International Journal of Engineering, Science and Mathematics
Vol.6, Issue 8, December 2017 (Special Issue)
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Fabrication and Experimental Investigation on Mechanical Properties of Aluminium Metal Matrix Composite by using Stir Casting

SK.Hyderali*
K.SathyaSrikanth**
J.Pavan Kumar, S.Muralidhar***
MallikarjunaPotta****

Keywords:

Composite materials;
Mechanical properties;
Metal matrix composites;
Stir casting;
Micro sturcture.

Abstract

From the last two decades there is a rapid increase in utilisation of Aluminium Alloy, particularly in Automobile, Aerospace industries, due to its low density, low weight and high strength. Aluminium metal matrix composite has received extensive attention for practical as well as fundamental reasons. Aluminium Alloy & Aluminium based metal matrix composites (MMC) have found many applications in the manufacturing of various components. The present work is focused on Fabrication & Investigation of Mechanical properties of Al6061, Graphite, Fly ash metal matrix composite. These materials are identified in the process of making high strength Aluminium Alloy. Stir casting process is employed for the fabrication of metal matrix composite. In our project the composition of MMC is varied for graphite (3%, 6%) & fly ash (6%, 3%) by keeping 91% by Al 6061. Fabricated samples are tested for Mechanical properties. The Tests includes Tensile test, Hardness test, and Wear test as per ASTM standards. Microstructures of the samples were tested by using metallurgical microscope & compare the microstructure for each.

Copyright © 2017 International Journals of Multidisciplinary Research Academy. *All rights reserved.*

Author correspondence:

MallikarjunaPotta,
Assistant Professor
Department of Mechanical Engineering, AITS, Kadapa, Andhrapradesh, India

* Department of Mechanical Engineering, BITS, VIZAG, INDIA
** Department of Mechanical Engineering, BITS, VIZAG, INDIA
*** Department of Mechanical Engineering, BITS, VIZAG, INDIA
**** Assistant Professor, Department of Mechanical Engineering, AITS, Kadapa, Andhra Pradesh, India

1. Introduction (10pt)

Metal Matrix Composites (MMCs) have improved properties compared to the conventional alloys. The two or more phases which are distinct combined together to form a composite. In recent years, the development of Aluminium based MMCs are very predominant due to their light in weight and low cost. The Al composites are used drastically in various fields such as defense, automobile and aerospace because of unique properties like high modulus of elasticity, resistance to corrosion and wear, specific strength, thermally stable, better ratio of strength to weight [1], [2].

The fabrication technique used for the production of Al based MMCs is Stir casting. It is employed due to simplicity, minimized final cost of production compared to conventional processes of metal routing, flexibility and possibility for mass production [3]–[5]. In the past the Tribological behavior of hybrid Al 6061 composite is tested for wear and hardness [6]–[8]. However the variation of the graphite and fly ash in the Al MMCs are not yet tested. Hence, the present paper focus mainly on fabrication of three samples with different compositions . First sample with 100% of Al 6061, second sample with 91% of Al 6061, 6% graphite and 3% fly ash and the third sample with 91% of Al 6061, 3% graphite and 6% fly ash. The fabricated samples are observed under 500X magnification for observing microstructural variations at the grain boundaries since wet ability is the major factor that shows the behaviour of composites with the mechanical properties. The hardness test and the wear resistance tests are carried and it is observed that the sample having higher graphite shows the better tensile property, hardness and wear resistance.

2. Material Selection

2.1 Aluminium (Al) 6061

Aluminum alloy Al-6061 is selected as base metal of Hybrid Particulate Metal Matrix Composite, with its enormous application in the fields of aerospace and automotives.6061 is a precipitation-hardened aluminum alloy, containing magnesium and silicon as its major alloying elements. It has good mechanical properties like high strength to weight ratio and good machinability properties.

Table 1 Chemical Composition of Al6061

Elements	**Contribution (%)**
Silicon (Si)	0.40-0.80
Magnesium (Mg)	0.8-1.2
Ferrous (Fe)	0.70
Copper(Cu)	0.15-0.40
Zinc (Zn)	0.25
Chromium (Cr)	0.04-0.35
Titanium (Ti)	0.15
Manganese (Mg)	0.15
Others (each element)	0.05 each
Others Total	0.15 Total
Remainder Aluminum	95.85-98.56

2.2 Graphite

Addition of graphite particle results in low friction of composite as it is good dry lubricant hence reduces wear and abrasion, its properties are high strength and high stability.

2.3 Fly Ash

Fly ash which is also known as "pulverized fuel ash". It is one of the residues generated by the combustion of coal and is composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants and together with bottom ash removed from the bottom of the boiler is known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminum oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.Fly ash act as a filler in Al casting reduces cost, decreases density and increase hardness, stiffness, wear and abrasion resistance.

3. Fabrication of Composite Samples

Firstly before melting, the aluminium alloy is preheated to 450°C-800°C for about 2hours in a graphite crucible inside the furnace.In order to enhance the wetness properties and to remove the adsorbed hydroxides and various gases, the reinforcement namely Graphite and fly ash is preheated to about 1000°C and 600°C for a period of 2hours. Next the matrix is heated at 760°C which is its liquidus temperature and the metal is completely melted. This melt is kept in semi-solid state by holding and cooling down the temperature between solidus and liquidus point. At this point of time, already preheated particles is introduced into the melt with 3 sequential steps rather than adding all at once in order to ensure proper mixing of alloy which is in semi-solid state. The entire slurry is heated again to the complete liquid state and periodically stirred for every 10-20 min with the speed of 200-400rpm. The temperature of the furnace should be maintained at 760°C±1000°C. Prior to pouring the melt, molds are preheated for about 250°C-300°C. The preheated stirrer is placed into the melt to a depth of 2/3 height of the molten metal from the base and maintained at 200rpm. At 730°C-800°C the melt is poured into the mould. The process repeatedly done by varying the compositions of composite powder. This careful experimentation results in proper mixing of the melt and better microstructure is obtained compared to conventional stirring.

Figure 1 Casted Composite Samples

3.Experimental Investigation

In this section, sample one contains 100% aluminum alloy 6061, sample two contains91% aluminum alloy 6061, 3% alumina and 6% fly ash & sample three contains 91% aluminum alloy 6061, 6% alumina and 3% fly ash

3.1 Tensile Test

The Tensile test involves applying an ever-increasing load to a test sample up to the point of failure. The process creates a stress/strain curve showing how the material reacts throughout the tensile test. The data generated during tensile testing is used to determine mechanical properties of materials. The sample is securely held by top and bottom grips attached in Universal testing machine. During the tensile test, the grips are moved apart at a constant rate to stretch the specimen. The force on the specimen and its displacement is continuously monitored and plotted on a stress-strain curve until failure.

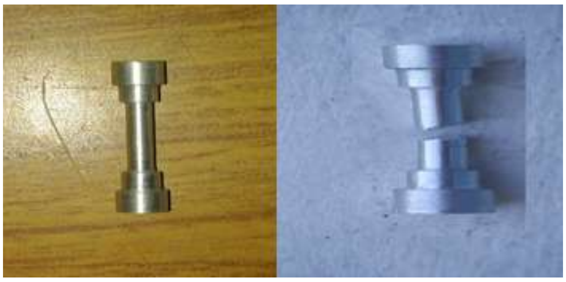

Figure 2 Specimen before and after test

3.2 Hardness Test

Brinell hardness test method mostly used to test materials that have a structure that too coarse or that have a surface that is too rough to be tested. 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. Test forces ranges from 500 to 3000 kgf. Brinell test will use 3000 kgf load with a 10mm ball. If a sample material is aluminum the test is most frequently performed with a 500 kgf load and 10mm ball

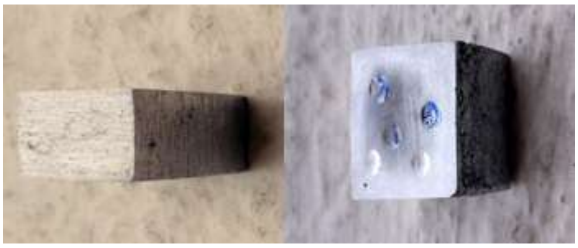

Figure 3 Specimen before test

3.3 Wear Test

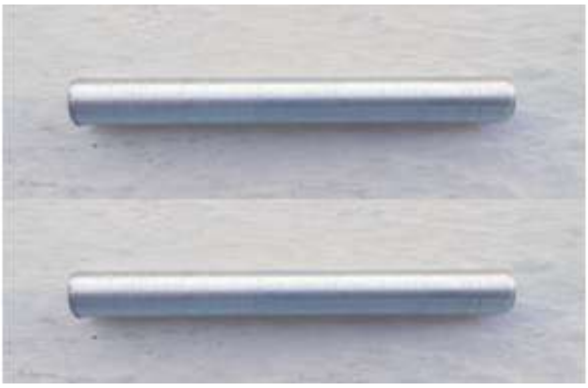

Figure 4 Specimen before test

Wear can also be defined as a process where interaction between two surfaces or bounding faces of solids within the working environment results in dimensional loss of one solid, with or without any actual decoupling and loss of material

4. Results and Analysis

The Metal matrix composites are prepared with a combination of Aluminum alloy-Graphite – Fly ash metal matrix in the specimen preparation mechanical testing's such as tensile test (ASTM E8), hardness test (Brinell), wear test (ASTM G99) are conducted and tested for the evaluation of mechanical properties and microstructure.

4.1 Tensile Test

The Metal matrix composite samples are tested in UTM machine till the samples are left to break till the ultimate tensile strength occurs.

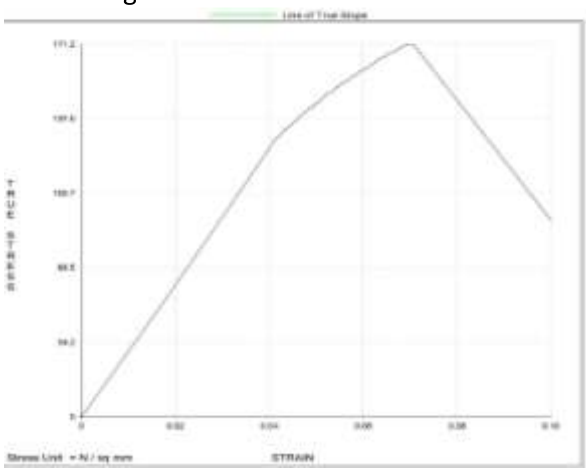

Figure 5Stress strain graph of sample 1, Al91%+G3%+F6%

The above graph is plotted between stress and strain of tensile test for sample 1, and Ultimate Tensile load, Ultimate Break Load and Elongation values are obtained as 2010.4 N, 1029.7 N, and 10%. Figure 6 shows the graph plotted between stress and strain of tensile test for sample 2, and Ultimate tensile test, Ultimate Break Load and Elongation values are obtained as 2069.3 N,2000.6N,4%. Figure 7 shows the graph plotted between stress and strain of tensile test for sample 3, and Ultimate tensile load, Ultimate Break Load and Elongation values are obtained as 1941.8N, 519.8N,and 14%.

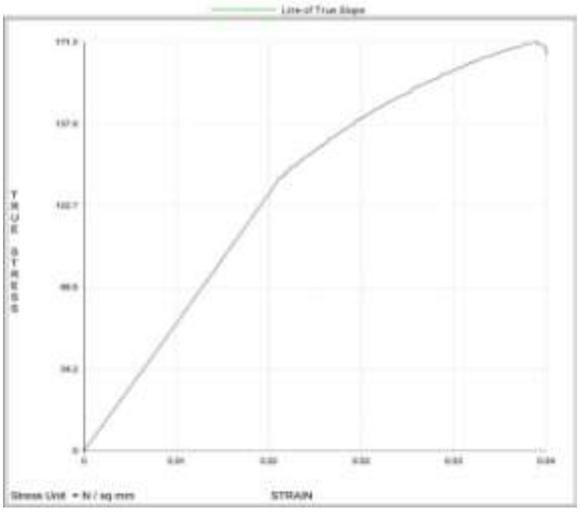

Figure 6Stress strain graph of sample 2, Al91%+G6%+F3%

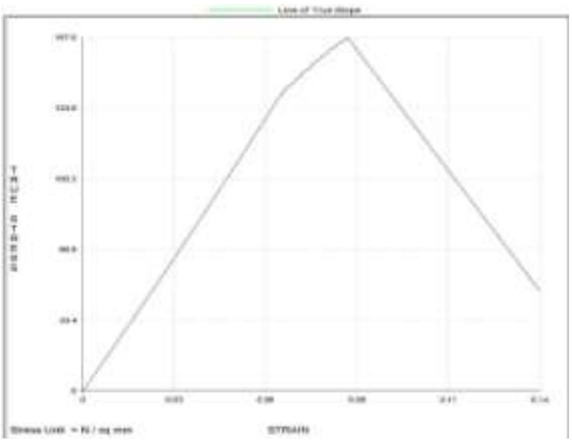

Figure 7 Stress strain graph of sample 3, Al6061

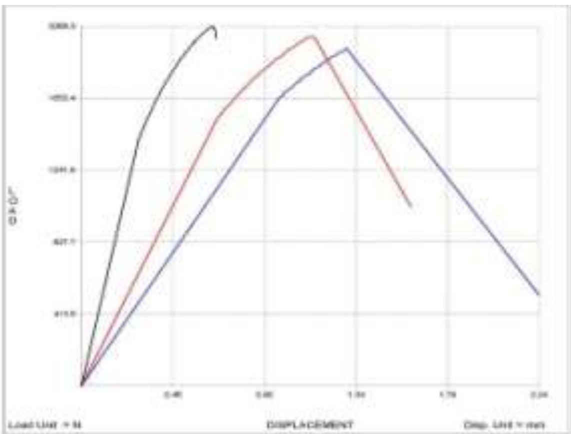

Figure 8 Comparison graph of Load - Displacement for tensile test

5.2 Hardness Test

The Brinell hardness test is carried out on the three samples and the results are tabulated in the given Table 2. The ball shaped indenter is made of hardened tungsten which is used for this hardness test. The diameter of ball shaped indenter is 10 mm and the load applied is 250 Kgf.

Table 2Hardness values of composite in (BHN)

Sample No	Composition of composite specimen	Hardness value(BHN)
1	Aluminium Alloy – 91% Graphite – 3% Fly ash – 6%	26.71
2	Aluminium Alloy – 91% Graphite – 6% Fly ash – 3%	30.26
3	Aluminium Alloy 6061	25.16

5.3 Wear Test

Wear test is the process of removal of material from one or both surfaces, when two surfaces are in relative motion with each other. Pin on disc tribometer is used to perform wear test. Pin and disc are the two specimens in this experimentation in which disc is a fixed specimen and the pin is a cast specimen with desired composition.

The friction force is measured by electronic force sensor for displaying, printing and storing the data and the profilometer is used to measure the amount of material removed. The input data given by the user is simply the load, friction force, wear rate etc. The test can be carried out under dry or lubricated conditions.

In the present test the aluminum is reinforced with 3% Graphite, 6% Fly ash of one composition, the other with the composition of 6% Graphite, 3% Fly ash and the base alloy are tested against the wear. The obtained results are presented below

Figure 9 Wear test graph of sample1, at 3kgs load

The wear was studied at a load of 3 kg with the speed of 400 rpm and the wear track diameter being 100 mm for a period of 10 min. The amount of wear fluctuation is presented in the below figure for the sample of 3% graphite, 6% Fly ash

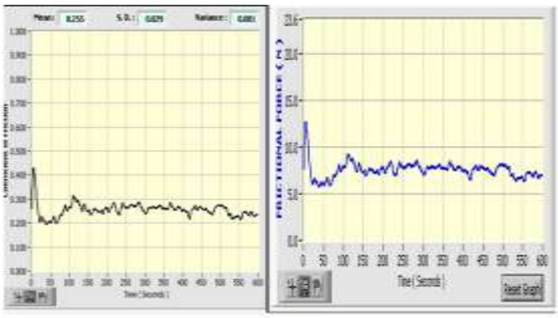

Figure 10COF and Frictional force for composition of 3%G, 6%F at 3 kgs load against time

The amount of wear fluctuation is presented in the below figure for the sample of 6%Graphite, 3% Fly ash

Figure 11Wear test graph of sample 2, at 3kgs load

The coefficient of friction was studied at a load of 3kg with the speed of 400 rpm and the wear track diameter being 100 mm for a period of 10 min. The amount of wear fluctuation is presented in the below figure for the sample of 6% graphite, 3% Fly ash

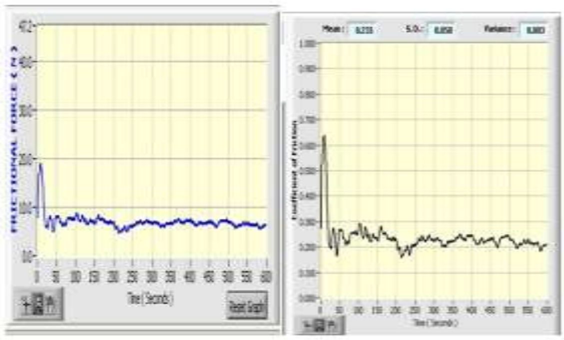

Figure 12 COF and Frictional force for the composition 6%G, 3%F at 3 kgs load against time

The amount of wear fluctuation is presented in the below figure for the sample of Al6061

Figure 13 Wear test graph of sample 3, at 3kgs load

The coefficient of friction was studied at a load of 3kg with the speed of 400 rpm and the wear track diameter being 100 mm for a period of 10 min. The amount of wear fluctuation is presented in the below figure for the sample of Alloy 6061.

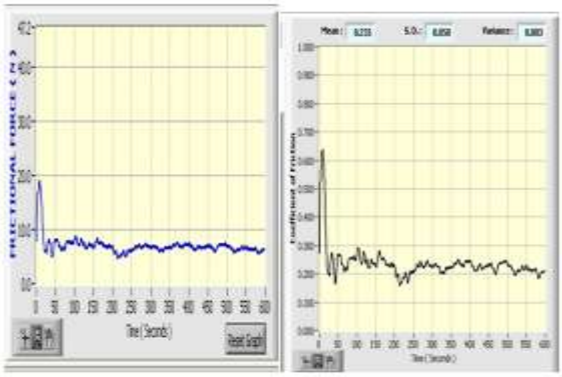

Figure 14 COF and Frictional force for composition of Alloy 6061 at 3 kgs load against time

Table 3 shows the results of wear rate and the friction factor for different compositions at the load of 3Kg's, speed 400 rpm, track diameter of 100 mm and time 10 minutes.

Table 3 Results of Wear Rate and Friction Force

S.no	Type of composition	Wear Rate(μm)	Friction Force
1	G6%,3%F	53	6.8
2	G3%,6%F	45	6.1
3	Al6061	51	3

6. Microstructure

Micrographs say that there is uniform distribution of fly ash particulates throughout the alloy and the porosity is low. It states that higher hardness is always associated with low porosities of MMC's. Also it is observed that there is good bonding between the matrix and reinforcement particles which results in better load transfer from matrix to the reinforcement material. Microstructure evaluation was done on optical microscope by polishing the samples with emery paper then the model was taken to the inverted metallurgical microscope viewing and then examined with monochromatic light source, and the photographs of micro structure are captured at magnification of 500X

Figure 15 100% Aluminum alloy of 500X

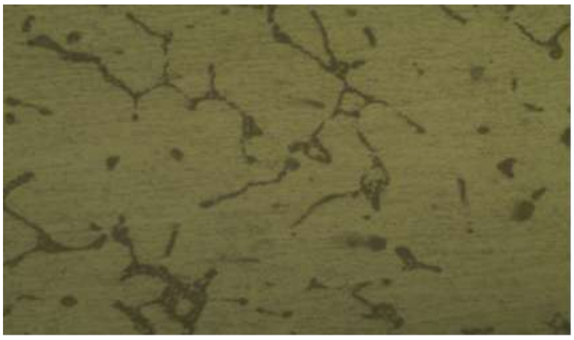

Figure 16 91% Al+3%G+6%F of 500X

In the above structure Fly ash and Graphite particles are equally dispersed. There is no difference in the microstructure of 91%Al+3%G+6%F & 91%Al+6%G+3%F.

7. Conclusion

In this work, following inferences are made from the three different samples are fabricated by using stir casting process. The composition of the samples is

Sample 1: 91% aluminum alloy 6061, 3% graphite and 6% fly ash,

Sample 2: 91% aluminum alloy 6061, 6% graphite and 3% fly ash and

Sample 3: 100% aluminum alloy 6061.

It has been observed that the tensile load of sample 2 (2069.3 N) is higher than other two samples because of its graphite content. The brinell hardness of sample 2 (30.26 BHN) is higher than that of other two samples. Dispersion of graphite and Fly ash particles in aluminum matrix increases the hardness of the matrix material. Microstructures of samples are examined by using metallurgical microscope.

References

[1] T. Raviteja, N. Radhika, and R. Raghu, "FABRICATION AND MECHANICAL PROPERTIES OF STIR CAST Al-Si12Cu/B4C COMPOSITES," *Int. J. Res. Eng. Technol.*, vol. 03, no. 07, pp. 2319–2322, 2014.

[2] D. C. V, Vengatesh, "Aluminium Alloy Metal Matrix Composite : Survey Paper," *Int. J. Eng. Res. Gen. Sci.*, vol. 2, no. 6, pp. 792–796, 2014.

[3] J. Hashim, L. Looney, and M. S. J. Hashmi, "Metal matrix composites : production by the stir casting method," *J. Mater. Process. Technol.*, vol. 92–93, pp. 1–7, 1999.

[4] K. S. N.Subramani, K.Vijayaraghavan, V.V.Arunsankar, "Analysis and Investigation on A2024 Metal Matrix Composites with B4C and Graphite," *Int. J. Innov. Res. Sci. Eng. Technol.*, vol. 2, no. 9, pp. 4636–4642, 2013.

[5] D. Kumar and J. Singh, "Comparative Investigation of Mechanical Properties of Aluminium Based Hybrid Metal Matrix Composites," *Int. J. Eng. Res. Appl.*, no. March, pp. 5–9, 2014.

[6] G. Pitchayyapillai, P. Seenikannan, K. Raja, and K. Chandrasekaran, "Al6061 Hybrid Metal Matrix Composite Reinforced with Alumina and Molybdenum Disulphide," *Adv. Mater. Sci. Eng.*, vol. 2016, p. 9, 2016.

[7] K. R. Padmavathi and R. Ramakrishnan, "Tribological behaviour of Aluminium Hybrid Metal Matrix Composite," *Procedia Eng.*, vol. 97, pp. 660–667, 2014.

[8] N. Radhika, R. Subramanian, and S. V. Prasat, "Tribological Behaviour of Aluminium / Alumina / Graphite Hybrid Metal Matrix Composite Using Taguchi ' s Techniques," *J. Miner. Mater. Charact. Eng.*, vol. 10, no. 5, pp. 427–443, 2011.