Synthesis of Al-TiO_2 Composites through Liquid Powder Metallurgy Route

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Abstract

The present work aims to fabricate aluminium metal matrix composites through liquid powder metallurgy route. The aluminium matrix composite contains TiO_2 reinforcement particle was produced to study the mechanical properties such as tensile strength and hardness. The characterization studies also carried out to evident the phase presence in the composite and the results are discussed for the reinforcement addition with the mechanical properties. Results show that, the addition of 5 weight percentage of TiO_2 to the pure aluminium improves the mechanical properties.

Key words: Metal Matrix Composites, TiO_2, Aluminium

1. Introduction

Aluminum based metal matrix composites have a high potential for advanced structural applications when high specific strength and modulus, as well as good elevated-temperature resistance, are important [1]. Traditionally, MMCs have been produced by such processing techniques as powder metallurgy, preform infiltration, spray deposition, mechanical alloying, and various casting technologies, e.g., squeeze casting, rheocasting, and compocasting. Such technology is based on the addition of the particulate reinforcement to the matrix materials, which may be in molten or powder form [1]. Among the different processing methods, powder metallurgy is an important one for the production of metal matrix composites. Two important advantages of powder metallurgy over other casting techniques include the uniform distribution of reinforcing particles within the matrix and less degradation due to lower processing temperatures. The basic manufacturing steps in the PM technique for producing particulate MMCs include the mixing of a matrix alloy powder with reinforcing particles, followed by compacting and sintering. PM can be applied to nearly any material that can be processed in powder form [2]. The feasibility of recycling Al7075 alloy chips with the help of commercially pure Al powders, via powder metallurgy route by hot extrusion process, was investigated. Furthermore, the effect of Al powders and their amounts on the mechanical properties of the recycled chips were studied. To evaluate the quality of the products, their microstructures were studied using optical microscope. Also, their mechanical properties, including tensile and microhardness, were evaluated [3]. Behaviors of TiO_2 in the alumina carbothermic reduction and chlorination process in vacuum at different temperatures were investigated experimentally by means of XRD, SEM and EDS. In the preparation of materials, the molar ratio of Al_2O_3 to C was 1:4, and 10% TiO_2 and excess $AlCl_3$ were added. The results show that TiC is produced by C and TiO_2 after TiO_2 transforms from anatase into rutile gradually. The purity of aluminum reaches 98.35%, and TiO_2 does not participate in alumina carbothermic reduction process and chlorination process in vacuum [4]. Although the preparation of such composites by melting and casting routes (i.e. stir casting) is by far the most economical one, but it is associated with some inherent problems arising mainly from both the apparent non-wettability of graphite by liquid aluminum alloys and the density differences between the two materials. Therefore, the introduction and retention of graphite particles in the molten aluminum is extremely difficult. Poor wettability and density differences also results in poor recovery of graphite particles in aluminum melt, inhomogeneous distribution of the dispersoid inadequate bonding between the metal and the graphite particles and formation of porosity at the graphite/matrix interface [5].

2. Experimental Details

The base metal is chosen as pure aluminium. The reinforcement is chosen Titanium dioxide particulates (TiO_2). The properties of the reinforcement are presented in table 1. With the base metal as Aluminium, the composite has been fabricated with 5 weight percentage of TiO_2 particulates. The fabrication setup is shown in figure 1.

Molecular formula	Molar mass	Density	Melting point	Boiling point
TiO_2	79.866 g/mol	4.23 g/cm^3	1843 °C	2972 °C

Table 1 Properties of reinforcement material

The liquid powder metallurgy technique was used to fabricate the composite specimen as it ensures a more uniform distribution of the reinforcing particles. This method is most economical to fabricate composites with discontinuous fibers or particulates. In this process, matrix alloy (Al) was first superheated above its melting temperature and then temperature is lowered gradually below the liquid us temperature to keep the matrix alloy in the semisolid state. At this temperature, the TiO_2 particles of 5 % were introduced into the slurry and mixed using a graphite stirrer.

The composite slurry temperature was increased to fully liquid state and automatic stirring was continued to about five minutes at an average stirring speed of 300-350 rpm under protected organ gas. The TiO_2 particles distributed uniformly throughout the matrix alloy. The melt was then superheated above liquid as temperature and finally poured into the cast iron permanent mould for testing specimen.

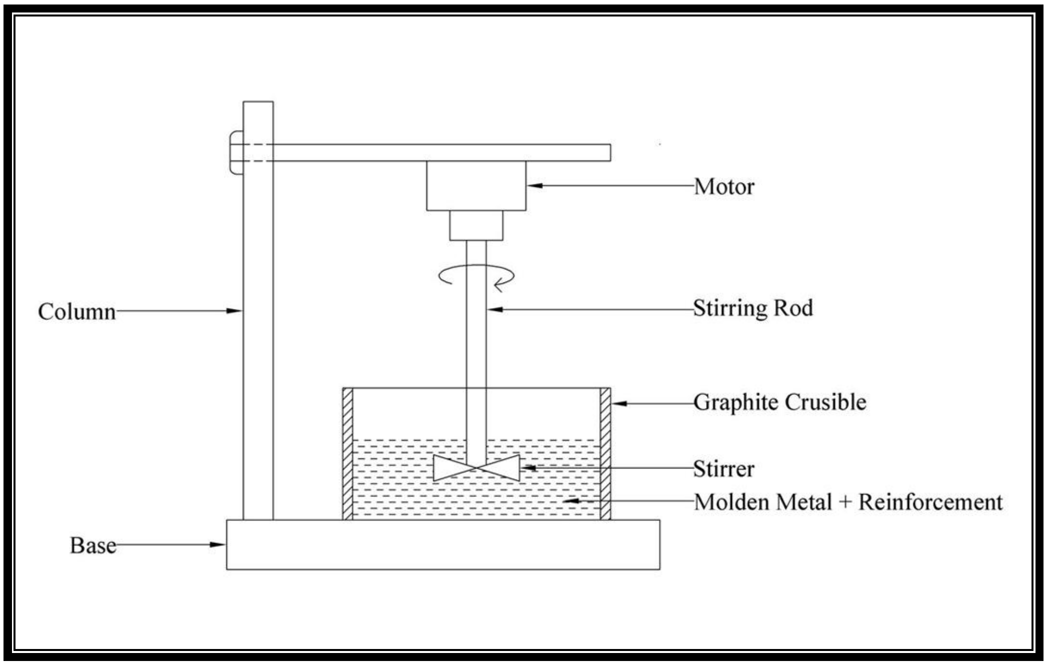


Fig.1 Experimental setup

Fig.2 Fabricated AMMC Rod

3. Results and Discussion

3.1 SEM Analysis of the composite

The microstructure of the Al-5%TiO_2 composite has been carried out through scanning electron microscope analysis. The figure 3 (a) shows the SEM image of the composite and it clearly evident the presence of titanium di oxide particles in the aluminium matrix.

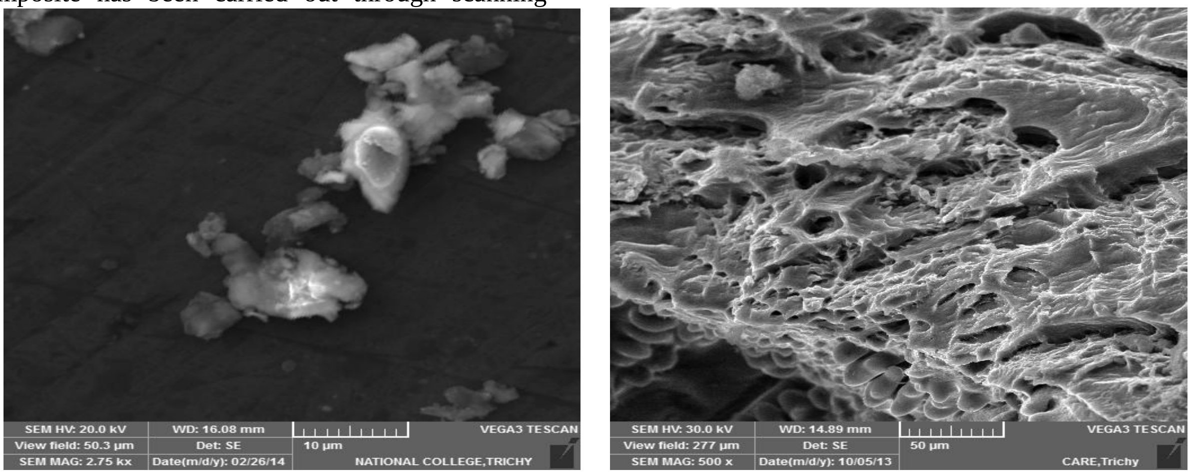


Fig.3 (a) SEM image of the Al-5%TiO_2 Composite (b) Tensile fracture surface of Al-5%TiO_2 composite

3.2 Mechanical Properties of the Composites

The tensile strength of the pure aluminium and aluminium composite has been carried out using universal testing machine and the test setup is shown in figure 4. The addition of titanium dioxide to the aluminium increases the tensile strength of the composite. The graph have been drawn between the tensile strength and percentage of titanium dioxide and shown in figure 5. It is understand that, the addition of reinforcement increases the tensile strength. The hardness test has been conducted using Rockwell hardness machine with 1/16 inch ball indenter by applying 100 kg of load. The B scale reading was taken. The increased hardness was observed for the aluminium composite. It has observed from the figure 5 that the addition titanium dioxide to the Al increases the hardness also.

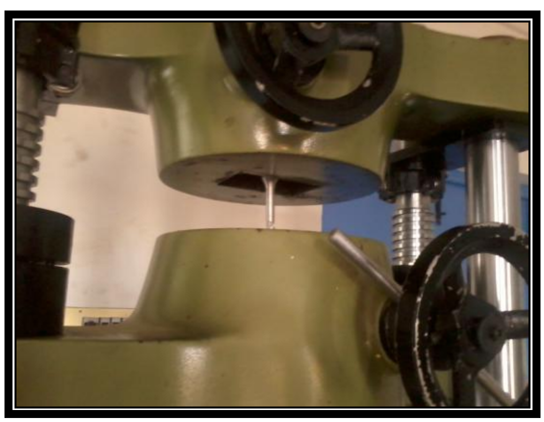
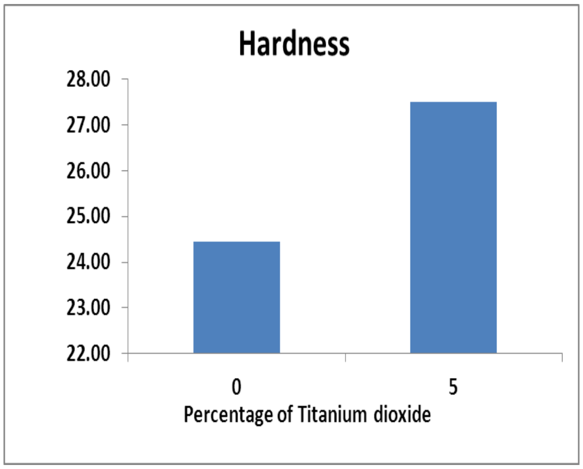


Fig.4 Tensile test setup



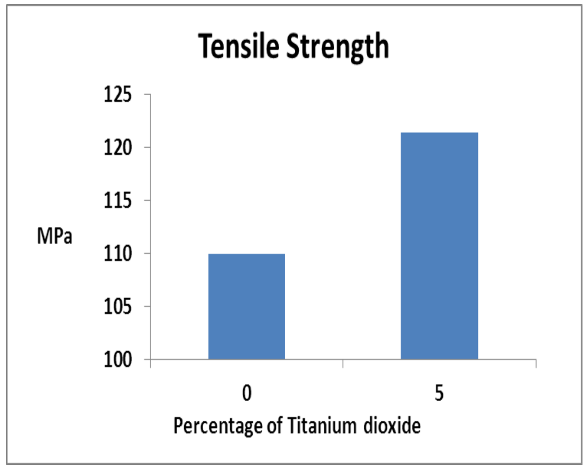


Fig.5 Effect of TiO_2 addition of Hardness and Tensile strength

3.3 Tensile fracture analysis of the composite

The tensile fracture analysis of the composite has been done using scanning electron microscope. It has been observed that the failure is ductile- brittle failure and it was caused by the presence of hard and brittle nature of titanium dioxide particles and it initiated the fracture. The fracture image is presented in the figure 3(b).

4. Conclusion

The following conclusions are drawn from the above work.

- The aluminium metal matrix composite contains titanium dioxide was fabricated successfully through liquid powder metallurgy techniques.
- SEM analysis reveals that the presence and distribution of the reinforcements in the matrix.
- The mechanical properties such as tensile strength and hardness were improved by the addition titanium dioxide to the pure aluminium matrix.
- Tensile fracture analysis proved the failure is ductile-brittle fracture.

References

[1] X.C. TONG and H.S. FANG, Al-TiC Composites In Situ–Processed by Ingot Metallurgy and Rapid Solidification Technology: Part I. Microstructural Evolution, METALLURGICAL AND MATERIALS TRANSACTIONS A VOLUME 29A, MARCH 1998—875.

[2] S. Pournaderi, S. Mahdavi, F. Akhlaghi, Fabrication of Al/Al2O3 composites by in-situ powder metallurgy (IPM), Powder Technology 229 (2012) 276–284.

[3] Z. Sherafat, M.H. Paydar, R. Ebrahimi, Fabrication of Al7075/Al, two phase material, by recycling Al7075 alloy chips using powder metallurgy route, Journal of Alloys and Compounds 487 (2009) 395–399.

[4] ZHU Fu-long, YUAN Hai-bin, YU Qing-chun, YANG Bin, XU Bao-qiang, DAI Yong-nian1, Behavior of titanium dioxide in alumina carbothermic reduction-chlorination process in vacuum, Transaction of nom ferrous metals society of china, 21 (2011), 1855-1859.

[5] F. Akhlaghi, S.A. Pelaseyyed, Characterization of aluminum/graphite particulate composites synthesized using a novel method termed "in-situ powder metallurgy, Materials Science and Engineering A 385 (2004) 258–266.