation in co-efficient of thermal expansion between matrix alloy and TiB_2 particles. These reinforcement particles act as obstacles to the movement of dislocations under load. It may be noted that, even dispersion of reinforcement helps in efficient load transfer from matrix material to reinforcement which results in enhanced strength of the composite.

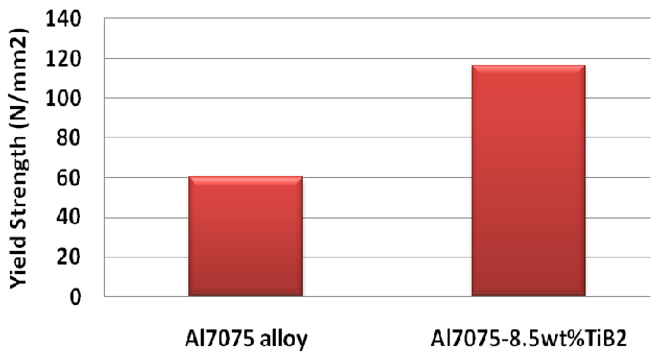

Figure-5
Yield strength of Al7075 alloy and Al7075-TiB_2 composite

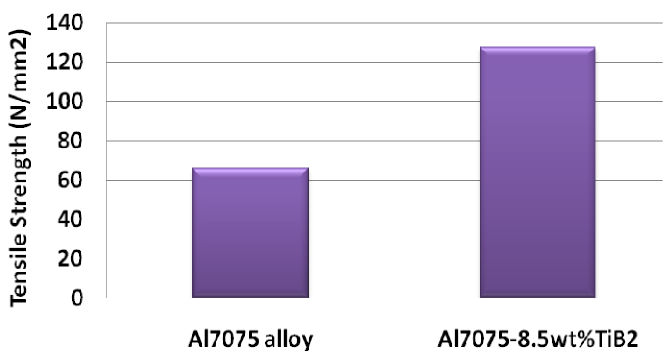

Figure-6
Tensile Strength of Al7075 alloy and Al7075-TiB_2 composite

Figure-7 shows the ductility of Al7075 alloy and Al7075-TiB_2 composite. It is observed that, the ductility of the developed composite is lesser than the Al7075 matrix alloy. Reduction in the ductility of the composite may be ascribed to presence of hard TiB_2 particles. A decrease of 36% is observed in the ductility of the composite when compared with the unreinforced alloy.

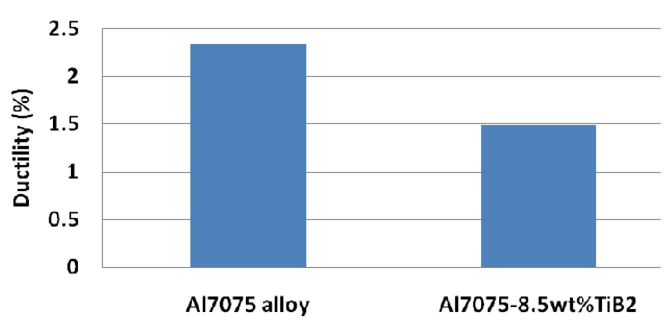

Figure-7
Ductility of Al7075 alloy and Al7075-TiB_2 composite

Conclusion

Al7075-TiB_2composite was fabricated successfully using Al–Ti and Al-Br master alloys by stir casting technique. Optical micrograph shows reasonably uniform distribution of TiB_2 and $AlTi_3$ particles. A considerable improvement in the hardness of the composite is observed when compared with the unreinforced alloy. Al7075-TiB_2 composite exhibited higher tensile strength, yield strength and lower ductility when compared with unreinforced alloy.

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