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Microstructure Study of Microwave Sintered Aluminium Titanium Dioxide Metal Matrix Composites

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Abstract: Aluminium metal matrix composites have many beneficial characteristics like light weight, high strength, stiffness and exhibit greater resistance to corrosion, oxidation, wear and having high damping capacity.In addition to base metal, the characteristics of reinforcing particles also play an important role in controlling the strength and hardness of metal matrix composite. The characteristic of metal matrix composites depends on the size, shape and volume percentage of reinforcement material and also depends on processing techniques. In the present work powder metallurgy technique is adopted to produce the composites due to its uniform distribution of reinforcing particle.Sintering plays a major role in the outcome of powder metallurgy composites. Microwave technology is adopted in present work to sinter the composites.

Investigation is carried out on TiO2 particles reinforced with aluminium and were prepared using powder metallurgy technique with various weight percentage combinations of TiO2 particles 10% by wt., 15% by wt. and 20% by wt., Compaction loads and microstructure were studied in the investigation.

INTRODUCTION

Today's engineering world requires materials that are lighter, stronger and less expensive. In service performance demands broad applications which are quite difficult to meet existing materials. Metal matrix composites (MMCs) have been identified for such properties includelight weight, low density,high thermal resistance, high ultimate tensile strength, excellent wear resistance, high corrosion resistance and other properties. Development of lightweight composite materials with excellent mechanical properties is an effective technique to enhance their applications in aerospace, automotive sheet metal, construction and other industries, for this applications aluminium is a common materialas it is a light weight material Among other metallic materials, aluminium based metal matrix composites have been used as the largest. Enhancement of properties of aluminium based MMCs can be optimized when the matrix shift load to the reinforcement effectively. In this work, powdered TiO_2 is introduced to the aluminium matrix whit the help of powder metallurgy technique. Powder metallurgy can produce different composites in the whole range of matrix reinforcement compositions. Challenges faced in this technique is to obtain a homogeneous distribution of the reinforcement in the metal matrix. In powder metallurgy manufacturing process, the matrix and reinforcement mixing process is the critical step for a homogeneous

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distribution throughout the composite material, although subsequent processes, such as powder extrusion, can help to optimize the reinforcement distribution. Reinforcements for MMCs can be in the form of continuous fibres, whiskers, particulates and wires. The most widely used ones are metal carbides (SiC, TiC, etc.), metal oxides (ZrO_2, Al_2O_3, TiO_2). The tensile strength, hardness, abrasive and sliding wear resistance of aluminium is improved immensely by the incorporation of TiO_2 particles in it. 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. TiO_2 particles react with aluminium matrix resulting in Al-TiO_2 Metal Matrix Composite which has good mechanical properties. The densities of different (Compacted, Sintered, Extruded) specimen are calculated.The purpose of this work is to obtain composite powders with improved reinforcement distribution by means of mechanical alloying and also to study this process by means of some process parameters and their influence on some of the material properties.

EXPERIMENTAL PROCEDURE

a. Material selection

Materials selected were pure aluminium and titanium di oxide powders,properties of these materials are shown in Table I and Table II.

Table I: Properties of Aluminium

Properties	Values
Elastic Modulus(GPa)	68-72
Density(g/cc)	2.7
Poisson’s ratio	0.33
Tensile Strength(MPa)	70-360
Melting temperature(℃)	582-652℃

Table II: Properties of TiO_2

Properties	Values
Elastic Modulus(GPa)	240
Density(g/cc)	4.23
Poisson’s ratio	0.28
Tensile Strength(MPa)	300-350
Melting temperature(℃)	1843

b. Mixing

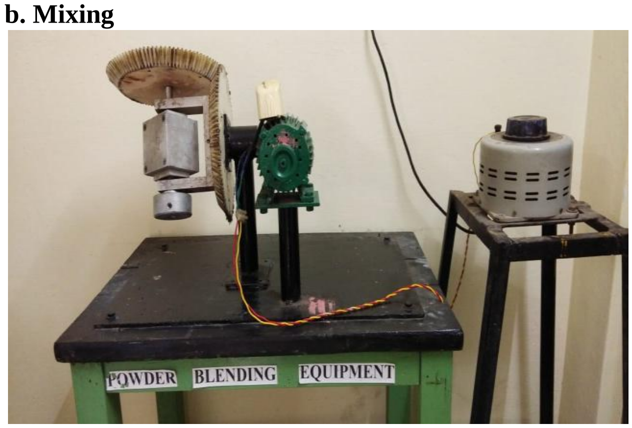

Figure 1: Powder Blending Machine

Mixing of the Aluminium powder and TiO_2 powder was carried out in a powder blending machine. Different composition of Al-TiO_2 composites with varying volume fraction of 10%, 15% and 20% were mixed.Initially the powders were weighed on a weighing machine, weighed powder was transferred in to the container, to eliminate agglomeration of powder particles ethanol was used, which also acts as a lubricant between the powders. The container was loaded into the machine and the machine was run for 30 minutes for each sample. After blending, wet powder from the container was removed and was dried until ethanol was evaporated from the mixture of the powder.

c. Compaction

Figure 2: Compaction die placed on UTM

The Al-TiO_2 green specimens were compacted with a die using a pressure ranging from 129 to 208 MPa. This pressure was used to obtain the integrity of particles in the specimen. A Universal Testing Machine (UTM) was used to obtain a green compact's. 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 30 mm in diameter and 50 mm in length.

Figure 3: Compacted Specimen

d. Sintering

Figure 4: Microwave Oven Used for Sintering

Microwave sintering was carried for the green compact obtained after compaction. Microwaves have the wavelength which range from 1mm to 1 m with a frequency from 300MHz to 300GHz.

Initially the setup was done, specimen was placed on a Silicon carbide which was used to conduct microwaves and transfer heat energy to the specimen.Specimen with Silicon carbide was placed in Alumina box and was covered with glass wool so that the heat generated and the microwaves generated could not scatter from the specimen.Microwave oven was switched on and was set to 900watt power, initially the trial for a specimen was carried out by setting the oven to 15 minutes.After 15 minutes the specimen was removed from the microwave oven and was allowed to cool on room temperature.

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Figure 5: Sintered Specimen

RESULTS AND DISCUSSION

(A) Compaction

(i) Compaction of Al+ 10%TiO_2

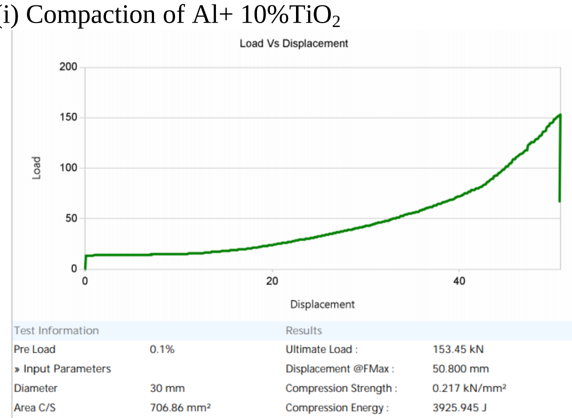


Figure 6: Compaction Load v/s Displacement 10% TiO_2

(ii) Compaction of Al+ 15%TiO_2

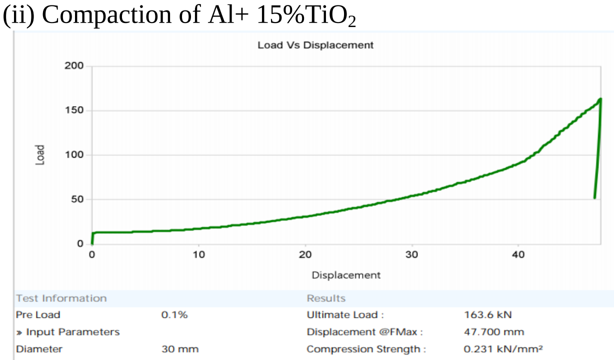


Figure7: Compaction Load v/s Displacement 15% TiO_2

(iii) Compaction of Al+ 20%TiO_2

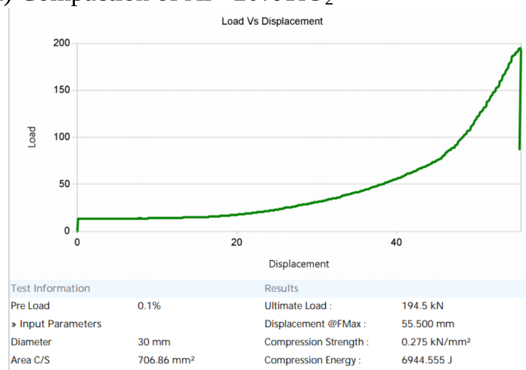
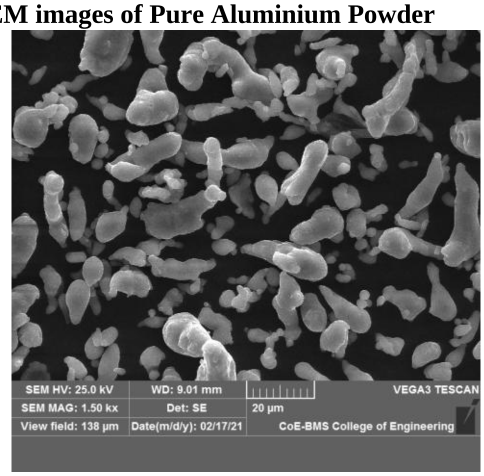


Figure 8: Compaction Load v/s Displacement 20% TiO_2

Compaction was carried out in the UTM and it was observed that the load for compaction of the specimen increased when there was a rise in percentage of Titanium dioxide in the Aluminium matrix. Figure 6, figure 7 and figure 9 show the different loads under which specimen with Al+10%TiO_2, Al+15%TiO_2 and Al+20%TiO_2 respectively were compacted. For Al+10%TiO_2 the maximum load observed was 153.45 kN, For Al+15%TiO_2 the maximum load observed was 163.6 kN.And for Al+ 20%TiO_2 the maximum load observed was 194.5 kN.

(B) Morphology

(i)SEM images of Pure Aluminium Powder



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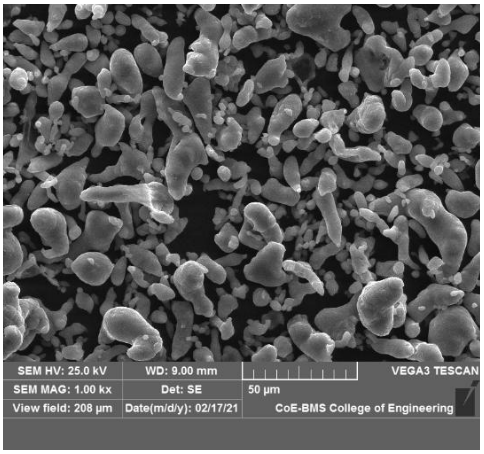

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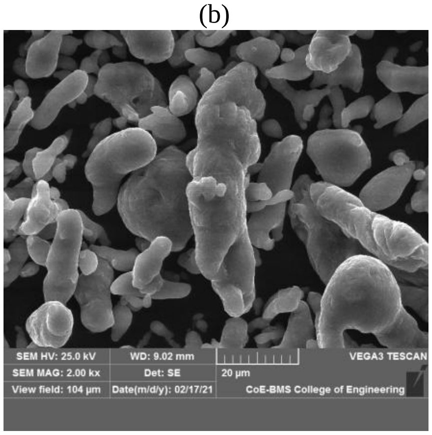

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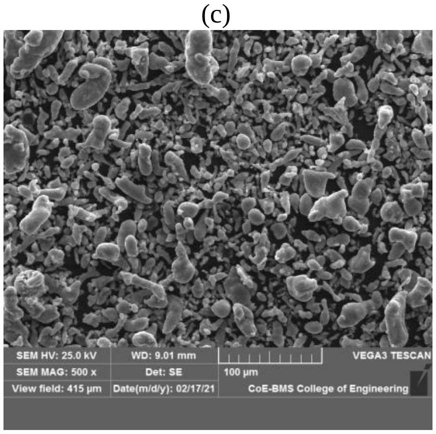
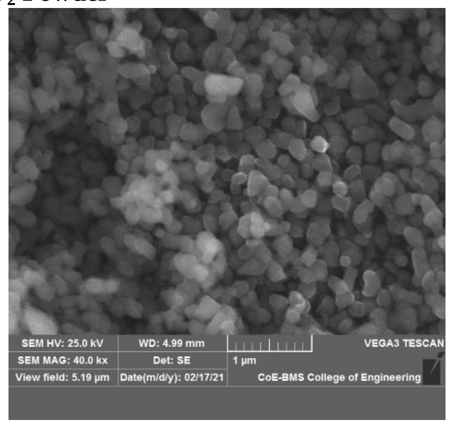


(d)

Figure 9: SEM images of Aluminium Powder

Average particle size of Aluminium powder used was 8.178µm

(ii)TiO_2 Powder



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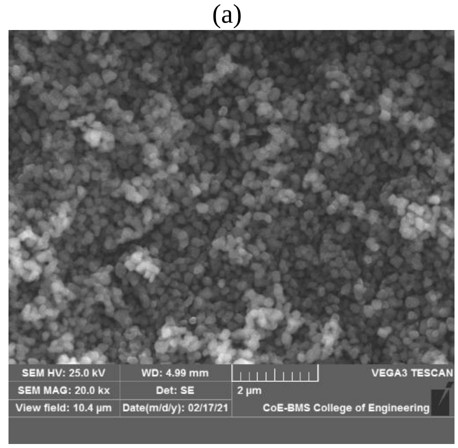

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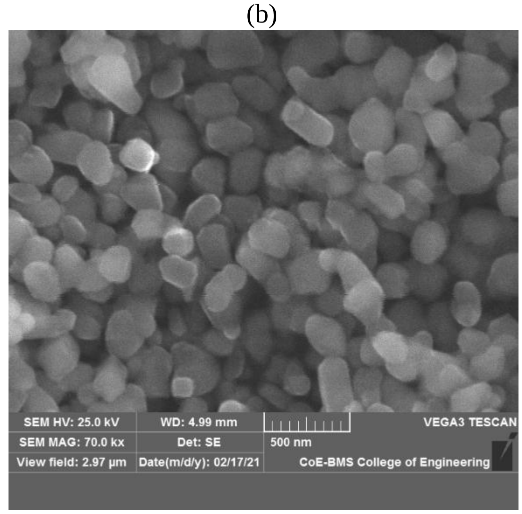

(c)

Figure 10: SEM images of TiO_2Powder

Average particle size of TiO_2Powder used was 112.87 nm

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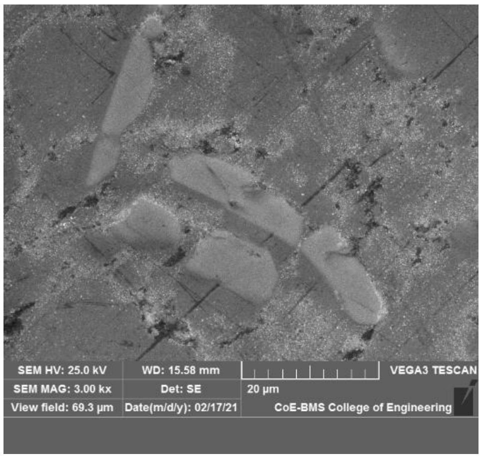
(iii) SEM images of Al+ 10%TiO_2



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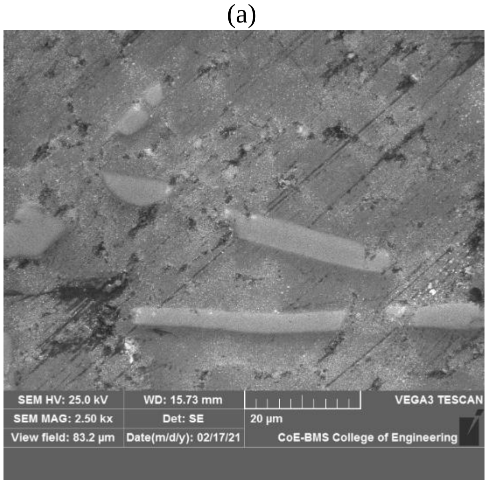

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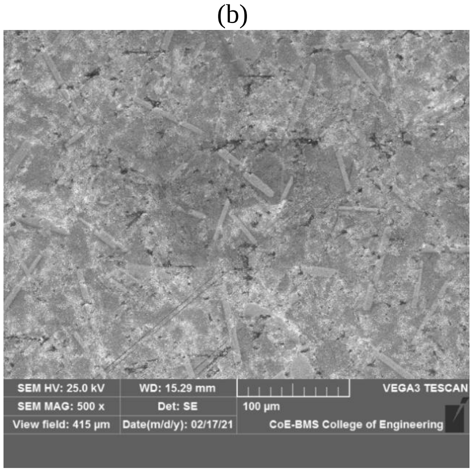

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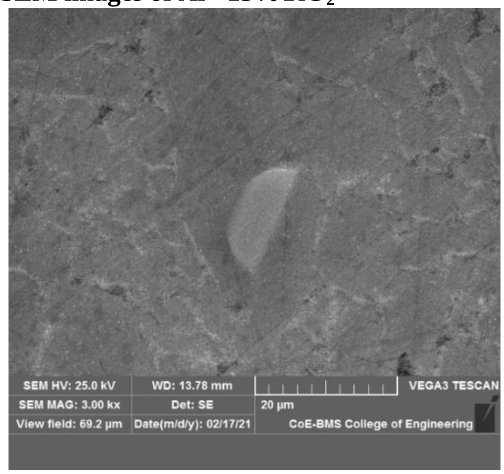
Figure 11: SEM images of Al+10%TiO_2

(iv) SEM images of Al+ 15%TiO_2



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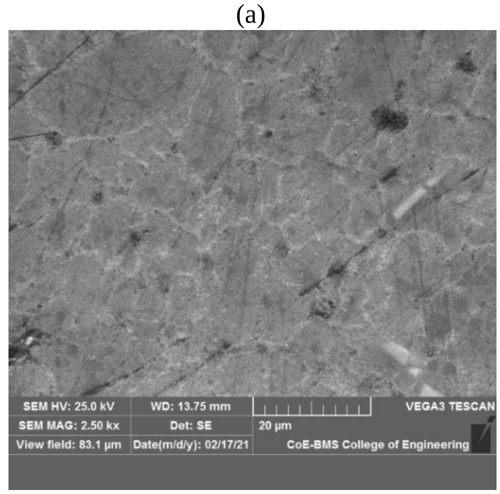

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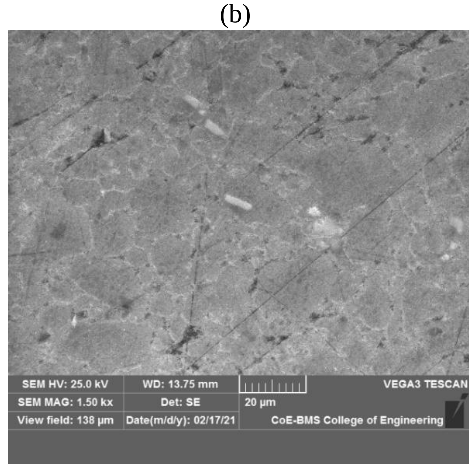

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Figure 12: SEM images of Al+ 15%TiO_2

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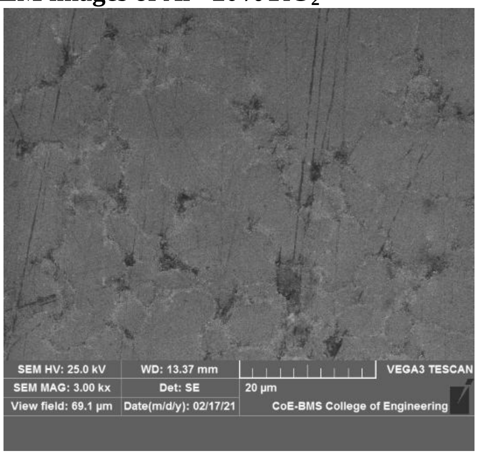
(iv) SEM images of Al+ 20%TiO_2



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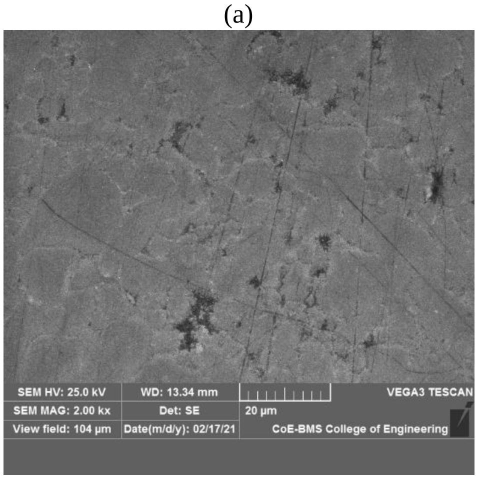

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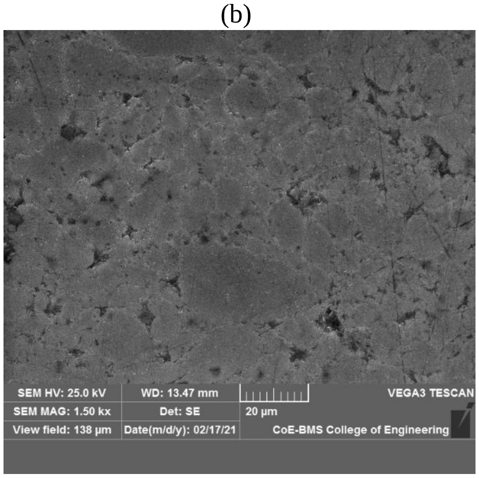

(c)

Figure 13: SEM images of Al+ 20%TiO_2

The microstructure examination was done to analyse the grain size and distribution of titanium oxide particles. Microstructure of Al-TiO_2 composites were studied using scanning electronmicroscope (SEM). Microstructure of sintered Al-$TiO_2$for different percentage (10, 15, 20) of TiO_2in Aluminium composites at different magnifications. 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.Aluminium particles have different shape with an average particle size of 8.178µm (particles size varies between 4 and 13µm). Morphology of titanium di oxide powder was also studied in which average particle size of 112.87nm (particles size varies between 79.19nm and 155.66nm) for titanium dioxide powder was found.Figure 11represents microstructures of the Al+10%TiO_2based composites reinforcement and the matrix can be clearly seen in figures. Al+15%TiO_2SEM images can be seen in figure 12 where the bonding of both powders is good, some pores and voids also visible in it. Al+ 20%TiO_2SEM images can be seen in figure 12. Micro cracks have been identified as seen in Figure 13(a).

(C) Density of the sintered specimen

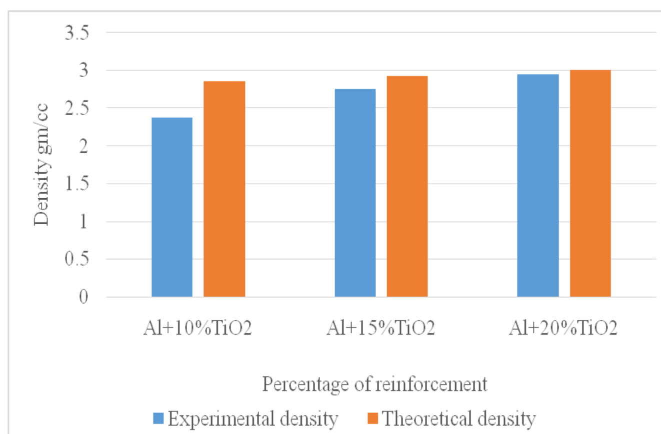

Figure 14: Experimental and Theoretical density for sintered specimen

Experimental and theoretical density were calculated. The actual density after each percentage was found using Archimedes's principle. During the compaction process, the density of the green compacts increased during the sintering process because of bonding mechanism of particles. From Fig. 14, The density and porosity were calculated by using the equations.

i. Calculated Density = (Density of Aluminium * Percentage of Aluminium) + (Density of Titanium dioxide * percentage of Titanium dioxide).
ii. Experimental Density = (Difference between apparent weight to the weight of the sample) / (Rise in water level).
iii. Percentage of porosity = (Difference between the calculated density and actual density) / (Calculated density) X 100 %.

Table 1: density of Compacted specimen

Sample	% of TiO_2	Experimental density (g/cc)	Theoretical density (g/cc)	% porosity
1	10%	2.657	2.853	2.830
2	15%	2.878	2.929	4.772
3	20%	3.046	3.006	7.376

CONCLUSION

In the present work, microstructure of pure aluminium reinforced with titanium dioxide (TiO_2) fabricated through powder metallurgy process was studied.

From the results it can be concluded that:

a) Maximum compaction loads observed for Al+10%TiO_2 was 153.45 kN, For Al+15%TiO_2 the maximum load observed was 163.6 kN. And for Al+ 20%TiO_2 the maximum load observed was 194.5 kN.
b) Microwave sintering of the green compacts was done, for 15 minutes in the microwave oven
c) The SEM micro-graphical studies discovered the even spreading of the TiO_2 particles in the matrix.
d) The density increases with increase in the percentage of reinforcement into the composites.

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