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Fabrication of TiO_2 Reinforced Aluminum Metal Matrix Composites Through P/M Process

Mahesh L
Mechanical Engineering Department
REVA Institute of Technology and Management
Bangalore, India

J Sudheer Reddy
Mechanical Engineering Department
Nitte Meenakshi Institute of Technology
Bangalore, India

***Abstract*— TiO_2 reinforced aluminum metal matrix composites with 5 to 15 weight percentage of TiO_2 were fabricated by using powder metallurgy process with pressure less sintering. The effect of reinforcement on the density, porosity, hardness, strength and microstructure of composites was investigated. The density, porosity, hardness and compressive strength of Al-TiO_2 composites were found to increase with increase in the weight % TiO_2 from 5 to 15 weight percent. The microstructure show that the uniform distribution of reinforcement particles.**

Keywords*—*Al-TiO2; Powder Metallurgy; Sintering; Hardness;

I. INTRODUCTION

Nowadays, Aluminum is being used extensively as a matrix in most of the Metal Matrix Composites [MMCs], owing to its highest prominence in applications where a combination of corrosion resistance, low density and high mechanical performance are required such as light weight automotive structures, forgings for suspensions, chassis and aerospace industry [1]. Among the various matrix materials such as titanium, magnesium and copper, aluminum cast alloys are the most widely used ones owing to low density and excellent strength, toughness and resistance to corrosion. Reinforcements for MMCs can be in the form of continuous fibers, whiskers, particulates (including platelets) and wires. The most widely used ones are metal carbides (SiC, TiC, WC, B_4C), metal oxides (ZrO_2, Al_2O_3, TiO_2) metal nitrides (AlN, Si_3N_4, TiN, TaN, ZrN) and metal borides (TaB_2, ZrB_2, WB) [2].

The tensile strength, hardness, abrasive and sliding wear resistance of aluminum is improved appreciably by the incorporation of TiC particles in it. [3]. Al-TiN composites developed through powder metallurgy process signifies a better densification enhancement, increased wear resistance and improvement in mechanical properties due to the presence of TiN particles at the grain boundaries when compared with aluminum matrix. Above 720^0C the SiC particles react with aluminum matrix resulting in Al_4C_3, which has poor mechanical properties [4].

The wear properties of Al-TiO2 indicate that the TiO2 particles provide an excellent combination of mechanical and wear-resisting properties [5]. The apparent density, tap density and theoretical density increase with the addition of TiO2 reinforcement to the pure Al matrix. The reason for the density increase is the filling with fine powders of TiO_2 of the pores formed in the matrix by large irregular Al particles [6]. TiO_2 can be used as a wear resistance material and can act as an effective toughening phase [7-8]. The green or sintered compact subjected to hot forging/pressing exhibited the largest densities and strengths and the relative density of the hot pressed compacts was about 90% [9]. In the present work the fabrication and characterization of TiO_2 reinforced Al metal matrix composites by a powder metallurgy (P/M) process is discussed.

II. EXPERIMENTAL PROCEDURE

A. Materials

The details of pure aluminum and titanium oxide powders used in this study are as shown Table I and Table II.

Table I. Chemical composition of Al powder

Purity	As	Pb	Fe
99.5 %	0.0005 %	0.03 %	0.5 %

Table II. Chemical composition of Tio2 powder

Purity	As	Pb	Fe
99 %	0.0005 %	0.003 %	0.02 %

The aluminum powder used is fine, uniform, smooth, metallic powder free from aggregates and its particle size is -200 mesh.

B. Mixing

Different composition of Al-TiO_2 composites with varying volume fraction of 5, 10 and 15 % were prepared. Powders were mixed using a horizontal ball mill for an about 30 minutes with a power to ball ratio 1:2 to prepare each blends. In order to eliminate agglomeration and cold welding of powder particles a control agent was used.

C. Compaction and Sintering

The Al-TiO_2 green specimens were compacted with a hardened steel die using a pressure of 250 MPa. Such a high pressure was used to obtain the integrity of the specimen. For each composition, approximately 35 g of powder was used. A uniaxial hydraulic press was used to obtain a green compacts. The hardened steel die cavity and punch were lubricated in order to reduce the friction resistance and easy ejection of specimen. The mixed powders are compacted to obtain a green compact of 25 mm in diameter and 25-27 mm in height. The specimens were de-lubricated in a muffle furnace at temperature of 250^{0}C for duration of 30 min. Sintering was done under a nitrogen atmosphere in a tube furnace at a temperature of 450^{0}C for a sintering time of 4 hours. The green density and sintered density were obtained by measuring the dimensions & weight of specimen accurately to 0.01mm and 0.001g respectively.

III. RESULT AND DISCUSSION

A. Microstructure

The microstructure examination was done to analyze the grain size and distribution of titanium oxide particles. The microstructure of Al-TiO_2 composites were studied using optical microscope. Figures 1, 2, 3 and 4 show the optical microstructure of sintered Al-TiO_2 composites at magnification of 20X. Microstructure indicates uniform distribution of reinforcement particles with the matrix, also indicates the bonding has been formed between each other and there is some amount of porosity is present.


Fig.1 Microstructure of Al


Fig.2 Microstructure of Al-5TiO_2


Fig.3 Microstructure of Al-10TiO_2

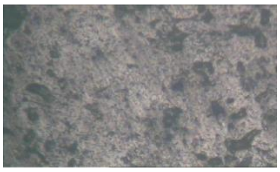
Fig.4 Microstructure of Al-10TiO_2

B. Hardness

The hardness of the Al-TiO_2 samples for each TiO_2 content sintered at 450^{0}C for a sintering time of 4 hours, were measured by Brinell hardness tester. The average Brinell hardness measurement was done on the polished surfaces of the un-sintered and sintered specimen with indenting load of 250 Kgf using 5 mm ball indenter. The hardness result shows that there is an increase in the hardness of Al-TiO_2 composite material with increase in weight % of TiO2 from 0 to 15 wt % of TiO_2. The results were shown in Figure 5.

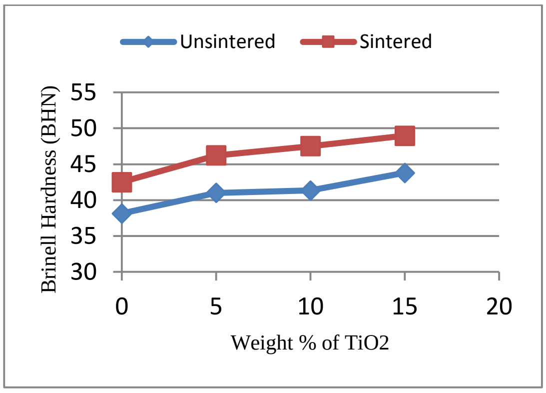

Fig.5 Brinell hardness of Al-TiO2 composites

C. Density

Specimens are prepared by applying 250 MPa compacting pressure, the average green (un-sintered) density and sintered density of composites increases with increase in content of TiO_2. The density of Al-TiO_2 composites in un-sintered and sintered condition are show in figure 6 and 7 respectively. The theoretical density of compacts increases with increase in weight % of TiO_2 since the density of TiO_2 is greater than the density of aluminum. The measured density does not show same kind of nature due presence of porosity. The sintered density of compact is less than the un-sintered one because during sintering the control agent used during mixing of powders is burned off.

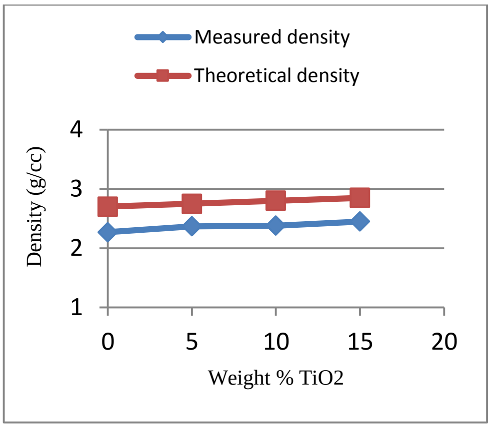

Fig.6 Density of un-sintered Al-TiO_2 composites

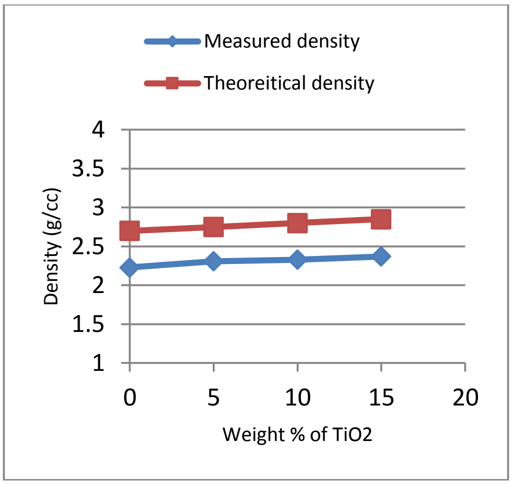

Fig.7 Density of sintered Al-TiO_2 composites

D. Compressive strength

For measuring the compressive strength for each composition of Al-TiO2 four samples tested. Figure 8 show the effect of TiO_2 particulate reinforcement content on the composite strength of the composite. It is observed that the compressive strength of composite increases significantly as the content of reinforcement increases from 0 to 15 weight percent. This increase in compressive strength may be due to presence of hard reinforcement particles and the particles are distributed in different orientations which results in significant difference in stress-strain relationship.

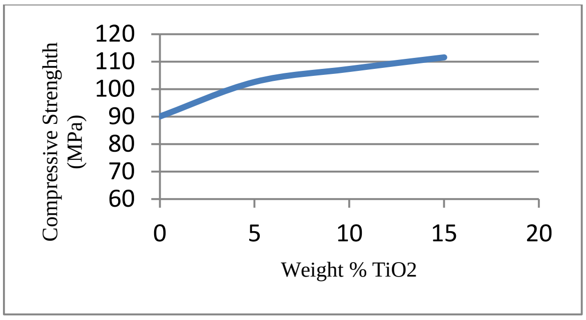

Fig.8 Compressive strength of sintered Al-TiO_2 composites

IV. CONCLUSION

In preparation of test specimen through powder metallurgy process, the manual compact play a vital role on shape and quality of final component. Mechanical alloying of powders result uniform distribution of reinforcement particles in a matrix phase and increase in surface area of aluminum powders helps in improving the bonding with reinforcement particles. Uniaxial compaction at 250 MPa followed by sintering at 450°C has been used to develop Al-TiO_2 composites. Brinell hardness, density and compressive strength increases with increase in reinforcement content from 0 to 15 weight percent of TiO_2.

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