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Fabrication and Analysis of Mechanical Properties of Aluminum MMC Produced by Stir Casting

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ABSTRACT

Aluminum alloys are popular materials in industrial applications because of their higher specific strength to weight ratio and excellent mechanical properties. These alloys are combined with other material to form composites. A composite material is a combination of two phases called matrix and reinforcement with different physical and chemical properties. When they are combined they create a material which is specialized to do a certain job, for instance to become stronger, lighter or resistant to electricity, etc. The need for superior execution and minimal expense materials caused scientists globally to change their concentration from solid to composite materials due to their better mechanical properties.

Many manufacturing processes are offered for the fabrication of aluminum metal matrix composites. Stir casting is recognized as a predominantly capable process, and its advantages turn over in its effortlessness and flexibility to a massive manufacturing.

This project proposes the fabrication of Aluminum Metal Matrix Composites (AMMCs) using stir casting technique by varying the amount of hybrid reinforcement particles. The mechanical properties such as tensile strength, impact strength, wear, hardness will be evaluated. Al6082-T6 is taken as the metal matrix phase, titanium diboride (TiB2) and graphite powder are taken as the reinforcement phase.

KEYWORDS – Stir Casting, Aluminum Metal Matrix Composites, TiB2, Graphite, Tensile Strength, Impact Strength, Wear, Hardness, Hybrid reinforcement

1. INTRODUCTION

Aluminum Alloys are one of the most widely used materials in industrial applications like automotive, aerospace and ship building due to their high strength to weight ratio and better mechanical properties [1]. Aluminum metal matrix composites (AMMCs) are widely replacing the conventional aluminum alloys in many applications due to their superior mechanical properties and tribological properties [2] [3]. A composite is a material made of two constituent phases namely a reinforcement phase and a matrix phase. Although these two phases are not soluble they can be macroscopically combined. A lot of research has been conducted to improve the properties of AMMCs by using various methods and different reinforcements like Al2O3, B4C, TiC, Fly Ash, TiB2, Graphite, SiO2 etc. [4] [5].

Hybrid Metal Matrix Composites (HMMCs) are one of the recently developed advance materials having better mechanical. Hybrid reinforcement is a combination of different reinforcements [9]. The Aluminum metal matrix composites are produced by liquid metallurgy techniques like conventional stir casting and electromagnetic stir casting [5] [6], squeeze casting [7], pressure infiltration [8]. The liquid metallurgy

techniques/methods are best suited for mass production. The literature on hybrid reinforcement titanium diboride (TiB2) and graphite and matrix AL6082-T6 alloy is few and can be much interesting due to excellent strength, hardness, and wear properties.

Apart from the liquid metallurgy one can also use powder metallurgy for the production of composites. But powder metallurgy is highly expensive and time consuming process. It is also difficult to obtain materials in bulk quantity [10]. Stir casting is the best economical method for fabrication of composite materials where reinforcement is mixed with the molten metal matrix by means of mechanical stirring [11].

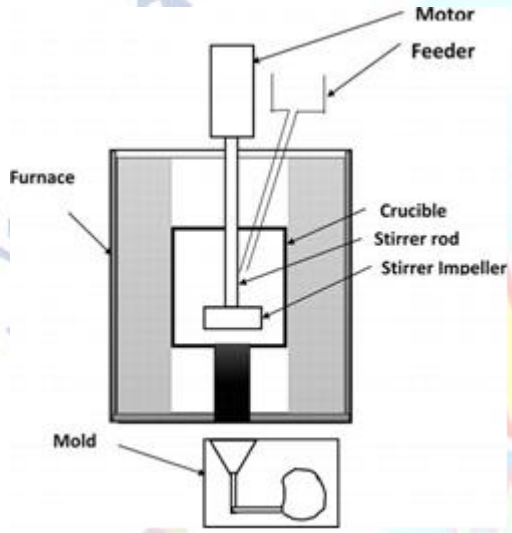

Figure 1: Basic Stir casting process

2. REALATED WORK

S. Johny james *et al*. [12] has produced the AL6061/ZrO_2-Al_2O_3 hybrid reinforced composite with 90% AL6061, 5% of ZrO_2 and 5% of $Al_{2O=3}$ and studied its properties like tensile strength, hardness, wear and corrosion. The result is found to be that tensile strength shown to have a significant improvement and there is a 70% increase in hardness. B. Stalin *et al.* [13] has experimented on optimization of wear process parameters on the composite AA6063/Si_3N_4 produced by stir casting.

R. Anvari *et al*. [14] investigated wear properties of AL6061/Al-Cr-O hybrid composite produced by FSP and the result shows that there is an improvement in wear resistance. S. Gopalakrishna *et al*. [15] fabricated AL6061/TiC composite using stir casting method and reported that the wear rate has been reduced by 40% by increasing the volume fraction content from 3% to 7%. Serjul Haque *et al*. [16] fabricated AL6061/SiC metal matrix composite using stir casting. They researched the wear properties and found that increasing stir speed decreases wear rate.

3. PROPOSED WORK

3.1 Fabrication of Composite and Specimen preparation :

The commercially available AL6082-T6 ingots are taken. The selected reinforcements are titanium diboride (TiB2) of 99.90% purity and with an average particle size of 10.0 μm and Graphite powder of 99.00% purity and with an average particle size of 44.0 μm. The chemical composition and mechanical properties of base metal and the reinforcements are shown in the Table 1, Table 2 and Table 3. The different casting composition for AL^082 hybrid composites are 0% TiB2 - 0% graphite (sample 1), 1% TiB2 – 1% graphite (sample 2), 2% TiB2 - 2% graphite (sample 3) and 3% TiB2 – 3% graphite (sample 4).

Table 1: Chemical composition of AL6082-T6 Alloy

Element	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
Wt%	0.25	0.10	0.50	1.00	0.80	1.00	0.10	0.20

Table 2: Chemical composition of TiB2

Property	**Value**
Density	4.52 g/cm^3
Molar mass	69.489 g/mol
CAS Number	12045-63-5
Melting point	3230 ^oC
Form	Powder
Size	10 μm
Purity	99.90%

Table 3: Chemical composition of Graphite

Property	**Value**
Density	1.8 g/cm^3
Molecular Weight	12.01
Melting Point	3600 ^oC
Boiling Point	4200 ^oC
Form	Powder
Size	44 μm
Purity	99%

A stir casting setup consists of a furnace, die, and stirrer assembly. The temperature range of the furnace is 950 ^0C and a preheater of temperature range 800 ^0C. The melting range of aluminium is 700 ^0C – 800 ^0C. A known quantity of AL6082 was loaded into the crucible of the furnace for melting. The melt was super heated to 800 ^0C

and maintained at that temperature. And the reinforcements are pre-heated in the preheater which is maintained at 300 ^{0}C – 400 ^{0}C. After melting of the aluminium the stirrer is introduced into the electrical furnace to mix the aluminium alloy and reinforcement for better bonding. The preheated reinforcement materials are then introduced into the furnace at a steady rate and the stirrer is rotated at 600 – 700 rpm. After a few minutes of stirring the melt is poured into the preheated die. After solidification the required casts are obtained.

Figure 2: Stir casting equipment

Figure 3: Specimens

3.2 Tensile Test:

The tensile test was conducted using Universal Testing Machine (UTM) to investigate the tensile properties of the specimens at Guddalavalleru College of engineering. The ASTM standard procedure was followed to perform the tensile strength at a room temperature by placing the specimen in the jaws of the machine and it was pulled until failure. The specimens are fixed properly in the jaws ensuring no slippage during testing.

Figure 4: Tensile Test Apparatus

Figure 5: Tensile Test Specimens

3.3 Impact Test:

The impact test was conducted using Izod impact strength testing equipment. The impact test equipment is shown in the Figure 6. The tests are conducted at room temperature and the specimens are prepared as per the ASTM standards.

Figure 6: Impact Test Apparatus

3.4 Hardness Test:

The hardness property of the composite materials is found out by Vickers hardness test. The Vickers hardness test equipment is shown in the Figure 6. It has two distinct force ranges, micro (10gm to 1000gm) and macro (1kg to 100kg). For this test micro force range (10gm to

1000gm) is used.The ASTM standard for micro force ranges is ASTM E384.

The steps for doing Vickers hardness tests are as follows. A controlled test force is applied to the sample by indenter normally up 10 – 15 seconds; the constant force is maintained for a specific dwell time. Then the indenter is removed and a square shaped dent appears on the sample. By measuring the two diagonals of the square indent the size is determined optically. The Vickers hardness number is calculated as a function of the test force divided by the surface area of the indent.

HV = Constant * test force / indent diagonal squared

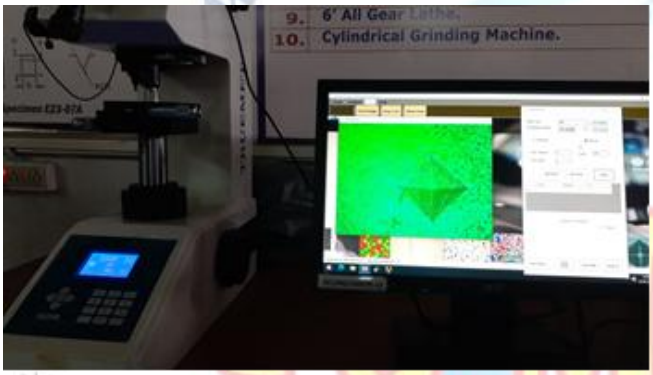

Figure 7: Hardness test Apparatus

3.5 wear Test:

The wear test is conducted on Friction wear test apparatus (pin on disc). The samples are prepared as per ASTM standards. The wear test was performed at room temperature under dry sliding conditions with a load of 1KN, rotational speed of 400rpm and sliding distance is 2000m. The weights of the specimen are taken before and after the test and wear loss is calculated.

Figure 8: Wear test Equipment (Pin on Disc)

4. RESULTS

4.1 Tensile Test Result:

The tensile test results for various samples are shown in the Table 4. The tensile properties of the composite have increased significantly by the addition of reinforcements. The tensile strength of pure AL6082 is 0.210 KN/mm2 which has increased to 0.265 KN/mm2 by adding 3% TiB2 and 3% Graphite Powder.

Table 4: Tensile Test Result

Samples	Composition	Ultimate Stress kN/mm^2
1.	Pure AL6082	0.210
2.	AL6082 + 1% TiB_2 + 1% Gr	0.235
3.	AL6082 + 2% TiB_2 + 2% Gr	0.249
4.	AL6082 + 3% TiB_2 + 3% Gr	0.265

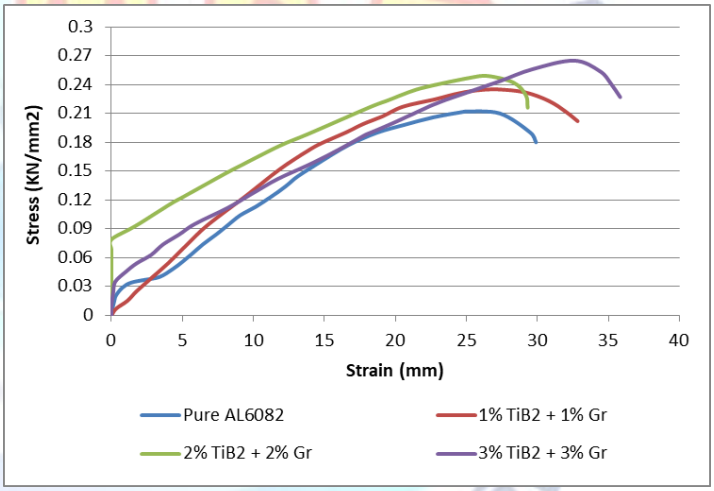

Figure 9: Stress vs Strain curve of all samples

4.2 Impact test result:

The Impact test results for various specimens are shown in the Table 5.The impact strength of the composite has increased significantly by the addition of reinforcements. The impact strength of pure AL6082 is 6.5 Joules which has increased to 10.9 Joules by adding 3% TiB2 and 3% Graphite powder.

Table 5: Impact Test Results

Sample	Composition	Impact Strength (Joules)
1	Pure AL6082	6.5
2	AL6082 + 1% TiB_2 + 1% Gr	8.7

3	AL6082 + 2% TiB_2 + 2% Gr	9.2
4	AL6082 + 3% TiB_2 + 3% Gr	10.9

4.3 Hardness test result:

The hardness test results for various samples are shown in Table 6.The hardness of AL6082 has increased by the addition of reinforcements. We can find the best composition is sample of 3% TiB2 and 3% Graphite powder. The hardness for this composition has increased from 75.29 HV to 91.52 HV when compared with the pure alloy.

Table 6: Hardness Test Results

Samples	Composition	Vickers hardness (HV)
1.	Pure AL6082	75.29
2.	AL6082 + 1% TiB_2 + 1% Gr	78.13
3.	AL6082 + 2% TiB_2 + 2% Gr	85.46
4.	AL6082 + 3% TiB_2 + 3% Gr	91.52

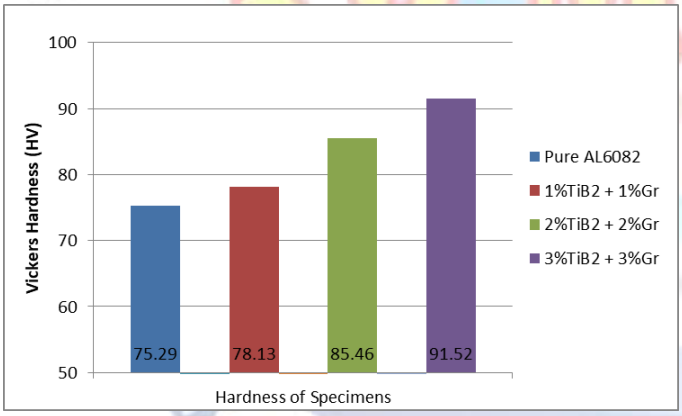

Figure 11: Vickers Hardness of all samples

4.4 Wear test result:

The wear test results of various samples are shown in the Table 7.The wear rate of the alloy has significantly decreased by the addition of reinforcements. The loss of weight has significantly decreased from 0.9564 to 0.596.

Table 7: Wear Test Results

Sample	Composition	Loss of Weight
1	Pure AL6082	0.9564
2	AL6082 + 1% TiB_2 + 1% Gr	0.765
3	AL6082 + 2% TiB_2 + 2% Gr	0.654
4	AL6082 + 3% TiB_2 + 3% Gr	0.596

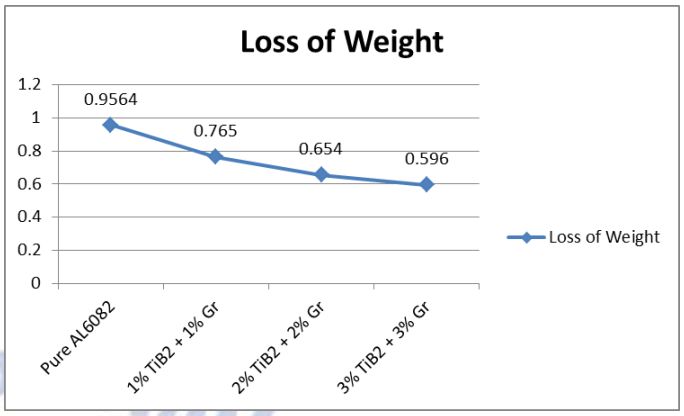

Figure 12: Wear Test Results

4.5 SEM Microstructures:

The microstructures are taken using a Scanning Electron Microscope (SEM) apparatus located in Osmania University Hyderabad. The SEM equipment used for taking the microstructures is shown in Figure9.

Figure 13: SEM Apparatus

5. CONCLUSION

From the experimentation it was determined that the mechanical properties of the AL6082 alloy have increased significantly by addition of reinforcements. The highest tensile strength was found to be 265 N/mm², the highest impact strength was found to be 10.9 Joules, the highest Vickers hardness was found to be 91.52 HV and the least wear weight loss was found to be 0.596 mg.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Bakes, H., Benjamin, D. and Kirkpatrick, C.W. (1979) Metal handbook, vol. 2. OH: ASM. Metals Park, 2, 3-23.

[2] Salehi, M., Farnoush, H. and Mohandesi, J.A. (2014) Fabrication and Characterization of Functionally Graded Al-SiC Nano Composite by Using a Novel Multistep Friction Stir PProcessing. Materials and Design, 63, 419-426. https://doi.org/10.1016/1.matdes 2014.06.013

[3] Sharifi, E.M., Karimzadeh, F. and Enayati, M.H. (2011) Fabrication and Evaluation of Mechanical and Tribological Properties of Boron Carbide Reinforced Aluminum Matrix Nano Composites. Materials and Design, 32, 3263-3271. https://doi.org/10.1016/j.matdes.2011.02.033

[4] Baradeswaran, A. and Elaya Perumal, A. (2013) Influence of B4C on the Tribological and Mechanical Properties of Al 7075-B4C Composites. Composites B, 54,146-152. https://doi.org/10.1016/j.compositesb.2013.05

[5] Alanemea, K.K., Akintunde, L.B., Olubambi, P.A. and Adewale, T.M. (2013) Fabri cation Characteristics and Mechanical Behavior of Rice Husk Ash-Alumina Rein forced Al-Mg-Si Alloy Matrix Hybrid Composites. Journal of Material Research and Technology, 2, 60-67. https://doi.org/10.1016/j.jmrt.2013.03.012

[6] Kumar, A., Lal, S. and Kumar, S. (2013) Fabrication and Characterization of A359/Al2O3 Metal Matrix Composite Using Electromagnetic Stir Casting Method.Journal of Material Research Technology, 2, 250-254. https://doi.org/10.1016/j.jmrt.2013.03.015

[7] Yigezu, B.S., Mahapatra, M.M. and Jha, P.K. (2013) Influence of Reinforcement Type on Microstructure, Hardness, and Tensile Properties of an Aluminum Alloy Metal Matrix Composite. Journal of Minerals and Materials Characterization and Engineering, 1, 124-130. https://doi.org/10.4236/jmmce.2013.14022

[8] Kalkanli, A. and Yilmaz, S. (2008) Synthesis and Characterization of Aluminum Alloy 7075 Reinforced with Silicon Carbide Particulates. Materials and Design, 29. 775-780. https://doi.org/10.1016/j.matdes 2007.01.007

[9] Srivastava, Ashish & Garg, Prayag & Kumar, Avdhesh & Krishna, Yamini & Varshney, Kanu. (2014). A Review on Fabrication & Characterization of Hybrid Aluminium Metal Matrix Composite. International journal of Advance research and innovation. 2. 242-246. https://www.researchgate.net/publication/270220073_A_Review_on_Fabrication_Characterization_of_Hybrid_Aluminium_Metal_Matrix_Composite

[10] Umasankar, V. (2014) Experimental Evaluation of the Influence of Processing Pa rameters on the Mechanical Properties of Sic Particle Reinforced AA6061 Alumi nium Alloy Matrix Composite by Powder Processing. Journal of Alloys and Com-1 pounds, 582, 380-386.

[11] Sugavanam, Parimala Murugaveni. Characterization of Titanium Di boride particulate reinforced AA6082 Aluminium alloy composites produced via Stir casting. IRJET, vol. 8 issue. 03 march 2021. 2755-2759

[12] S. Johny James, M. Ganesan, P. Santhamoorthy, P. Kuppan,Development of hybrid aluminium metal matrix composite and study of property,Materials Today: Proceedings,Volume 5, Issue 5, Part 2,2018,Pages 13048-13054,ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2018.02.291

[13] B. Stalin, P. Ramesh Kumar, M. Ravichandran. Optimization of wear parameters and their relative effects on stir cast AA6063-Si3N4 Composite Materials research express, vol 5, issue 10 2018.

[14] Anvari, S.R., Karimzadeh, F. and Enayati, M.H. (2013) Wear Characteristics of Al-Cr-O Surface Nano-Composite Layer Fabricated on Al6061 Plate by Friction Stir Processing. Wear, 304, 44-151.

[15] Gopalakrishnan, 5, and Murugan, N. (2012) Production and Wear Characterisation of AA 6061 Matrix Titanium Carbide. Composites Part 8, 43, 302-308

[16] Haque, S., Ansari, A.H. and Bharti, P.K. (2014) Effect of Process Parameters on Wear Rate of Al 6061-Cu reinforced SiCp Metal Matrix Composites. Journal of Material Environmental Sciences, 5, 01485-1489.