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Mechanical and Micro Structural Characterization of Al6082-TiO_2 Metal Matrix Composites produced via Compo Casting Method

K. Yoganandam*, K. Raja and K. Lingadurai

Department of Mechanical Engineering, University College of Engineering, Anna University. Dindigul – 624622, Tamil Nadu, India; yogamech89@gmail.com

Abstract

Objectives: Aluminum Matrix Composites (AMCs) are considered as a distinct category of the advanced materials, which have superior strength, light weight and good wear resistance. **Methods/Statistical Analysis**: In the present study, Al6082 is chosen as matrix material and Titanium Oxide (TiO_2) particles as reinforcement. Aluminum-TiO_2 composites reinforced with various weight percentages (0, 3, 6 and 9 wt. %) were produced by semi-solid state compo casting route. The microstructure of fabricated composites and monolithic alloys were examined by Optical Microscope (OP). Hardness and Ultimate Tensile Strength (UTS) of the produced composites were investigated. **Findings:** The test results show that the mechanical behaviors of the fabricated composites are enhanced by increasing the Titanium Oxide content. The UTS and hardness of the produced composite enhanced with the addition of higher percentage of TiO_2. **Application/ Improvements:** The mechanical performances of the Al-TiO_2 AMCs are higher than that of the base monolithic alloy.

Keywords: Al6082, Compo Casting, Microstructural Characterization, TiO_2

1. Introduction

Al 6xxx alloy based Metal Matrix Composites (MMCs) have lured structural, automobile, aircraft and aerospace manufacturers because of their low density, superior modulus of elasticity and the superior specific stiffness[1]. The aluminum based Metal Matrix Composites are used in different engineering applications like pistons, engine drive shafts, cylinder block liners and bicycle frames[2]. Aluminum Matrix Composites show greater properties than conventional materials in terms of improved mechanical properties and thermal properties and high wear resistance[3]. Conventional preparation of aluminum matrix composite involves the accumulation of ceramic particles, for instance, SiC[4], TiC[5], AlN[6], B_4C[7], Al_2O_3[8], TiB_2[9] and ZrB_2[10] into molten matrix. AMCs are fabricated employing several traditional processes and some patented techniques. The most established processes are centrifugal casting, powder metallurgy, squeeze casting, exothermic reaction process (in situ), stir casting and compo casting[11–13]. Among the available methods, compo casting is the most preferred and inexpensive method of manufacturing the AMCs[14]. Compo casting technique enhances the wet ability. It is economically good and can be performed at lower temperature. Reinforcing particles incorporate at semi solid state. A very few number of findings have been stated regarding the production and properties of aluminum based compo casting composites[15]. The current work mainly focuses on the production, micro structure analysis and mechanical properties of Titanium Dioxide (TiO_2) ceramic particulate reinforced AA6082 aluminum alloy synthesized by compo casting route.

*Author for correspondence

2. Experimental Details

2.1 Materials and Fabrication Procedure

The chemical composition of AA6082 is shown in Table 1. AA6082 was chosen as a matrix alloy and the Titanium Oxide particles of size 320 mesh are used as the reinforcement materials for fabrication Figure 1. In this process, the (AA6082) aluminum alloy was melted to 850^{0}C to obtain liquid form and then the temperature is gradually reduced till it reaches 620^{0}C where it attains a semisolid state. Then the calculated quantity of TiO_2 particles was added slowly. After mixing, the temperature was increased so as to get liquid stage and then stirring was continued to about 600 seconds at 350 revolutions per minute and the composite melt was quickly poured into a preheated mould. The produced castings were taken with different weight percentages of TiO_2 particles (0, 3, 6 and 9 wt %).

Table 1. Chemical composition of Aluminum Alloy (AA6082)

Elements	Wt.%
Silicon	1.23
Magnesium	0.78
Manganese	0.5
Iron	0.33
Copper	0.08
Chromium	0.14
Zinc	0.05
Aluminum	Balance

Figure 1. Photograph of casting furnace.

2.2 Microstructure

The fabricated composite were characterized using optical microscope. The samples were generally polished employing the normal metallographic procedure and the polished specimens were etched with keller's agent.

2.3 Macro Hardness and Micro Hardness

Macro hardness was assessed employing Brinell hardness tester at five hundred kilogram of load was applied for ten seconds at five various locations on all samples. The micro hardness was assessed employing Vickers hardness tester at five hundred gram of load was applied for ten seconds at five various locations on all samples. The mean values of macro hardness and micro hardness were recorded.

2.4 Tensile Test

The tensile test samples were prepared in accordance with the ASTM-E08 standard. The Ultimate Tensile Strength (UTS) was assessed with a fully computerized Universal Testing Machine (UTM) at room temperature (30^{O}C).

3. Results and Discussions

3.1 Micro Structural Examination

Figure 2(a) - Figure 2(d) shows the optical photographs of AA6082 MMCs containing 0% TiO_2, 3% TiO_2, 6% TiO_2 and 9% TiO_2 respectively. The optical images show the nearly uniform distribution of reinforcement over the matrix for AA6082-9 wt. % TiO_2 composites. Optical images reveal that the TiO_2 particles are mainly located in the eutectic of the liquid phase surrounding the dendrite α-Al grains and in the grain boundaries there are some porosity. The variation in the quantity of TiO_2 particles is seen with raised weight percentage of reinforcement. Therefore, an effective mechanical behavior was expected for AA6082-9 wt. % TiO_2 composite.

3.2 Ultimate Tensile Strength of the Composites

Figure 3 shows that the Ultimate Tensile Strength of the AMCs is enhanced with increased weight percentage of TiO_2 particles content in the AA6082 matrix. The higher variation in the co-efficient of thermal expansion mismatch between AA6082 aluminum alloy and titanium oxide encourages more amount of dislocation in the com-

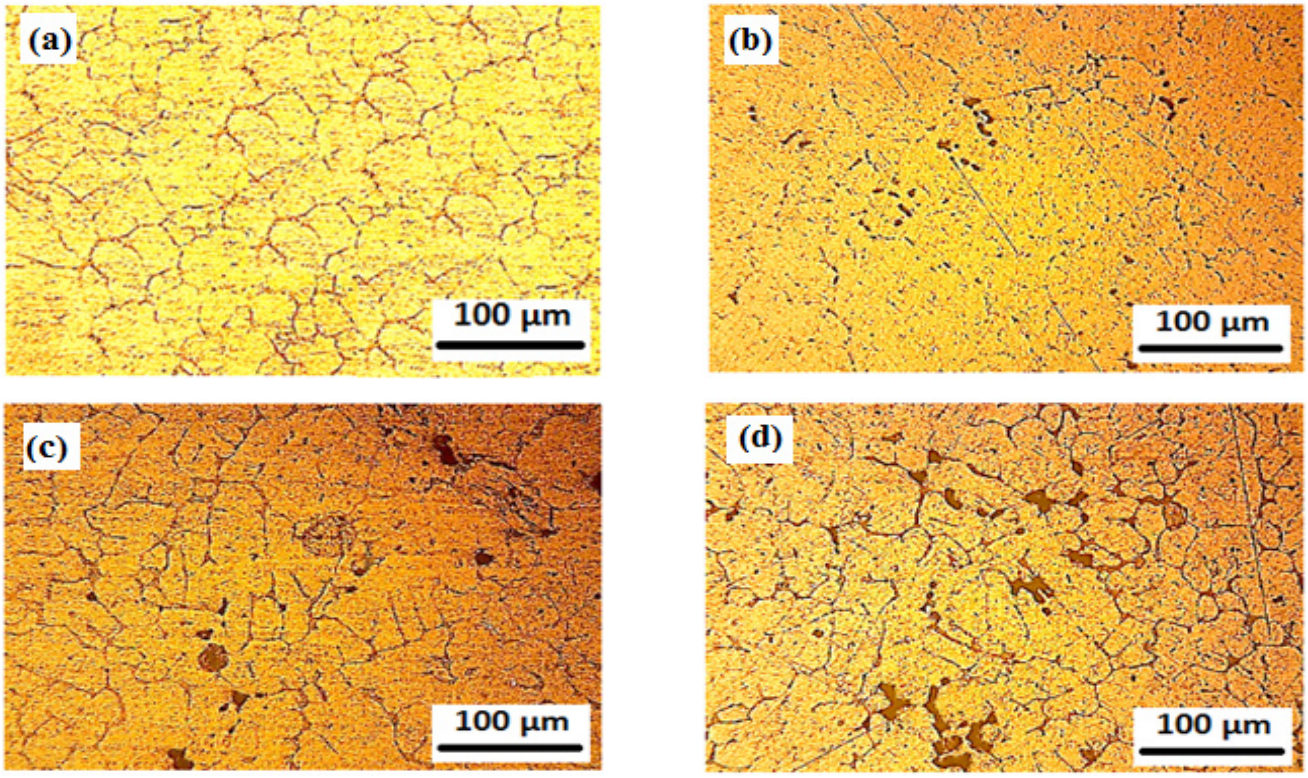

Figure 2. Optical photographs of AA6082 MMCs containing: (a) 0 wt% TiO_2 (as-cast), (b) 3 wt% TiO_2, (c) 6 wt% TiO_2 and (d) 9 wt% TiO_2 AMCs.

posites. At higher dislocation density, dislocations interact with each other which ultimately develop the strength of the fabricated composite materials[16]. If the bonding between the AA6082 matrix and the TiO_2 reinforcement is instead solid enough, the Ultimate Tensile Strength of the produced composite can be greater than that of the matrix materials.

The gradual development in Ultimate Tensile Strength of the produced composite reveals that the stresses are efficiently shifted through interface. Figure 4 shows the photographs of tensile samples of Al6082-TiO_2 AMCs before and after test, respectively.

3.3 Hardness of the Composites

The results of the micro and the macro hardness tests are plotted in Figure 5. The increase in hardness is attributed to the incorporation of TiO_2 in the semi solid condition. Incorporation of Titanium Oxide to the aluminum matrix materials led to improved hardness is shown in Figure 5. The maximum increase in macro and micro hardness is observed at 9 wt. % of TiO_2.

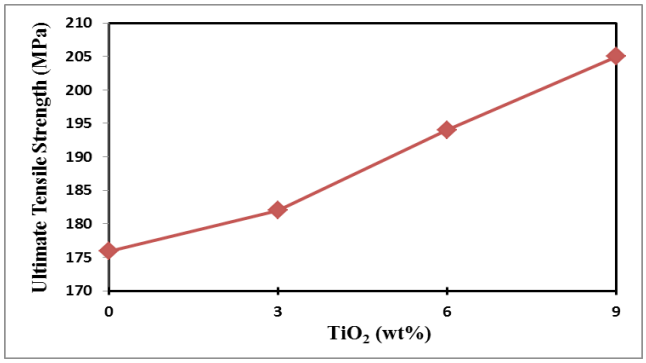

Figure 3. Effect of weight percentage of TiO2 on Ultimate Tensile Strength of AA6082 MMCs.

Figure 4. Photographs of tensile specimens of Al6082-TiO_2 AMCs on before and after fracture.

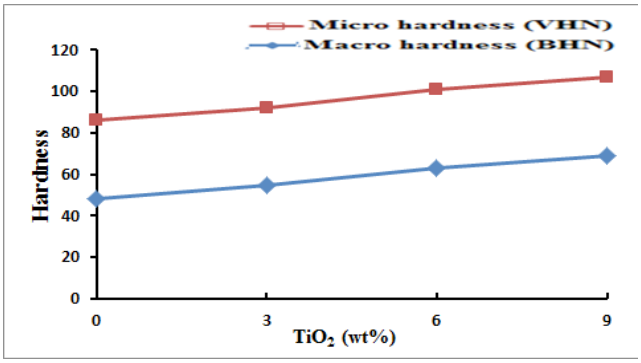

Figure 5. Effect of weight percentage of TiO_2 on hardness of AA6082 MMCs.

4. Conclusion

In the current work, AA6082 matrix alloy reinforced with several percentages of TiO_2 particles were successfully prepared by compo casting route.

- The higher mechanical properties were observed for the composites compared with un reinforcement alloy.
- Optical images displayed the nearly uniform distribution of reinforcement in the AA6082 matrix.
- Ultimate Tensile Strength of the produced composites found to increase with enhanced TiO_2 up to 9%. Highest hardness was obtained for AA6082-9 wt. % TiO_2 composites.

5. References

1. Canakci A. Microstructure and abrasive wear behavior of B_4C particle reinforced 2014Al matrix composites. Journal of Material Science. 2011 Apr; 46(8):2805–13.
2. Rao RN, Das S. Effect of sliding distance on the wear and friction behavior of as cast and heat-treated Al-SiCp composites. Materials and Design. 2011 May; 32(5):3051–8.
3. Vijayaramnath B, Elanchezhian C, Annamalai RM, Aravind S, Atreya TSA, Vignesh V, Subramanian C. Aluminum Metal Matrix Composites – A review. Review Advanced Material Science. 2014; 38:55–60.
4. Reddy AC, Zitoun E. Matrix Al-alloys for silicon carbide particle reinforced Metal Matrix Composites. Indian Journal of Science and Technology. 2010 Dec; 3(12):1184–7.
5. Vinayagam M, Karthick M, Belginpaul DL. Fabrication and development of aluminum alloy AA6063-Titanium carbide composite prepared by in situ method. International Journal of Applied Engineering Research. 2015 Jan; 10(5):12475–82.
6. Mohanavel V, Rajan K, Arul S, Senthil PV. Study on microstructure and mechanical behavior of Particulate Reinforced Aluminum Matrix Composites (PRAMCS). International Journal of Advanced Engineering Technology. 2016; 7:252–3.
7. Vijayaramnath B, Elanchezhian C, Jaivignesh M, Rajesh S, Parswajinan C, Ghias ASA. Evaluation of mechanical properties of aluminum alloy-alumina-boron carbide metal matrix composites. Materials and Design. 2014 Jun; 58:332–8.
8. Srivastava MK, Mandal RK, Mohan S, Pathak JP, Ojha SN. Wear characteristics of Al-Al_2O_3 composites produced by powder metallurgy process. Indian Journal of Engineering and Materials Sciences. 1999; 6:27–33.
9. Mohanavel V, Rajan K, Senthilkumar KR. Study on mechanical properties of AA6351 alloy reinforced with Titanium di-Boride (TiB_2) composite by in situ casting method. Applied Mechanics and Materials. 2015 Aug; 787:583–7.
10. Dinaharan I, Murugan N, Parameswaran S. Influence of in situ formed ZrB_2 particles on microstructure and mechanical properties of AA6061 Metal Matrix Composites. Materials Science and Engineering A. 2011 Jul; 528(18):5733–40.
11. Anand SS, Mohan B. Enhanced hardness property in the development of Al-TiC composites through P/M techniques. Advanced Materials Research. 2012 Jul; 548:243–9.
12. Mohanavel V, Arun Kumar E, Karthik M, Kumar P, Devaraj N. Evaluation of mechanical properties of AA6360 aluminum alloy – B_4C – Al_2O_3 Metal Matrix Composites (MMCs). International Journal of Applied Engineering Research. 2015; 10(68):753–6.
13. Sajjadi SA, Ezatpour HR, Beygi H. Microstructure and mechanical properties of Al-Al_2O_3 micro and nano composites fabricated by stir casting. Materials Science and Engineering A. 2011 Nov; 528(29-30):8765–71.
14. Sajjadi A, Niroumand B. Microstructure and mechanical properties of Al356/SiCp cast composites fabricated by a novel technique. Journal of Materials Engineering and Performance. 2013 Jan; 22(1):85–93.
15. Amirkhanlou S, Niroumand B. Synthesis and characteristics of 356-SiCp composites by stir casting and compo casting methods. Transactions of Nonferrous Metals Society of China. 2010 Sep; 20(S3):s788–93.
16. Gladston JAK, Sherief NM, Dinaharan I, Selvam JDR. Production and characteristics of rich husk ash particulate reinforced AA6061 aluminum alloy composites by compo casting. Transactions of Nonferrous Metals Society of China. 2015 Mar; 25(3):683–91.