Processing & Characterization of Titanium Carbide & Titanium Oxide Particulate Reinforced Aluminium Metal Matrix Composite for Aerospace Applications

Mr. Azeem Dafedar, Prof. Rahul Bhandari, Dr. T. R. Vijayaram

Abstract—In this research, a composite material containing Aluminium (Al), Titanium Oxide (TiO_2), and Titanium Carbide (TiC) are mechanically manufactured by method of powder metallurgy which will be effective in aerospace application. The composites will be tested by using different percentage composition of materials. The process will start by mixing Aluminium matrix with Titanium Oxide and titanium Carbide reinforced with different percentage composition and the results will be compared with the values of pure Aluminium. The phase composition and morphology of material will be evaluated from hardness test. The microstructure of specimens will be revealed to investigate on continuous distribution of TiO_2 and TiC in the metal matrix, which will be responsible for enhancement of tensile strength of the material. This feature is very likely and due to addition of Titanium Carbide (TiC) and Titanium Oxide (TiO_2) in Aluminium (Al) matrix, there will be a good interface bonding of uniformly dispersed submicron size of reinforced materials. Good stiffness, high strength to weight ratio, good thermal properties which are very beneficial for aerospace applications are emphasized in the current paper.

Index Terms— matrix, composites, sintering, micro structures, Brinell hardness

1 INTRODUCTION

Since from last couple of years metal matrix composites have drawn the attention of many scientists. They are having properties like low density, good wear resistance and high specific strength [1-3]. Particle reinforced metal matrix composites are likely to find high volumes of commercial applications. Isotropic properties, ease of fabrication and improved properties are the basics for metal matrix composites [1-5]. In this research, a composite material containing Aluminium (Al), Titanium Oxide (TiO_2), and Titanium Carbide (TiC) are mechanically manufactured by method of powder metallurgy which will be effective in aerospace application. The metal matrix composites derive good demand for their use in automobile and aerospace applications [6].

The objective of this experiment is to increase the hardness of Aluminium by adding Titanium Carbide and Titanium Oxide as reinforced materials in it. Material should possess uniform distribution of metal matrix compound which should be well suited for aerospace applications.

2 LITERATURE REVIEW

2.1 J Jiang and B Dodd worked on aluminium-based metal-matrix composite (MMC) materials for cold working operations. Localized shear flow will be controlled by compression of composites. A new processing technique for cold workability of the MMC's has been developed with compaction process.

2.2 D.J Lloyd studied about particle reinforced metal matrix composites. These metals are now produced commercially. Different reinforcement with metal matrix composites are studied. With powder metallurgy processing, the composition of the matrix and the type of reinforcement are independent of one another.

2.3 S Jerome, B Ravi Shankar explained in situ Al–TiC (5, 10 and 15 wt. %) composites. These composites manufactured by using a reaction mixture of K_2TiF_6 and graphite powder with molten metal. The effect of ceramic particulate addition in composites was studied. This experiment is carried out at a very high temperature. The sliding wear tests were conducted at room temperature, 120 and 200 °C. The wear rate increases with the increase in applied load. But it decreases with increase in the weight percentage of TiC in MMC.

ISSN 2229-5518

2.4 "An introduction to metal matrix composites (T. W. Cleyn)". This book gives clear idea about metal matrix composites with the processing, manufacturing methods. Clear pictorial descriptions are given of the basic principles governing various properties and characteristics. This shows the mechanical, thermal, electrical, environmental, and wear behavior.

2.5 "Metal Matrix Composites Mechanisms and Properties (R. K. Everest and R. J. Arsenault) ". This book has the influence of properties of materials. Properties like strengthening mechanisms, mechanical properties, fracture and fatigue. Also the properties which affect the nature of materials physical properties, and environmental effects. Two volumes of this book keeps focus on the environmental behavior and physical aspects of the materials.

2.6 "Composite Materials: Science and Engineering (K. K. Chawla)". This book not only includes the conventional part of composites but also it keeps focus on polymer matrix composites, composites with Nano filaments. This book featuring all figures in color. Also includes new solved examples and problems as well as increased coverage of: Carbon/carbon brakes, Composites for civilian aircraft and jet engines, Second generation high-temperature superconducting composites.

3 BASIC POWDER METALLURGY PROCESS

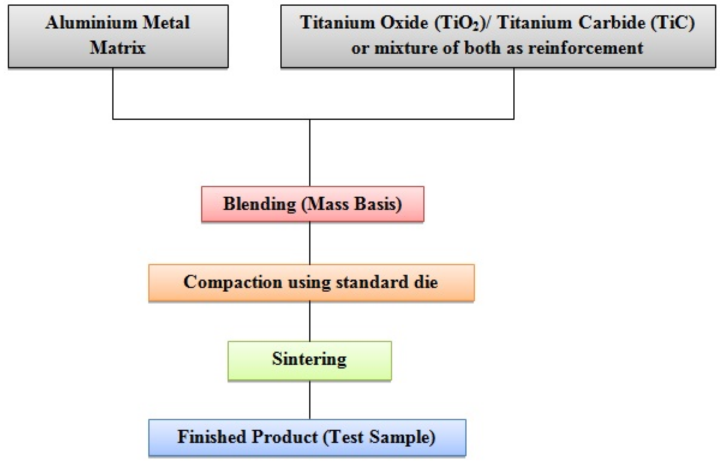


figure no. 1- step by step method of powder metallurgy

Titanium Carbide is choosen for reinforcement due to its fundamental properties like toughness and physical properties like elastic modulus of approximately 400GPa and a shear modulus of 188GPa, which are necessary in aerospace applications. Also Titanium oxide which is mostly used in paints and varnishes possess very good fundamental properties like corrosion resistance.
In this research, a composite material containing Aluminium (Al), Titanium Carbide (TiC) and Titanium Oxide (TiO_2) are mechanically manufactured by method of powder metallurgy. Initially a sample of only aluminium is considered for testing which is having two compaction values as 100 MPa and 120 MPa then another sample in which some amount of Titanium Oxide (TiO_2) is added in it which is further used for testing. Finally the sample in which a mixture of Titanium Carbide & Titanium oxide is mixed with aluminium is taken into consideration for testing. These all materials are taken in powder form and blended accordingly, made to go under a compaction using a die under a pressure of 100 and 120 mpa respectively. After that it is taken into sintering in an oven and heated till 470°C where all the internal stresses are released and the intermolecular homogeneous or heterogeneous bonds are strengthened.

4 EXPERIMENTAL DETAILS

A die of internal diameter of 10mm is used for making samples *(figure 2)*. 1.5 grams of powder is added into the die and compaction is done on it *(figure 3)*. Compaction pressure is 100MPa and 120MPa *(figure*

ISSN 2229-5518

4) and Sintering temperature is maintained constant for all samples as 470°C. The sample is weighted and compacted with different pressures and kept in furnace at a temperature of 470°C and curing time is 1 hour *(figure 5)*. Then the sample is taken out and kept at room temperature for cooling *(figure 6-7)*.

figure no. 2

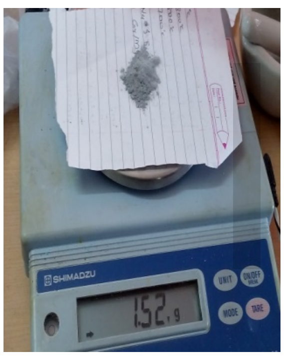


figure no.3

figure no. 4

figure no. 5

In powder metallurgy process compaction of sample with proper sintering temperature forms the good microstructure. For studying microstructure there is no need of chemical etching which is required in the process where composite is manufactured by molten matrix addition of solid reinforcement into it. These prepared composite samples that will be tested are of different percentage composition of materials and microscopic study will also be done.

figure no. 6

figure no. 7

Aluminum (Al)	Titanium Carbide (TiC)	Titanium Oxide (TiO_2)	Compaction Pressure (MPa)	Sintering Temperature (Deg C)
100%	0%	0%	100	470
100%	0%	0%	120	470
96%	2%	2%	100	470
96%	2%	2%	120	470
98%	0%	2%	100	470
98%	0%	2%	120	470
92%	4%	4%	100	470
92%	4%	4%	120	470

Table no.1- composition contents of reinforced material and matrix composition

The phase composition and morphology of material will be evaluated from hardness test. The microstructure of specimens will be revealed to investigate on continues distribution of TiO_2 and TiC in the metal matrix in a microscope with 100X zooming using electronic microscope.

ISSN 2229-5518

figure no. 8 – Electronic microscope used for testing the microstructure

5 RESULTS AND DISCUSSION

5.1 Microstructure study:

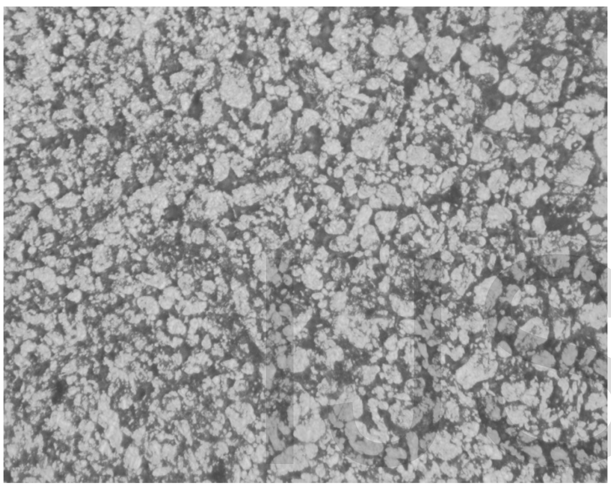


figure no. 9 – Pure aluminium under 100 mpa (100X)

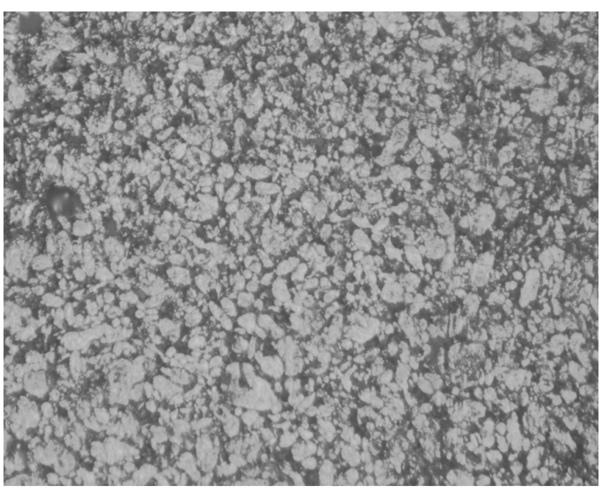


figure no. 10- Pure aluminium under 120 mpa(100X)

Figure 9 shows pure Aluminium at sintering temperature of 470C and with 100 MPa pressure. From figure 9 and figure 10 it is clear that as we increase compaction pressure but keep the sintering temperature same, the grain boundaries for figure 10 is compacted.

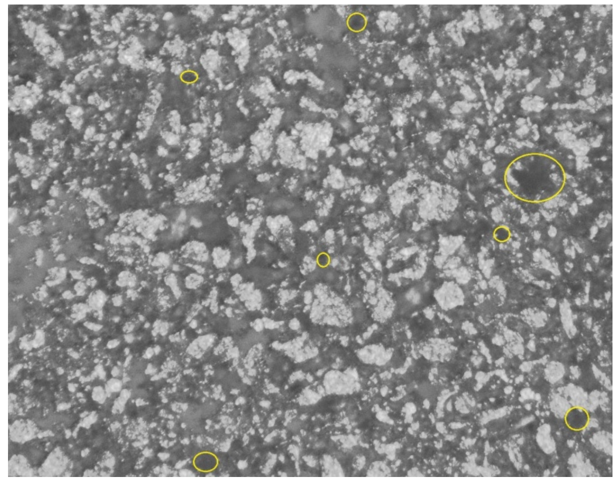


figure no. 11- aluminum with reinforcement of titanium oxide(TiO2) under 100 mpa (100X)

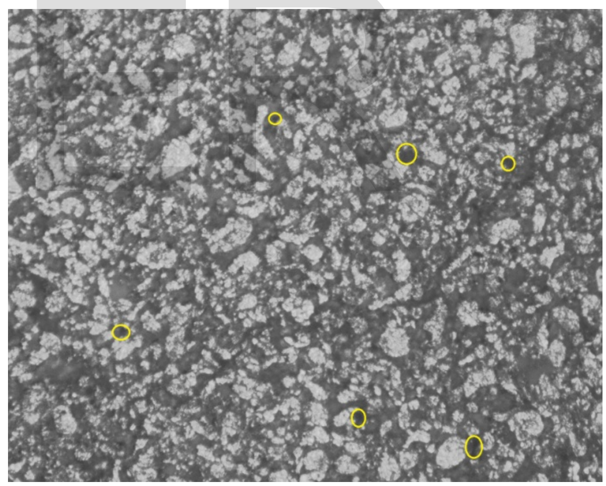


figure no.12- aluminium with reinforcement of titanium oxide(TiO2) under 120 mpa (100X)

Figure 11 and figure 12 are based on Al+TIO_2 metal matrix composite at two different compaction pressures. Black spot in the microstructure which are encircled by yellow rings shows the TiO_2 which is equally distributed in Aluminium.

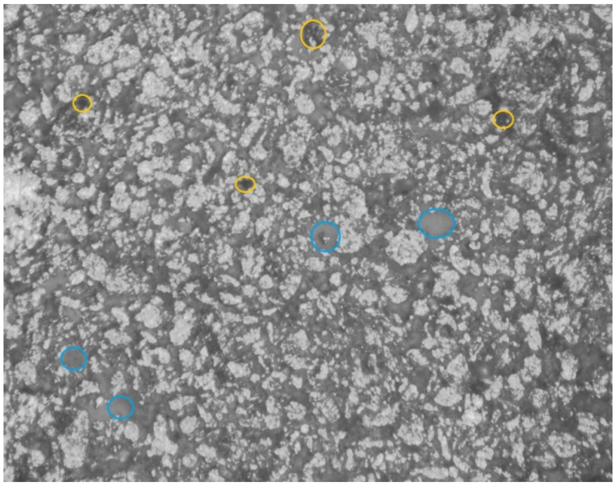


figure no. 13- aluminum with reinforcement of titanium oxide(TiO2)& Titanium carbide(TiC) under 100 mpa

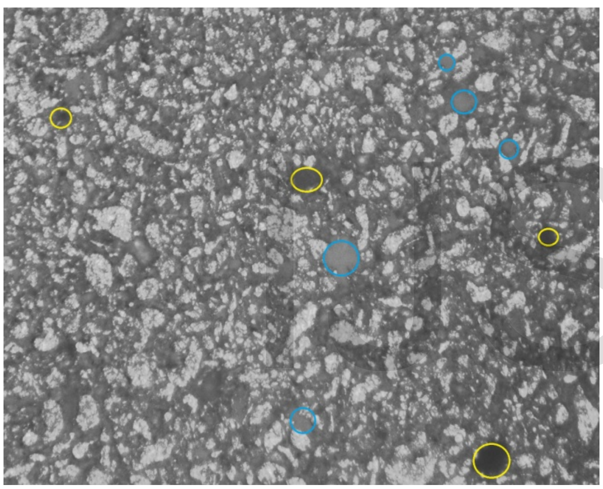


figure no.14- aluminium with reinforcement of titanium oxide(TiO2)& Titanium carbide(TiC) under 120 mpa

Figure 13 & 14 is microstructures of Al+TiO_2+TiC metal matrix compound. Black spot encircled by yellow rings shows the TiO_2 and grey part(clay like) encircled by blue rings is TiC. Both reinforcements are uniformly distributed in metal matrix Al.

6 BRINELL HARDNESS VALUE

After studying microstructure it is very important to find the hardness value for components. The sample was then made to undergo a load of 60 kg on it. Take reading at different points & calculate the average of values. Following table shows the value of Brinell hardness number of different components.

figure no 15. - Brinell hardness test on the samples

Let P_1, P_2, P_3 be the value of BHN at different location of specimen. At different points of specimen we get slightly different values of BHN. For finding actual value of BHN of specimen take average of all three values.

SPECIMEN (Al+TiO_2+TiC)	Compaction Pressure (MPa)	Sintering Temperature (C)	BRINELL HARDNESS NUMBER $(P_1+P_2+P_3)/3$
100+0+0	100	470	B48
100+0+0	120	470	B55
96+2+2	100	470	B95
96+2+2	120	470	B100
98+2+0	100	470	B80
98+2+0	120	470	B90
92+4+4	100	470	B105
92+4+4	120	470	B115

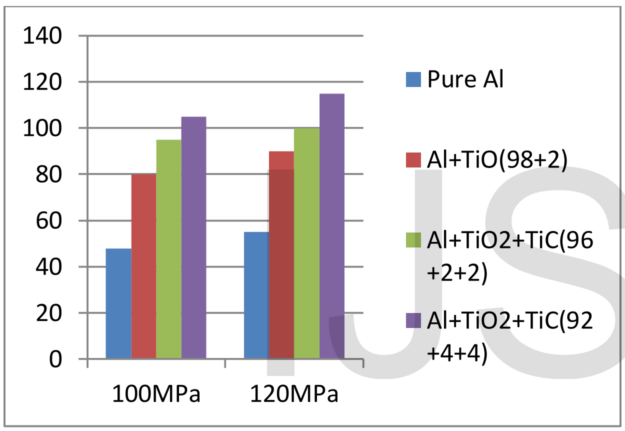
Table no. 2-Brinell hardness value of different compositions of matrix & reinforcements

ISSN 2229-5518

As the percentage of reinforcement such as TiO2 and TiC increases in Aluminium there is increase in the value of Brinell hardness number also. For pure Aluminium, value of BHN is very less. If we add small amount of TiO_2 in it the hardness value will increase at very considerable amount, the value comes around BHN 80. Similarly by adding TiO_2 and TiC in small quantity again value comes will be more than the Al+TiO_2 value.

6.1 HARDNESS COMPARISON

Following clustered column chart helps in illustrating the hardness value (BHN) comparison between pure Aluminium and Aluminium with different inclusions.



7 APPLICATIONS

1. The main application of metal matrix compound is in aerospace industry. As Aluminium is major constituent here therefore weight of the product is very less and strength is high.
2. Now a day's automobile industry are also trending towards low weight high performance concept vehicle. For automobiles we can use this metal matrix compound as a load carrying member.

8 CONCLUSIONS

By adding small amount of reinforced metal in Al, the hardness of Al increases drastically. If we add 2% of TiO_2 to pure Al we can increase the hardness by almost 2X, with increase of compaction pressure from 100 to 120 MPa we get increase in Brinell value. Again if we want to increase hardness value just add TiC and TiO_2 inclusion in Aluminium. By increasing compaction pressure by keeping sintering temperature same we can increase the hardness. Add the reinforcement in 2% or 4% or 6% or 8% each. Up to certain limit of addition of reinforcement in metal matrix the hardness increases. As Al is very light in weight and by adding very small amount of reinforcement into it the hardness increases which is very effective in applications where there is requirement of low weight high strength properties like in the field of aerospace and automobile.

9 REFERENCES

[1] J. Jiang, B. Dodd," *Workability of Aluminium-based metal-matrix composites in cold compression*". Volume 26 (1995) 62-66.

[2] D. J. Lloyd, "*Particles reinforced aluminium and magnesium matrix composites*", Rev. 39 (1994) 1-23.

[3] S. Jerome, B. Ravi Shankar, K. M. Pranab, S. Natarajan, "*Synthesis and evaluation of mechanical and high temperature tribology properties of in-situ Al-TiC composites*", Tribology International 43 (2010) 2029-2036.

[4] T. W. Clyne, P. J. Withers," *An introduction to metal matrix composites*", Cambridge University Press, U.K 1993.

[5] R. K. Everest, R. J. Arsenault, "*Metal Matrix Composites: Processing and Interfaces*", Academic press U.S.A 1991.

[6] K. K. Chawla, "*Composites Materials: Science and Engineering, Springer-Verlag*", New york, 1987