COMPARISON OF REINFORCEMENT ADDING TEMPERATURE ON STRUCTURE PROPERTY AND MECHANICAL BEHAVIOR OF Al - MATRIX COMPOSITE REINFORCED WITH TiB_2 CERAMIC PARTICLES

F. Abdi[1], H. Abdizadeh[2*], K. Shirvani Moghaddam[3], and H.R. Baharvandi[4]

[1,3]Azad University of South Tehran, Tehran, Iran
[2]School of Metallurgy and Materials Engineering-University of Tehran, Tehran, Iran
[4]Malek Ashtar University of Technology, Tehran, Iran
[*]abdizade@ut.ac.ir

ABSTRACT

Cast metal matrix composites fabricated through stir casting method have the cost advantages over the composites made by other processing techniques. These kinds of composites have a good wear resistance, hardness and thermal properties. In this study, physical properties and mechanical behavior of aluminum matrix composites reinforced by TiB_2 under different temperature conditions has been investigated. Samples were made using aluminum alloy A356.1 as matrix metal and TiB_2 particles (1 micron size) as reinforcement material in different casting temperatures (750, 850, and 950^{0}C) with 5%volume percent of TiB_2 particles. The microstructure and mechanical behavior of composite samples were studied. Results showed that TiB_2 particles are homogeneously dispersed throughout the matrix metal. The hardness and tensile strength of the composites are higher than those of the monolithic aluminum and the best processing temperature in this study seems to be 950^{0}C.

Keywords: Aluminum Matrix Composites, Reinforcement, TiB_2, Microstructure, Mechanical Behavior, Casting.

1. INTRODUCTION

Metal matrix composites are produced from metals and ceramics to obtain the unique combination of properties such as high modulus, strength and wear resistance, good ductility and thermal conductivity, low density and thermal expansion [1-3]. To produce these composites, both solid and liquid phase processing methods have been used; the later have the advantages that the fluidity of the metal allows for the use of a wide range of reinforcements and the capability of producing near-net shaped casting. The major problem in fabricating metal matrix composites by liquid phase is the poor wetability, which leads to the non-uniform distribution of the particles [4-6]. Vortex technique (liquid phase processing) involves incorporating of ceramic particulates into vortex molten alloy shaped by the rotating impeller.

Particle reinforced composites are very general due to availability, low cost, independence of characteristics from the particle orientation, and fabrication via a wide range of processes. The properties of particle reinforced metal matrix composites depend on the microstructure and uniform distribution of particles throughout matrix and chemical reaction between particles and matrix (interface).

Aluminum matrix composites have received a great interest, because they combine low weight, low cost, high specific strength and excellent wear resistance [7-10]. Aluminum matrix composites were studied by many researchers [11-19]. However,

TiB_2 reinforced aluminum matrix composite has not been attracted enough attention. Due to high hardness and excellent modulus of TiB_2, it was used in the present investigation.

2. EXPERIMENTAL PROCEDURES

In this study, A356.1 aluminum was used as matrix. Chemical composition of this material is shown in table 1. TiB_2 powder was used as reinforcement phase. TiB_2 powders (with spherical shape) had a mean particle size of 1 micron. Aluminum was melted inside a crucible in electric furnace at 750, 850, and 950^{0}C.

The melt was stirred with a graphite stirrer at a constant rotation speed of 400 rpm. About 3 gr cryolite was plunged into the melt to improve the foundry conditions and prevent from slag formation. Stirring was continued for a few minutes. 5 Vol.%TiB_2 was added, while the melt was stirred. Molten composite then was poured inside a metallic mold. Metallic mold was used to prevent unwanted conditions and to increase the solidification speed.

Table 1: chemical composition of A356.1

Element	Al	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Ni	Pb	Sn
Percentage	**91.73**	**7.23**	**0.32**	**0.18**	**0.02**	**0.38**	**0.05**	**0.01**	**<0.01**	**0.05**	**0.02**	**0.01**

XRD (PW-1800 model, Philips) was used to detecte the present phases in the samples. The microstructures were determined by Scanning Electron Microscopy (CAMSCAN-MV2300 MODEL, OXFORD). Specimens were polished and etched using Keller solution. Indentation tests were performed using a Vickers pyramid diamond hardness testing machine (GMAH Wolpert). The specimens were polished to 1 micron meter before the tests. The load of 10KN was used with a loading time of 260 s. Two samples were prepared and 5 tests were preformed in each of them. For tensile test specimen's preparation, the samples were made in a cylindrical shape based on ASTM.B557 standard [20]. Two specimens were used for each measurement.

3. RESULTS AND DISCUSSIONS

Figures 1-3 show the XRD patterns of samples produced at 750, 850, and 950^{0}C. It can be seen that TiB_2 and aluminum are present in the samples. Also it has been shown that both aluminum and TiB_2 are existed in the slag. It can be concluded that along with TiB_2, some parts of TiB_2 was not absorbed in the melts.

Figures 4-6 show the SEM micrograph of the produced composites. The figures show that TiB_2 particles are homogeneously dispersed throughout the samples. The white and dark spots represent TiB_2 particles and aluminum respectively. The amount of the dispersed TiB_2 particles in the samples produced at 950^{0}C is higher than that of the others. This could be a cause of high porosity of system in such temperature, interring of air and gas and inhibition of their exiting after pouring. These figures also indicate that the homogeneity of particle dispersion in the sample prepared at 950^{0}C is higher than the other samples. It also can be seen that the interfaces in the specimens produced at 750 and 850^{0}C are perfect and there is not any pore or any other deficiency in this region. However, dark spots in figure 6 indicate the pore existence in the interface of aluminum matrix and TiB_2 particles in the samples produced at 950^{0}C. This was also confirmed by their lower densities. SEM micrographs of the samples also indicate that the grain size of aluminum composites decreases with increasing of casting temperature.

However, it seems that reinforcement particles increase the number of nucleus and solidification speed. Increasing the casting temperature increases the incorporation of reinforcement particles into the matrix metal; therefore, the grain size of the aluminum reinforced with ceramic particles is being smaller.

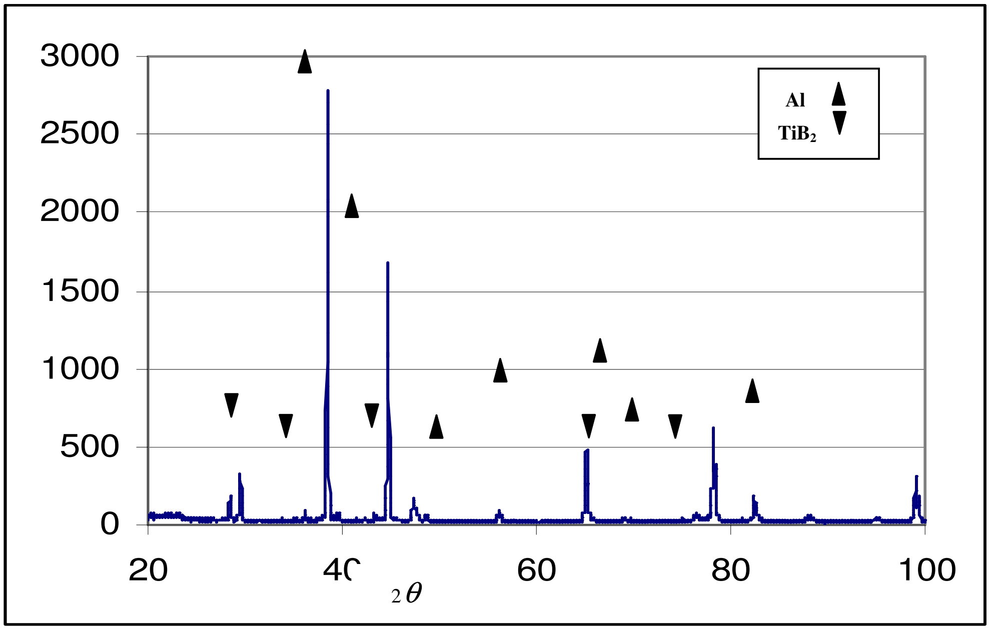

Figure 1: XRD patterns of Al-TiB_2 composite casted at 750^0C.

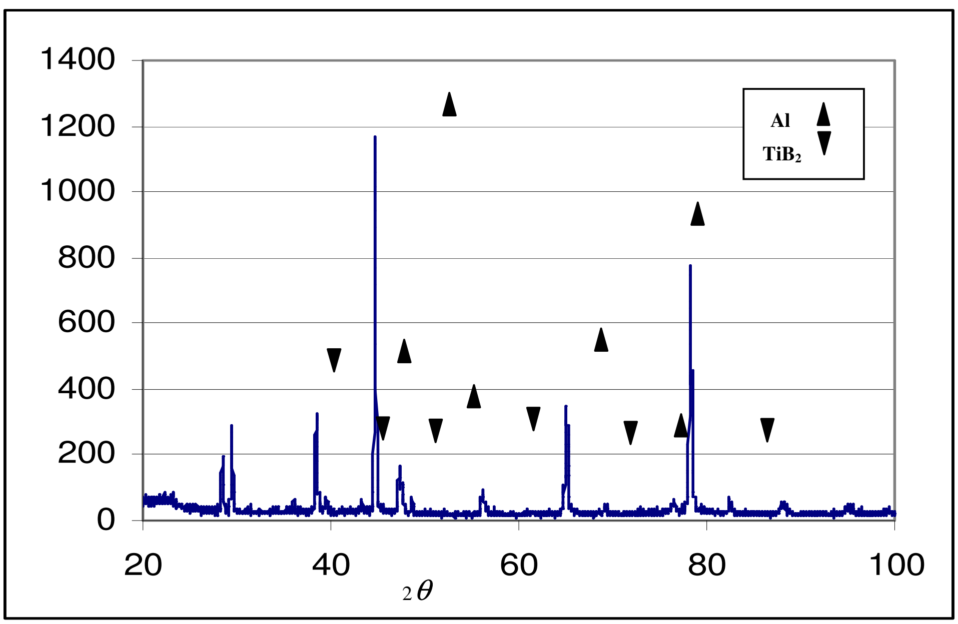

Figure 2: XRD patterns of (Al-TiB_2) composite casted at 850^0C.

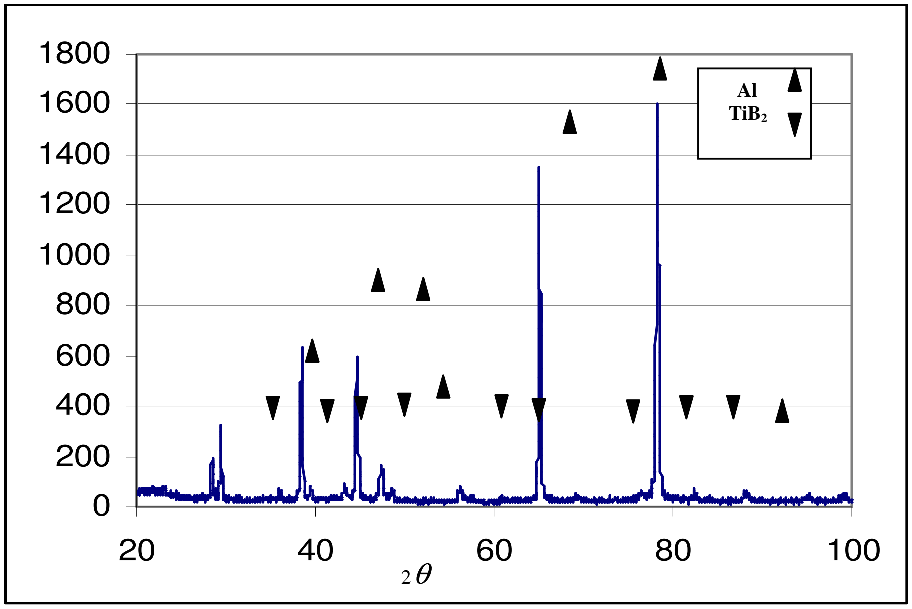

Figure 3: XRD patterns of (Al-TiB_2) composite casted at 950^0C.

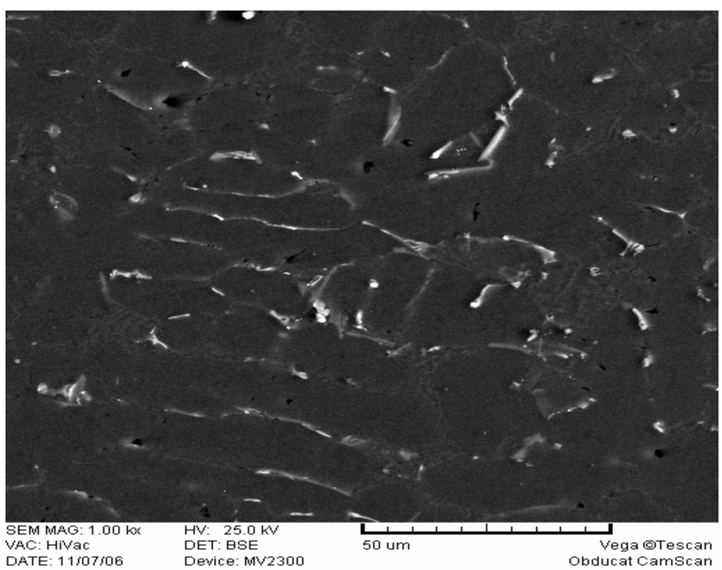

Figure 4: SEM micrograph of (Al-TiB_2) composite casted at 750^0C.

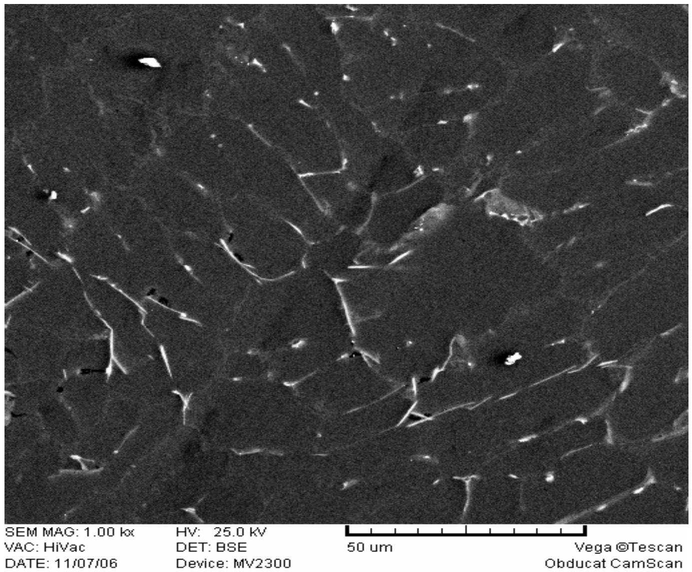

Figure 5: SEM micrograph of (Al-TiB_2) composite casted at 850^0C.

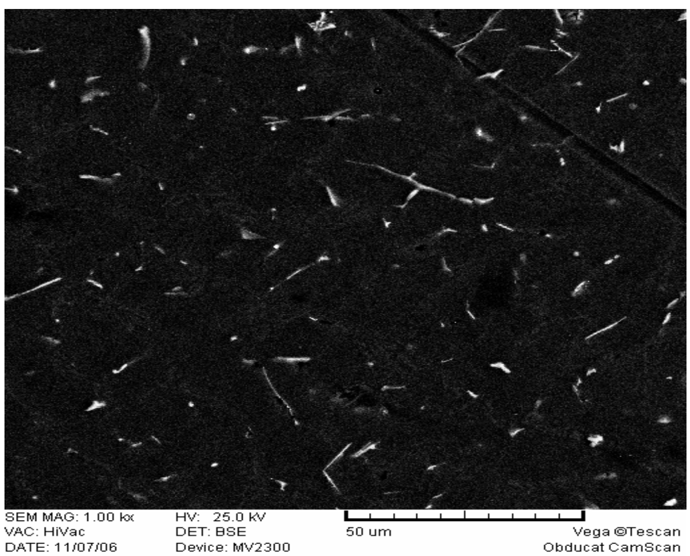

Figure 6: SEM micrograph of (Al-TiB_2) composite casted at 950^0C.

The effect of processing temperature on density is reported in figure 7. It shows that the density decreases with temperature increasing. This may be due to pore formation in the samples produced at higher temperature, as it was shown in SEM micrographs (figure 6).

Figure 8 illustrates the influence of processing temperature on the hardness of the composites. The hardness of A356.1 alloy is about 55 Vickers. TiB_2 phase is much harder than that of this aluminum alloy. Therefore, according to the rule of mixture, increasing of TiB_2 additive increases the hardness of the composite. Due to the grain size reduction with processing temperature increasing (up to 850^0C), with temperature increasing, the hardness of the specimens enhances (figure 8). With further temperature increasing, it decreases because of pore formation in the TiB_2 and aluminum matrix interface.

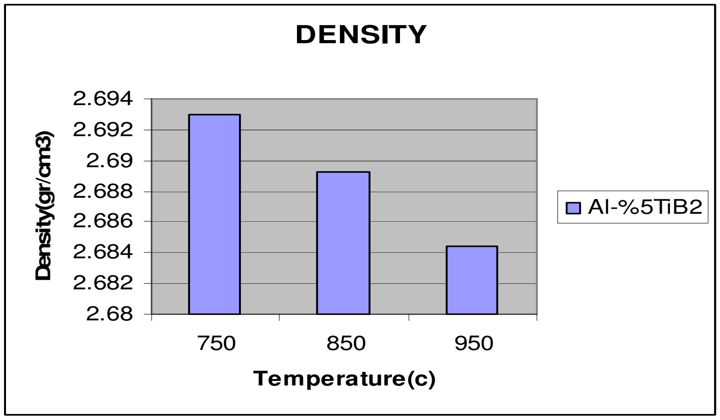

Figure 7: Effect of processing temperature on apparent density.

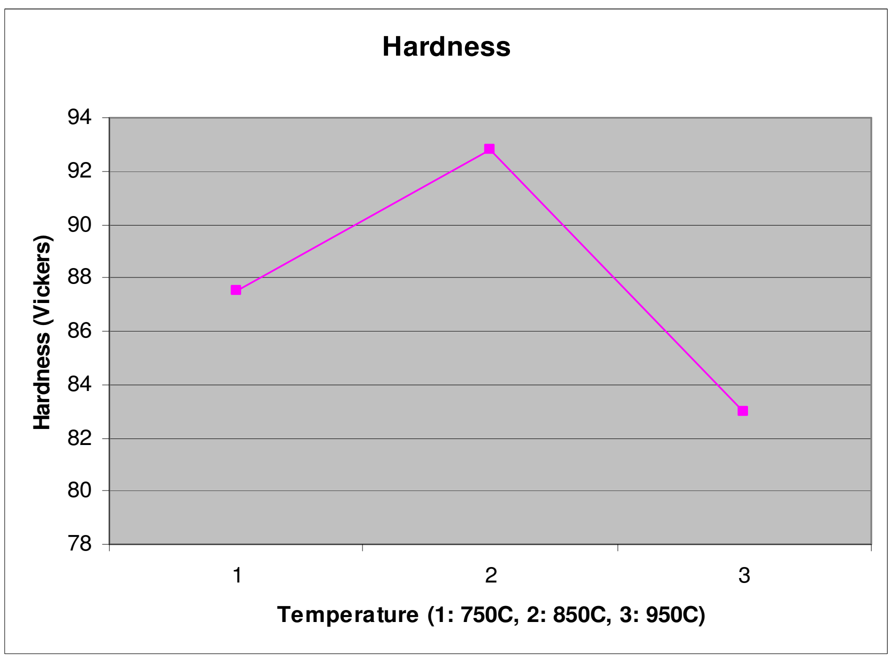

Figure 8: Hardness of composites versus the processing temperature.

Table 2 :Hardness of composites

Temperature	**750°C**	**850°C**	**950°C**
Hardness(HV_{30})	87.5	92.8	83
Hardness increasing compare to matrix aluminum alloy	59.1%	68.7%	50.9%

The tensile strength versus the processing temperature is plotted in figure 9. It reveals that the temperature increasing has a positive effect on the tensile strength. Table 3 shows that TiB_2 additive increases the tensile strength of aluminum that is initially 145MPa. This may be due to the dislocation pending by TiB_2 particles. This value increases by increasing of temperature; because the amount of TiB_2 particles at the matrix increases with increasing of temperature and work-hardening rate enhances.

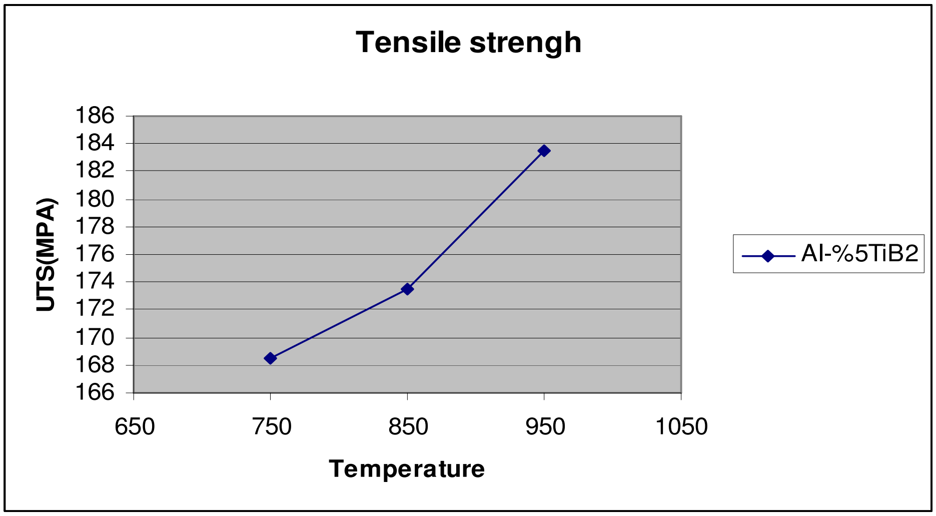

Figure 9: Effect of processing temperature on tensile strength of composite.

Table 3- tensile strength of composite.

Temperature	**750°C**	**850°C**	**950°C**
UTS(MPa)	168.5	173.8	183.5
Tensile Strength increasing compare to matrix aluminum alloy	16.2%	19.8%	26.5%

4. CONCLUSIONS

1- TiB_2 particles are homogeneously dispersed throughout aluminum matrix in Al-TiB_2 composites.

2- The maximum density of Al-TiB_2 composite was obtained at 750^0C of casting temperature.

3- The hardness and tensile strength of Al-TiB_2 composite are higher than those of the monolithic aluminum.

4- The best processing temperature seems to be 950^0C; because maximum values of properties for these composite were obtained in this casting temperature.

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