IJESR/ICETEISM-2019/Special Issue/ Article No-86/400-403 ISSN 2277-2685

International Journal of Engineering & Science Research

Hot Forged Al6061/TiB_2 in-situ Composites: Study on Microstructure and Microhardness

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Abstract—In the present investigation, microstructure and microhardness studies were conducted on hot forged Al6061/TiB_2 in-situ composites with varying content of in-situ formed TiB_2 particles. By facilitating reaction between Al-10%Ti and Al-3%B master alloys at 800°C in the Al6061 melt, TiB_2 particles were formed by in-situ technique. Using appropriate quantity of master alloys, about 5 wt% and 10 wt% TiB_2 particles were formed in the Al6061 composites. The Al6061 and its in-situ composites were subjected to hot forging at 500°C and about 50% reduction was accomplished. Optical microscopy analysis was conducted to check the dispersion of TiB_2 particles in the in-situ composites. Vicker's microhardness test was conducted as per ASTM E384 standard to check the influence of varying TiB_2 particle content on microhardness of Al6061 alloy. The dispersion of TiB_2 particles was found to be fairly uniform throughout the Al6061 matrix with minimal clustering. The microhardness of in-situ composites was found to increase with the increase in TiB_2 particles content.

Keywords—*Al6061 alloy; Hot forging; Microstructure; Microhardness.*

I. INTRODUCTION

In recent few years, the key research region for the researchers in the production field is the Aluminum metal matrix composites. AMC material frameworks offer predominant combination of properties in such a way, that today no current conventional metals/alloys can equal. Aluminum metal matrix composites are developed and got high demand for use in automobile, aerospace, Defense, transportation, chemical and some specialized industries due to its better strength, high stiffness, greater wear resistance, high performance, high elastic modulus and lightweight over conventional metals/alloys [1-5]. The one amongst the most significantly used alloys of the 6000 Sequence is Al6061 as it has a variety of good mechanical properties, excellent corrosion resistance, good surface quality and high workability [6]. In recent years' researchers have used huge variety of ceramic dispersoids such as Graphite [8], SiC [6], TiC [9], TiO2 [9], B4C [6], Al2O3 [7-8] and Si3N4 [9] as reinforcement material in Al6061 based MMCs. But TiB_2 emerges as an excellent reinforcement when compared to those reinforcements [10-11], due to its low density, high hardness, brilliant wear resistance, corrosion resistance, high melting temperature, good wettability and superior chemical compatibility. Now a day, researchers are concentrating on growing effectively reasonable, high quality metal matrix composites. In-situ technique for preparing metal matrix composites one such procedure includes blend of reinforcing particles inside the matrix material and provide many desirable properties over ex-situ or conventional techniques [12-15]. Few of the merits of the composites synthesized by in-situ procedure consist of, grain refinement, reduced size and uniform supply of reinforced particles and good interfacial bond amongst matrix and reinforcement.

II. EXPERIMENTAL DETAILS

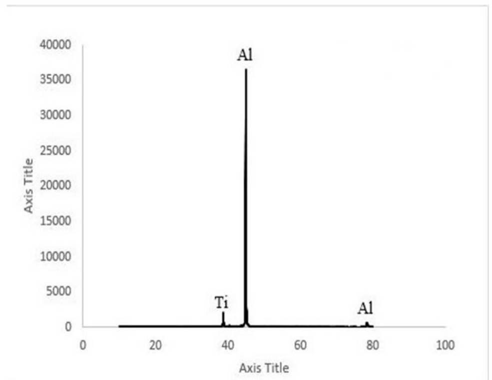
Al6061-TiB2 composites were produced by liquid metallurgy process. The two master alloys used in this study are Al–10%Ti and Al–3%B, and their chemical compositions are given below in Table1. An electric resistance furnace (ERF) was used to melt Al6061 and the two master alloys. The stoichiometric Ti: B ratio of 1:2 [17] was adopted. Commercially accessible chlorine tablets (hexachloroethane) were used to degas the melt. Then the possible presence of signs of unwanted materials during composite preparation were removed by introducing the scum powder into the furnace. The weight percentage of Al–10%Ti was assorted from 5% to 10% in periods of 5% while the weight of Al–3%B was assorted from 10% to 20% in periods of 10%. The blend of matrix alloy and the two master alloys were heated in an electric resistance furnace (ERF) at a temperature of 800oC and allowed to stand for a period of 30 min for the in situ reaction to occur. Mechanical stirrer was used for appropriate mixing of the in situ products and then it was then poured into the preheated metallic moulds [16-17]. These casted Al6061 alloy and synthesized composites were subjected to open die hot forging (Flattening) using a flat die at an initial die temperature of 300oC and initial billet temperature of 500oC at a normal strain rate of 0.0107mm/sec and about 50% reduction was adopted for both matrix alloy and composites [18]. The prepared composites were machined appropriately to get samples for carry out Microstructure, micro hardness and grain size analysis. Microstructure, micro hardness and grain size analysis were carried on both matrix alloy and the synthesized in situ composites. Microstructure studies were conceded on Advanced Metallurgical Laboratory, Bangalore. Microstructure studies were conducted by means of Nikon Microscope LV150-Clemex Analyzer using ASTM E3-11(2017) standard procedure. Micro hardness tests were carried on completely polished samples of both alloy and synthesized composites as per ASTM E384 standard [19-20]. 1Kg of load was applied on all the samples a using Vickers micro hardness tester. To avoid the probability of indenter relaxing on the hard reinforcement particles the test was conceded out at 3 different locations. The hardness of the samples is estimated by taking the average of these 3 location readings.

Further, to discover the precise weight level of TiB_2 shaped, known loads of composite samples were broken up in hydrochloric acid. The matrix was dissolved in acid leaving behind the in situ reinforcements. The separated particles were altogether cleaned, dried and weighed. The distinction in the weight of composite material utilized for examination and the weight of separated particles was taken as the proportion of measure of TiB2 and Al_3Ti. The measure of TiB_2 in the extricated powders was assessed by using the proportions of peak intensities of TiB_2 and Al_3Ti obtained from XRD considers.

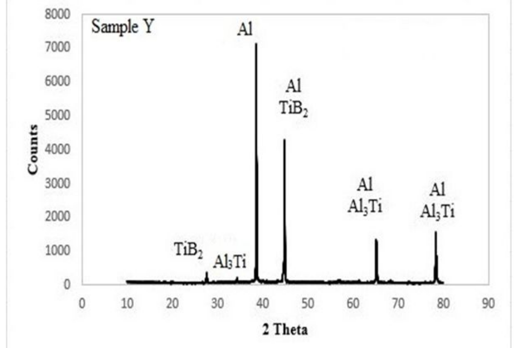
TABLE I. CHEMICAL COMPOSITIONS OF AL 6061 ALLOY AND AL–10%TI AND AL–3%B MASTER ALLOYS.

Al 6061 alloy		**Al–10%Ti master alloy**		**Al–3%B master alloy**	
Mg	0.8-1.2	Ti	10.27	B	2.94
Si	0.4-0.8	Fe	0.37	Fe	0.32
Fe	0.7	Others	0.11	Others	0.1
Cu	0.15–0.40	Al	Remaining	Al	Remain ing
Cr	0.04–0.35				
Zn	0.25				
Mn	0.15				
Ti	0.15				
Others	0.2				
Al	Remaining				

III. RESULTS AND DISCUSSION



a)



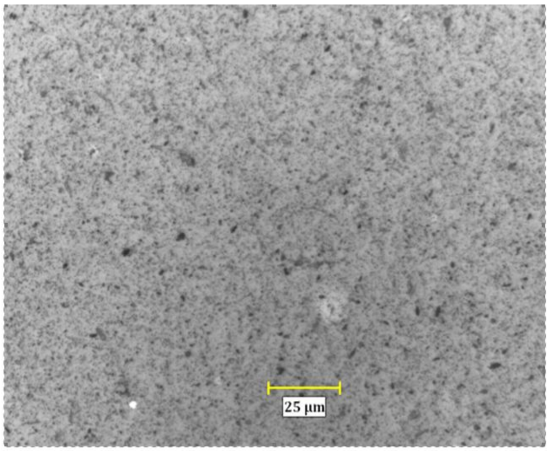
b)

Fig. 1. XRD pattern of the in-situ composites (a) Al6061 alloy (b) sample-Y

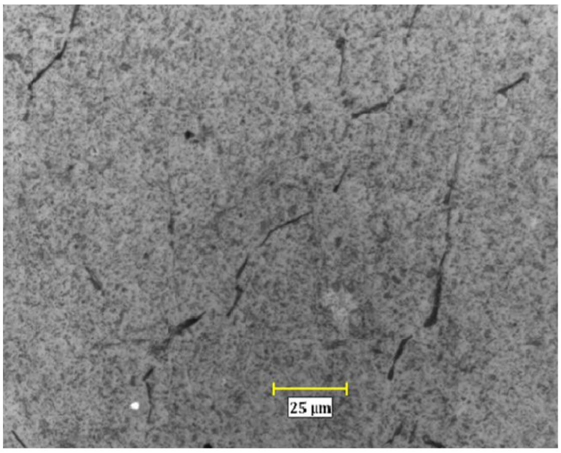
Fig 1 are the XRD pattern of the Al6061 alloy and in-situ composites. From the XRD analysis it is clearly confirmed that the TiB_2 particles are formed by the in situ process.

A. Microstructure

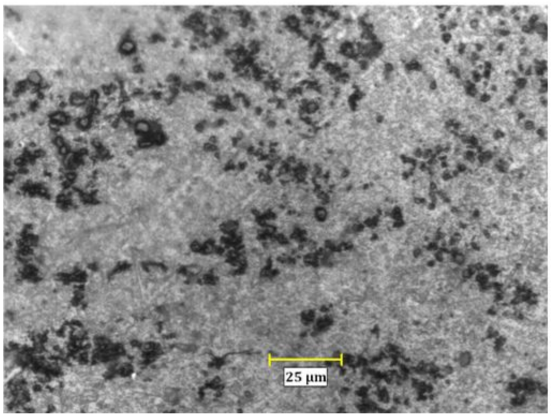
2 are optical microphotographs of Al 6061 alloy and the synthesized hot forged composites. All synthesized composites consist of uniformly distributed TiB_2 particles along with traces of flake like Al_3Ti in the matrix of aluminium solid solution. Particles are uniformly dispersed. Anyway few bunches of TiB_2 particles are additionally observed in the micrographs. It is additionally seen that the TiB_2 particles are allied in the direction of metal flow upon hot forging. Also it has been observed that there were no traces of particle fracture and debonding upon hot forging.



a) Al6061 alloy



b) sample X



C) sample Y

Fig. 2. (a)–(c) Optical microphotographs of Al 6061 alloy andits composites: (a) Al 6061 alloy, (b) Sample-X and (c)Sample-Y.

B. Microhardness

Fig 3 shows the results of microhardness of Al6061 and the synthesized hot forged composites. The Al6061 and the synthesized hot forged composites hardness values are reported below in table 2. From the results it is noticed that the synthesized hot forged composites possess higher hardness value when compared with base alloy Al6061 and also it has been noticed that hardness value hardness value increases as the weight percent of TiB_2 particles increases.

TABLE II. MICRO HARDNESS OF AL 6061 ALLOY AND ITS COMPOSITES

Al 6061+Weight % of TiB_2	Hardness (VHN)
0	53
5	67.5
10	102

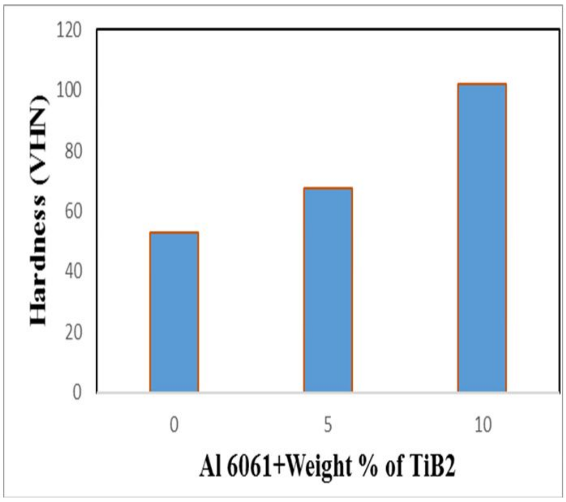


Fig. 3. Variation of microhardness of Al 6061 alloy and its composites

IV. CONCLUSION

The in situ Al6061 – TiB_2 composite was synthesized effectively by liquid metallurgy process by using Al–10%Ti and Al–3%B two master alloys. The synthesized alloy and composite was effectively hot forged at a temperature of 500o C. the presence of in situ TiB_2 particles in the synthesized composites are confirmed by the XRD studies. From microstructure study it has been noticed that the synthesized in situ hot forged composites consist of uniformly distributed TiB_2 particles. Micro hardness study reveals that the hardness value increases as weight percent of TiB_2 particles increases.

ACKNOWLEDGMENT

The authors wish to acknowledge their sincere thanks to parents for their love & support. The authors also express their deep sense of gratitude to Department of Mechanical Engineering, Acharya Institute of Technology, Bengaluru for their constant encouragement & support.

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