Volume 7, Issue 2, April 2020 ISSN: 2348-8565 (Online)
International Journal of Modern Engineering and Research Technology
Website: http://www.ijmert.org Email: editor.ijmert@gmail.com

Mechanical Characterisation of Magnesium Matrix Composite for Aerospace Application

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ABSTRACT

This work magnesium matrix composite was developed by reinforcing magnesium with titanium diboride with different level of reinforcement through powder metallurgy. Magnesium and magnesium alloy with its better strength, light weight, low density, corrosion resistance and good mechanical properties are predetermined for aerospace engineering. This work magnesium matrix composite was developed by reinforcing magnesium with titanium diboride with different level of reinforcement through powder metallurgy. Powder metallurgy process is very efficient and less expensive to enhancing the matrix mechanical and physical properties. Compression, hardness and density were performed on the fabricated reinforced specimens. The observed results shows that the different level of reinforcement have certain range of improvement on the mechanical properties of the magnesium matrix composites. The results showed that the impact of ceramic on the compression strength and the test results compare with pure magnesium specimen and the results revealed that the hardness was increased with addition of titanium diboride reinforced matrix composite. The results shows that the increasing mechanical properties were achieved by titanium diboride ceramic matrix magnesium composite and it's concluded as most suitable for Aerospace engineering.

Keywords:— *Metal Matrix Composite, Reinforcement, Powder metallurgy, Hardness, Compression strength.*

I. INTRODUCTION

The metal matrix composites are an advance type of mechanical member which is compounded by metal and ceramics, as a matrix, by different process. Design and developing new composites leads to create wide range of applications in different engineering. Magnesium alloys and composites were developed due to its advantages of light weight characteristics in various engineering applications. Many researches was developed new high strength and ductile Mgalloys and composites which were suitable for vast applications especially defence and aerospace industries.

The reinforcing materials were used to increase strength of matrix such as magnesium, aluminium, copper. The work is going to increasing the strength and reduce the weight of the composite with good mechanical properties for lighter weight structural components. Chua et al. developed AZ91-SiC matrix composite and studied the effect of SiC particles on mechanical properties. The matrix composite were prepared by hot extrusion at 400 C and after hotextrusion the extruded specimens were treated, quenched and aged at different time durations. The value of hardness of the composite was not increased significantly when compared to AZ91 alloy with ageing. The result showed that the tensile and yield strength were increased with small size of SiC particle. The large particle size of ceramics were diluted the yield strength1. Muhammad et al.analysed the impact of alumina and SiC hybrid reinforcement on mechanical properties in Magnesium alloy.The alloy matrix slurry was blend at 2500 rpm for 1 hr due to the uniform mixing. The cold compaction at 580MPa and sintered at 630 C. The hardness properties were determined better properties with the increase percentage ofreinforcement2. Powder metallurgy is effective method for fabricate the matrix composite materials. Increasing demand for light weighting drives the interest for magnesium to be used in various engineering applications to achieve better mechanical strength, higher fuel economy, emission reduction etc. Other than its low density, magnesium based materials also exhibit high specific mechanical properties, excellent machinability, high damping characteristics, high thermal stability, high thermal and electrical conductivity, and resistance to electromagnetic radiation3-6. Powder metallurgy (P/M) technique is most likely used to fabricate Mg metal matrix composites. A uniform distribution of reinforcement particulates in the metal matrix can be achieved by using powder metallurgy technique with or without the chemical reactions between the reinforcements and matrix and the composites can fabricate by using powders without melt7. Titanium diboride (TiB2) is well known as a ceramic material with relatively high strength and durability as characterized by the relatively high values of its melting point, hardness, strength to density ratio, and wear resistance8. Based on the development and requirement of massive strength Mg alloys for structural and biomedical applications. The development of engineering materials such Mg composites by changing the reinforcements with different proportions and reinforcing with ceramics. In this work concentrated as Magnesium is a metal matrix and Titanium diboride is a reinforcement through powder metallurgy.

II. Materials and Methodology

The magnesium powder has been used as matrix material which is compatible with the adding reinforcement and also which has been attained superior mechanical properties. Titanium diboride is taken as a reinforcement, which is the more stable with magnesium and also withstands high temperature. The particulate state of the reinforcement has been attain better distribution in the matrix also to provide isotropic property for the composite. The properties of magnesium and titanium Diboride were displayed in Table 1 and Table 2.

Table 1. Properties of Magnesium

Material	Magnesium
Phase	Solid
Melting point	923 K (650 °C, 1202 °F)
Boiling point	1363 K (1091 °C, 1994 °F)

Table 2. Properties of Titanium Diboride

Material	Titanium Diboride
Melting point	3,230 °C (5,850 °F; 3,500 K)
Density	4.52 g/cm3
Molar mass	69.489 g/mol

It is a silvery-white alkaline earth metal and one third lighter than Aluminium due to that Magnesium alloy is widely used in aerospace engineering and defence. The Magnesium powder was heated and it has ignites with white light and releases huge amount of heat. The fire produced by magnesium is not extinguished by water, since water reacts with hot magnesium and releases hydrogen which can cause the fire to burn more ferociously. We are taking magnesium as a metal matrix with as powder is shown figure 1.

Figure 1. Mg-TiB_2 Matrix Material

Figure 2. Mg-TiB_2 Matrix Composite Material

Magnesium metal powder were mixed with Titanium diboride. The blending is an operation of intermingling of different metal powders of various level of compositions. The objective of blending was to ensureuni form distribution of metal powder, due to that, ball mill were used for blending. Compaction was done by using punch and die which is machined to fine tolerances on high pressure. The mixed powder was poured into the die and also compacted by Universal Testing Machine. The compacts was sintered in a muffle furnace of 450^{o}C for 30 minutes at the heating rate of time. Normally metals were sintered at 90% of the melting temperature of base metals. Here furnace were used to sintering operation. During sintering, the bonding relation between the metal powder particles takes place continuously and results in growth of grain boundaries. The Magnesium matrix composites was prepared for various level of compositions. The percentage of reinforcements are shown in Table 3.

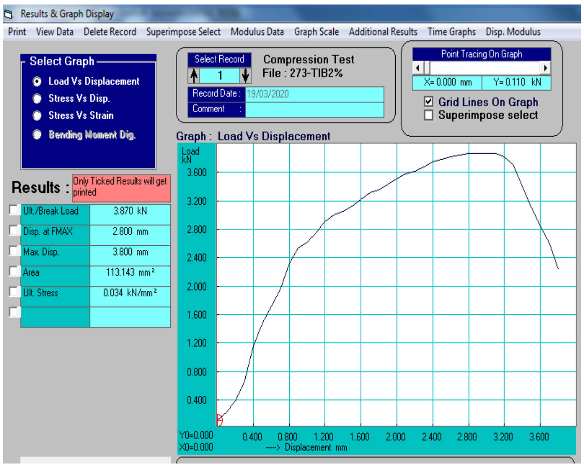
Table 3. Matrix and reinforcement of Magnesium matrix composite

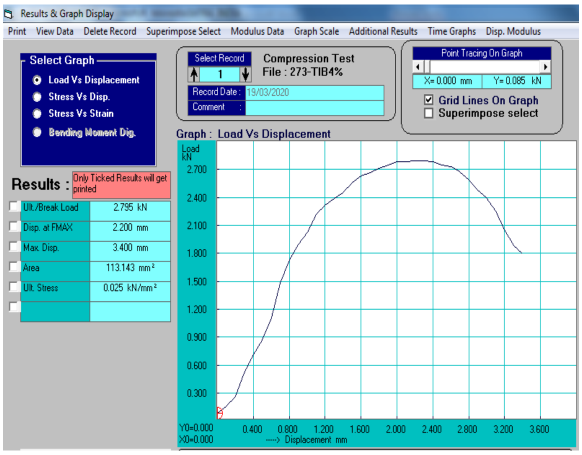
Specimen code	Magnesium (Mg)	Titanium Diboride (TiB_2)
1	98%	2%
2	96%	4%
3	94%	6%
4	100%	-

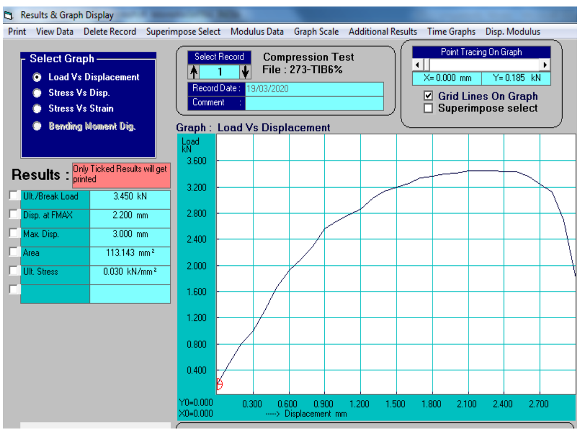
III. Results and Discussion

Compression strength

The Metal matrix composites were exhibit different mechanical properties because of the difference of reinforcement materials. Compared with pure magnesium, the metal matrix composites have a significant improvement in the ultimate tensile strength (UTS), yield strength (YS) and elongation (E). The compression strength value were measured on different level of reinforcements by Vicker's hardness tester as shown in below table 4.The diamond reinforcements was used to apply load for the measurements of compression. From the observed results, the increasing percentage of titanium diboride were increased the value of compression strength. It's clearly shown form the figure 3.







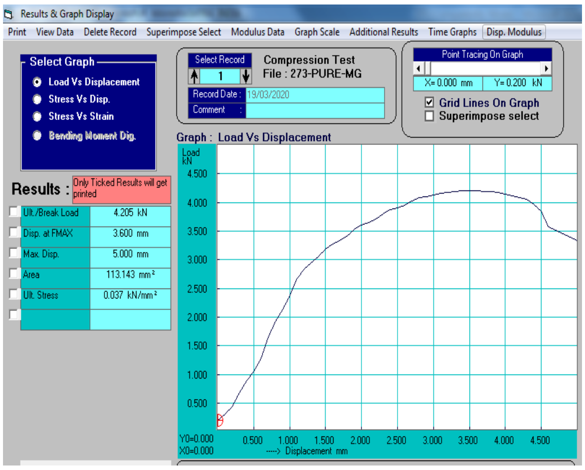


Figure 3. Compression Strength for the Reinforcements

IV. HARDNESS

The hardness value were measured on different level of reinforcements by Vicker's hardness tester as shown in below table 4.The diamond indenterwas used to apply load for the measurements of hardness. A load of 200gm mass applied on the specimen without any jerk for about 40 seconds. The Vicker's hardness number was observes against the different percentage of reinforcements of the fabricated composite specimens. From the observed results, the increasing percentage of titanium diboride were increased the value of hardness. It's clearly shown form the Table 4. The increasing percentage of titanium diboride increases the hardness from 38.7 HV to 78.4 HV. The results evidently shown from the table, the hardness increased by the addition of 6% wt of TiB_2.

Table 4. Hardness values for various level of composites

Composition	Intent1 In HV	Intent 2 In HV	Intent 3 In HV
Mg	41.0	41.6	38.7
Mg TiB2- 2%	47.2	46.5	45.7
Mg TiB2- 4%	46.6	49.0	49.7
Mg TiB2- 6%	74.8	72.7	78.4

Density measurement

The graph below shows that the density of prepared specimens before and after sintering operation for different composition of magnesium metal matrix composites. It is seen that, with the increase in reinforcement percentage, the density of composites also increases before and after sintering process due to the higher density of titanium diboride. It is also observed that rate of change of sintered density is higher 6% of TiB_2 reinforcement due to the higher density of reinforcement than the base metal. Sintering involves bonding among particles and densification. The before density were calculated as below mathematical model and also after density were measured experimentally.

Specimen 1. Mg TiB2- 2%

Volume = $\pi r^2 h$

1.73= πr^2 x $\frac{98}{100}$ = 1.70 $\frac{98}{100}$ 3

= 3.14 x (0.6015)2 x 2.998

4.52 x $\frac{2}{100}$ = 0.09 $\frac{2}{100}$ 0

= 3.405= 1.796

Density = $\frac{5.685}{3.405}$

$\frac{5.685}{3.405}$ = 1.669 g/cm3

Specimen 2. Mg TiB2 – 4%

Volume = $\pi r^2 h$

= 1.7 = $\pi r^2 3$ x $\frac{96}{100}$ = 1.66 $\frac{96}{100}$ 0

= 3.14 x (0.602)2 x 2.996

4.52 x $\frac{4}{100}$ = 0.10 $\frac{4}{100}$ 8 = 1.76

= 3.409

Density = $\frac{5.679}{3.409}$

$\frac{5.679}{3.409}$ = 1.665 g/cm3

Specimen 3. Mg TiB2 – 6%

Volume = $\pi r^2 h$

= 1.7 = $\pi r^2 3$ x $\frac{94}{100}$ = 1.62 $\frac{94}{100}$ 62

= 3.14 x (0.6025)2 x 3.084

= 4.52 x $\frac{6}{100}$ = 0.27 $\frac{6}{100}$ 12

= 3.509

= 1.8974

Density = $\frac{6.120}{3.509}$

= $\frac{6.120}{3.509}$ 1.744 g/cm3

Specimen 4. Mg – 100%

Volume = $\pi r^2 h$

= 1.7 = $\pi r^2 3$ x $\frac{100}{100}$ = 1.73 $\frac{100}{100}$

= 3.14 x (0.602)2 x 3.137

= 3.569

Density = $\frac{5.959}{3.569}$

$\frac{5.959}{3.569}$ = 1.669 g/cm3

Table 5. Calculated Density values for the reinforcements.

S.no	W_1	W_2	W_3	Aw	d_1	d_2	d_3	A d	h_1	h_2	h_3	A h
Mg Tib2 - 2%	5.685	5.683	5.686	5.685	12.03	12.01	12.05	12.03	29.92	30.04	30.00	29.98
Mg Tib2 - 4%	5.576	5.680	5.681	5.679	12.03	12.05	12.04	12.04	29.95	30.01	29.93	30.84
Mg Tib2 - 6%	6.110	6.135	6.114	6.120	12.05	12.07	12.04	12.05	30.83	30.86	30.85	29.96
Mg -100%	5.961	5.959	5.958	5.959	12.04	12.03	12.05	12.04	31.49	31.71	31.52	31.57

V. Conclusion

Magnesium metal matrix composites reinforced with 2wt%, 4wt% and 6wt% Titanium diboride particles were added successfully. The experiment was successfully observed on test specimen for the matrix compaction of magnesium and titanium carbide as reinforcement by using powder metallurgy technique. The better compression strength were achieved from the reinforcements. Due to the higher density of titanium digoride, with the increase in value of reinforcement percentage, the density of composites also increases before and after sintering fabrication process. The density of composites after sintering process decreases than that of before sintering. It was also conclude that, as compared with pure magnesiumthe hardness values of magnesium metal matrix composites reinforced with 6% of titanium diboride reinforcement were increased. In all aspects of experimental results were shown better properties are achieved in the 6%of titanium diboride reinforcements and also all the observation shows a good bonding and distribution of reinforcement particles achieved through thismethod of fabrication.

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