Vandana Publications
IJEMR

Volume-7, Issue-3, May-June 2017
International Journal of Engineering and Management Research
Page Number: 312-317

Production and Characterisation of Aluminum – Titanium Di Boride Composite Using Powder Metallurgy Technique

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ABSTRACT

In this project, a composite material containing Aluminum (Al), Titanium Di boride (TiB_2) 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 Aluminum matrix with Titanium diboride reinforced with different percentage composition and the results will be compared with the values of pure Aluminum. The phase composition and morphology of material will be evaluated from hardness test. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. These composites are widely used in industries like aerospace, defense, automobiles, bio materials as well as sports etc. In present work aluminum alloy reinforced with TiB_2 MMCs materials are prepared by the powder metallurgical technique have cost advantage over the composites made by the other. Three different volume fractions (0%, 4%, and 8%) of particulate TiB_2 are used in the production of aluminum matrix composite at 680^0 C. This feature is very likely and due to addition of Titanium diBoride (TiB_2) in Aluminum (Al) matrix, there will be a good interface bonding of uniformly dispersed submicron size of reinforced materials.

Keywords-- Metal matrix composites (MMCs), SEM analysis, Hardness Test, Density Test

I. INTRODUCTION

From the last few years in much industrial application the important parameter in material selection is specific strength, weight and cost. Here we discussed the review paper relevant to this. Before going the review section we must know the difference between the composite and MMC. The composite defined as the made of several part or element but only combined different material not a non-metal whereas the non-metal is mixed with material this called MMC. Clearly we had seen the review paper. the main mixed material most probably like aluminum alloy and then it group, silicon carbide, fly ash, graphite, boron carbide, RHA, fly ash cenospehere, silicon nitride, silicon carbide, titanium diboride etc..., in this material we fabricated by using different method with respected to the grain size the generally we go for the stir casting and powder metallurgy technique and finally they going to tested the mechanical properties like tensile strength, ductility, compressive strength, density, Hardness, elongation etc..,

Rama Rao [1] and others examined that aluminum alloy-boron carbide composites were fabricated by liquid metallurgy techniques with different particulate weight fraction (2.5, 5 and 7.5%). Phase identification was carried out on boron carbide by x-ray diffraction studies microstructure analysis was done with SEM a composites were characterized by hardness and compression tests. The results shows increase the amount of the boron carbide. The density of the composites decreased whereas the hardness is increased.

Balasivanandha prabu [2] and others investigated that better stir process and stir time. The high silicon content aluminum alloy –silicon carbide MMC material, with 10% SiC by using a variance stirring speeds and stirring times. The microstructure of the produced composite was examined by optical microscope and scanning electron microscope. The results with respected to that stirring speed and stirring time influenced the microstructure and the hardness of composite. 792also they investigate that at lower stirring speed with lower stirring time, the particle group was more. Increase in stirring time and speed resulted in better distribution of particles. The mechanical test results also revealed that stirring speed and stirring time have their effect on the hardness of the composite. The uniform hardness valued was achieved at 600 rpm with 10min stirring. But above this stir speed the properties degraded again.

Karunamoorthy [3] and others analyzed that A 2D microstructure-based FEA models were developed to study the mechanical behavior of MMC. The model has taken into account the randomness and clustering effects. The particle clustering effects on stress-strain response and the failure behavior were studied from the model. The optimization of properties was carried out from analysis of microstructure of MMC since the properties depend on particles arrangement in microstructure. In order to model the microstructure for finite element analysis (FEA), the micro-structures image converted into vector form from the raster than it conversion push to IGES step and mesh in FEA model in ANSYS 7. The failure such as particle interface decohesion and fracture the predicted for particle clustered and non-clustered micro structures. They analyzed that failure mechanisms and effects of particles arrangement.

II. OBJECTIVES

The main intention of this project is to conduct a comparative study between two methods for estimating the design strength of composite materials. Composite materials have been used in the aerospace, automotive and boating industries for decades. Applications of composite materials in infrastructure projects are relatively new. Several agencies such as the American Concrete Institute (ACI) published guidelines to assist designers in using composite materials. The American Society for Testing and Materials (ASTM) published standards addressing several aspects of composite materials for several applications including for the structural design of the infrastructure projects. There is a major difference between the methods for estimating the strength of composite materials from both organizations. This study will review both methods using experimental data of typical test coupons. Composite materials offer engineers many advantages that are especially appealing for infrastructure projects. Light weight, durability in harsh environments and high tensile strengths are just a few examples of why the use of composite materials in infrastructure projects has increased in recent years.

III. EXPERIMENTAL SETUP

Al-TiB_2 nano composite was produced via powder metallurgy method using aluminum, powder with a purity of 99.97% and D_{50} = 20 ìm, as the matrix material and TiB_2 nanoparticles with D_{50} = 80 nm as the reinforcement. The fabrication steps in powder metallurgy route were: Al powder alloy has been mixed with TiB_2 nanoparticles, and then cold isocratic pressing machine (CIP) was employed to produce the samples. Finally, green compacts were sintered at two different temperatures of 650, and 680 °C. Various TiB_2 contents of 0, 4 and 8 vol. % have been considered for each processing temperatures.

EXPERIMENTAL SETUP DESCRIPTION:

Powder Metallurgy (PM)

Powder Metallurgy: Metal parts are made by compacting fine metal powders in suitable dies and sintering (heating without melting).

Typical products: From tiny balls for ball-point pens, to gears, cams, and bushings, to cutting tools, to porous products (filters and oil-impregnated bearings).

Most commonly used metals in P/M: iron, Cu, Al, tin, Ni, Ti, and refractory metals.

For parts made of brass, bronze, steels, and stainless steels, pre-alloyed powders are used, where each powder particle itself is an alloy.

Sequence of Operations:

Powder Metallurgy process basically consists of the following operations in sequence:

1. Powder production

Fig: powder making process

2. Blending

Fig: Blending process

3. Compaction

Fig: Compacting process

4. Sintering:

Fig: sintering process

Design Considerations for PM

- The shape of the compact must be as simple and uniform as possible.
- Avoid sharp changes in contour, thin sections, variations in thickness, and high length-to-diameter ratios.
- Provision must be made for ejecting the green compact from the die without damaging the compact; for example, holes or recesses should be parallel to the axis of punch travel.
- Implement the widest dimensional tolerances that are consistent with their intended applications, in order to increase tool and die life and to reduce production costs.
- Dimensional tolerances of sintered P/M: ±0.05-0.1mm.

IV. RESULTS AND DISCUSSIONS

HARDNESS TEST:

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied. Some materials (e.g. metals) are harder than others (e.g. plastics). Macroscopic hardness is generally characterized by strong Inter molecular bonds, but the behaviours of solid materials under force are complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness.

Indentation Hardness

Indentation hardness measures the resistance of a sample to material deformation due to a constant compression load from a sharp object; they are primarily used in engineering and metallurgy fields. The tests work on the basic premise of measuring the critical dimensions of an indentation left by a specifically dimensioned and loaded indenter.

The Brinell hardness test method as used to determine Brinell hardness is defined in ASTM E10. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings. Brinell testing often use a very high test load (3000 kgf) and a 10mm wide indenter so that the resulting indentation averages out most surface andsub-surfaceinconsistencies.

The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured across at least two diameters – usually at right angles to each other and these result averaged (d). A chart is then used to convert the averaged diameter measurement to a Brinell hardness number. Test forces range from 500 to 3000kgf.

Test Method Illustration
D = Ball diameter
d = impression diameter
F = load
HB = Brinell result

Typically the greatest source of error in Brinell testing is the measurement of the indentation. Due to disparities in operators making the measurements, the results will vary even under perfect conditions. Less than perfect conditions can cause the variation to increase greatly. Frequently the test surface is prepared with a grinder to remove surface conditions. The jagged edge makes interpretation of the indentation difficult. Furthermore, when operators know the specifications limits for rejects, they may often be influenced to see the measurements in a way that increases the percentage of “good” tests and lessre-testing.

Two types of technological remedies for countering Brinell measurement error problems have been developed over the years. Automatic optical Brinell scopes use computers and image analysis to read the indentations in a consistent manner. This standardization helps eliminate operator subjectivity so operators are less-prone to automatically view in-tolerance results when the sample’s result may be out-of-tolerance.

Calculations of hardness values:

s. no	Material	Load kg	Ball diameter (mm)	Indentation dia. (mm)	BHN Kgf/mm2
1	Aluminum metal matrix	60	2.5	1.27	44.08
2	Aluminum metal matrix	60	2.5	1.28	43.34
3	Aluminum metal matrix	60	2.5	1.26	44.84
4	Aluminum metal matrix	60	2.5	1.29	42.61
5	Aluminum metal matrix	60	2.5	1.28	43.34

ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

Al6061 With 0% of TiB_2

$$1.\ BHN1 = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.27^2})} = 44.08$$

$$2.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.28^2})} = 43.34$$

$$3.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.26^2})} = 44.84$$

$$4.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.29^2})} = 42.61$$

$$5.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.28^2})} = 43.34$$

BHN $=(BHN_1+BHN_2+BHN_3+BHN_4+BHN_5)/5$

BHN $=$ (44.08+43.34+44.84+42.61+43.34)/5=43.56

Al6061 With 4% of TiB_2

s.no	Material	Load kg	Ball diameter (mm)	Indentation dia. (mm)	BHN Kgf/mm 2
1	Aluminium metalmatrix	60	2.5	1.24	46.41
2	Aluminium metalmatrix	60	2.5	1.23	47.23
3	Aluminium metalmatrix	60	2.5	1.25	45.62
4	Aluminium metalmatrix	60	2.5	1.24	44.84
5	Aluminium metalmatrix	60	2.5	1.23	45.62

$$1.\ BHN1 = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.24^2})} = 46.41$$

$$2.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.23^2})} = 47.23$$

$$3.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.25^2})} = 45.62$$

$$4.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.26^2})} = 44.84$$

$$5.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.25^2})} = 45.62$$

BHN $=$ $(BHN_1+BHN_2+BH_3+BH_4+BH_5)/5$

BHN= (46.41+47.23+45.62+44.84+45.62)/5=45.94

Al6061 With 8% of TiB_2

s. no	Material	Load kg	Ball diameter (mm)	Indentation dia. (mm)	BHN Kgf/ mm2
1	Aluminium metal matrix	60	2.5	1.23	47.23
2	Aluminium metal matrix	60	2.5	1.21	48.92
3	Aluminium metal matrix	60	2.5	1.22	48.06
4	Aluminium mmetal matrix	60	2.5	1.20	49.29
5	Aluminium mmetal matrix	60	2.5	1.22	48.06

$$1.\ BHN1 = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.23^2})} = 47.23$$

$$2.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.21^2})} = 48.93$$

$$3.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.22^2})} = 48.06$$

$$4.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.20^2})} = 49.79$$

$$5.\ BHN = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} = \frac{2\times 60}{\pi 2.5(2.5-\sqrt{2.5^2-1.22^2})} = 48.06$$

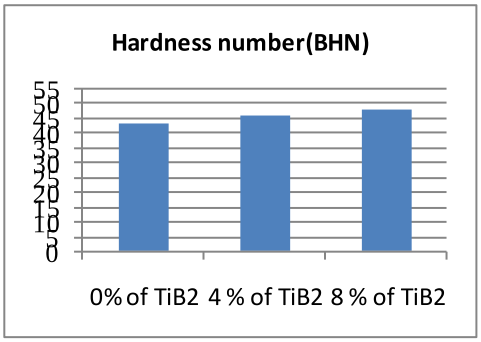
BHN $=$ $(BHN_1+BHN_2+BHN_3+BHN_4+BHN_5)/5$

BHN= (47.23+48.93+48.06+49.79+48.06)=48.41

Brinell's hardness analysis of the aluminum composite:

Al 6061 – weight % of TiB_2	Average Hardness
0	43.642
4	45.944
8	48.414

 ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962



Graph: hardness values of Al6061 – TiB_2

In this observation, the Hardness value of the pure Al6061 is 43.642BHN by increasing the volume percentage of the TiB_2 to 4% the Hardness value is 45.944BHN and by increasing the volume percentage 8% the Hardness value is 48.414 finally the volume percentage of TiB_2 increases 0% to the 8% the Hardness value is increases to the 48.414BHN increases by 4.77BHN

SEM ANALYSIS

Microstructure analysis of Al6061 & TiB_2 using scanning electron micrographs (SEM):

Scanning electron micrographs of the Al6061-TiB_2 Nano composites with different amounts of reinforcement phase, sintered at 680 °C is presented in the figure shown below. The images are taken in BSE (back-scattered electron) mode in order to distinguish between different phases based on the difference of average atomic numbers of each phase, mainly aluminum and TiB2. In this respect, the notable micro structural phenomena are agglomerations and porosity voids which appear as lighter and darker areas compared with ambient gray colour of background, respectively. As mentioned, TiB_2 has a higher density than aluminum matrix and tends to appear brighter. Notwithstanding, uniform distribution of reinforcement particles of TiB_2 is attained in non-agglomerate areas (matrix phase).In the set of images for samples sintered at 680^0 C, it could be observed that with increasing the volume percent of TiB_2 the scale of agglomeration and consequent micro structural deteriorations as porosity and crack increases. The agglomerated regions are appeared as brighter TiB_2-rich particles in the rather darker background which chiefly consists of aluminum. Agglomeration could be a result of localized distribution of powders during combination because of the difference in size and density of aluminum and TiB_2 powders. The porosity of samples tends to grow and propagate with increasing the amount of TiB_2 corresponding the agglomeration and retarded sintering which confirms the results of density measurements that is, the TiB_2- richer samples are more prone to micro structural deteriorations. However, the overall amount of porosity has been decreased in the samples sintered at 680°C due to amended sintering and coalescence of green compacts. Such contrast is especially more evident in corresponding samples (in 4 and 8) with lower amounts of TiB2. Micro structural deteriorations are more severe in case of Al-4TiB2 and Al-8TiB2 samples as appears in the both sets of images which would affect the mechanical properties of nanocomposites. This implies that the conditions of preparing composites should be adjusted with increasing the amount of reinforcement phase to achieve equivalent qualities and properties. Finally, In spite of regional agglomerations, a uniform distribution of reinforcement particles could clearly be observed in the SEM images.

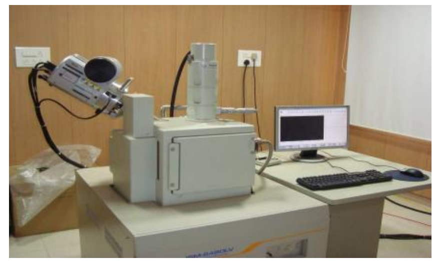


Fig: Scanning Electron Microscope

The microstructure of the Al6061 without TiB_2

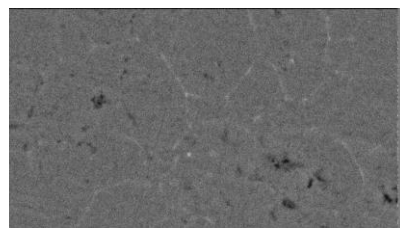


Fig: Micro Structure of Al6061

The microstructure of the Al6061 with 4% of TiB_2

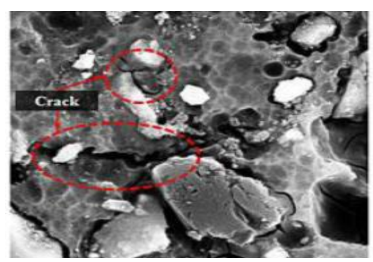


Fig: The Microstructure of the Al6061 With 4% of TiB_2

The microstructure of the Al6061 with 8% of TiB_2

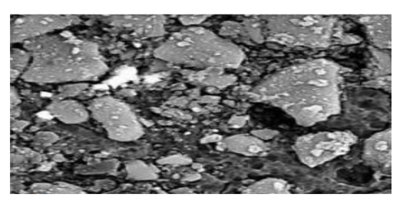


Fig: The Microstructure of the Al6061 With 8% of TiB_2

V. CONCLUSIONS

From literature review related to the Aluminum alloy metal matrix Composite material we have concluded that, the pure aluminum mixed with sum other material through the process like stir casting, powder metallurgy technique and followed by different fabrication procedure. The mechanical characteristics of Al6061-TiB_2 aluminum matrix composite was studied in detail. The study reveals that there is an increase in the hardness property of the Aluminum with the reinforcement of TiB_2. Inclusion of reinforcement in the Aluminum improves the micro-hardness value of the Aluminum. From the result, it is understood that increase in the amount of TiB_2 will certainly increase the hardness number of the Aluminum. Increase in the composition of TiB_2 was clearly found with the help of the images in the microstructure. Density measurements of samples revealed that the density value increases with increasing the volume percentage of ceramic phase mainly due to that the result show that increasing better mechanical properties than reducing the weight and cost. For the microstructure analysis of the Al6061 – TiB_2 by the SEM analysis shows that at the 4% of the TiB_2 we observed some cracks because of the agglomerations in the material. At 8% of the TiB_2 there is no agglomerations formed. Keep on increasing the volume percentage of the TiB_2 more agglomerations are formed.

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