Tribological Characterization of Al-Beryl Aluminium Metal Matrix Composite

Sandeep G M, Shiv Pratap Singh Yadav
Assistant Professor
Nitte Meenakshi Institute of Technology
Bengaluru, India

Prajwal Naik, Rajesh K, Sunil Kumar P, Srinath K B
UG Student
Nitte Meenakshi Institute of Technology
Bengaluru, India

Vinayaka N
Assistant Professor
JSS Academy of Technical Education
Bengaluru, India

***Abstract*— Composites are playing a vital role in development of mankind, for they have drastically improved all walks of life be it transportation, entertainment, health care and many more areas. Use of Aluminium metal as a MMC has brought in revolutionary changes in manufacturing and usage of metals. The presented paper deals with wear characterization of Aluminium 6061 MMC reinforced with Beryl forming the Al-Beryl Metal Matrix Composite. The composite is prepared by stir casting process followed by wear test using pin-on-disc wear testing machine. The results have been found and interpreted.**

Keywords—Al-Beryl; Metal Matrix Composite; wear; stir casting;

I. INTRODUCTION

Composite materials are engineering materials which are made from two or more constituent metals or non-metals with ominously different physical and chemical properties in such a way that the resulting material has certain improved properties. One constituents is called the reinforcement and the one in which it is embedded called the matrix. Based on the type of matrix used they are classified into; Metal Matrix, Polymer Matrix and Ceramic Matrix Composite. Each type of matrix has their respective fields of application. The topic of interest in this paper is MMC hence ventures into the application. The application of MMC's includes automotive disc brakes, tank armors, aircraft landing gears and several others.

Stir casting process is found suitable for manufacturing composites with up to 30% volume fractions of reinforcement [2]. A homogeneous distribution of particles in the composite matrix is critical for achieving high strength because uneven distribution can lead to premature failure in reinforcement free and rich areas. Subsequently dry friction wear test was conducted on a pin-on-disc wear testing machine.

II. LITERATURE SURVEY

By conducting the literature survey it is observed that many researchers have characterized different Metal Matrix Composites (MMC) by preparing the specimen by stir casting method and subsequent wear test of the specimen. It is also found that most researchers have given a lot of attention towards aluminum reinforced with compounds such as titanium di boride silicon carbide (SiC), magnesium oxide (MgO) and several other alloying elements, but very few researchers have done it with Beryl. Therefore this project was chosen as a contribution to material science, the objective of the project is to perform a wear test on the Al-Beryl MMC specimen prepared by stir casting and consequently perform the wear test. Parameters such as tensile strength, hardness and also the effect of different operational parameters such as sliding speed, load and co-efficient of friction is studied. It is also seen in the literature, that load and sliding speed has considerable effect on co-efficient of friction and wear rate. The presented work ventures into details of the characterization of Al-Beryl MMC.

III. COMPOSITION

A. Aluminum is the third most copious element in the earth crust [1]. Aluminum alloy 6061 is one of the most extensively used among 6000-series aluminum alloys. It is a versatile, heat treatable extruded alloy with medium to high strength capabilities

Table 1: Composition of Al - 6061 alloy (wt. in %)

Element	Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	Be	V	Al
Wt.%	0.92	0.76	0.28	0.22	0.1	0.07	0.06	0.04	0.003	0.01	98

B. One of the chief ores of beryllium is beryl, beryllium is a good conductor of heat and electricity which display remarkable elasticity when alloyed to copper and nickel, and for this reason they are usually used in springs and spark-proof tools.

Table 2: Composition of beryl (wt. in %)

Element	SiO2	Al_2O_3	BeO	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO
Wt.%	65.4	17.9	12.3	0.8	1.34	0.48	0.55	0.004	0.05

IV. METHODOLOGY

Al-6061 and Beryl raw materials are procured. Requisite specimens were prepared from the raw materials as per standards for all the experiments. The experiments conducted are briefly explained below.

A. *Tensile test*

The tensile test was conducted on the Al-Beryl MMC material in which the specimen were prepared according to the ASTM E8 specifications as shown in Fig: 1.

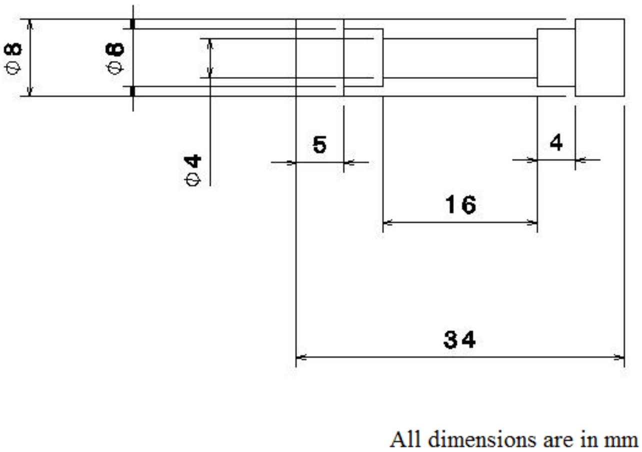


Fig. 1. Specimen specification.

The specimen is clamped in the jaws of the Electronic Tensometer as shown in the figure 2. The computer will tabulate the degree of elongation of specimen, break load and ultimate tensile strength of the specimen. Further a graph is plotted with variables load versus displacement.

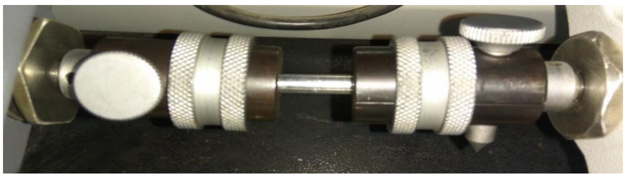


Fig. 2. Specimen clamped between jaws.

B. *Hardness test*

The commonly used property of a metal is its hardness. Hardness exposes the strength of the material and also the resistance of the material to wear and scratch. It is defined as "The resistance of the material to the permanent deformation or the indentation or penetration".

The Brinell hardness test characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece. It is one of several definitions of hardness in materials science.

The indentation is measured and hardness calculated using:

$$\text{BHN} = \frac{2P}{\Pi D(D-\sqrt{D^2-d^2})} \qquad (1)$$

Where:
BHN = Brinell hardness number (kgf/mm2)
P = applied load in kilogram-force (kgf)
D = diameter of indenter (mm)
d = diameter of indentation (mm)

C. *Pin-on-disc wear test*

The wear test is done to know the characteristics of different materials in which materials are rubbed one against the other. The test is done using the standard ASTM apparatus designed and manufactured by DUCOM. The machine is called pin on disc type wear testing machine.

In this experiment the concern is not mainly on wear characterization of the material, instead it revolves around primarily towards the co-efficient of friction which is involved between the surface of the bodies in contact, the amount of stresses that is evolved during the operation and the effect of these stresses on the plastic deformation of the requisite material we are testing. The material which is adopted in this experiment is Al-6061 and Beryl. Al-6061 as disc material and Al-Beryl as pin, this experiment is mainly related to rise of stresses, co-efficient of friction and effect of these two on the plastic deformation of the Al-6061 material. Here we are also concerned about the depth through which the material has been cut from the surface. Finally we compare all these results with each other that are being tested for different loads and speeds.

Figure 3 depicts the wear testing machine used to carry out the experiment.

Fig. 3. Pin-on-disc wear test setup

V. RESULTS

A. Tensile Test

The tensile test was conducted according to standards using Electronic Tensometer. The load displacement curves obtained is shown in Fig 4.

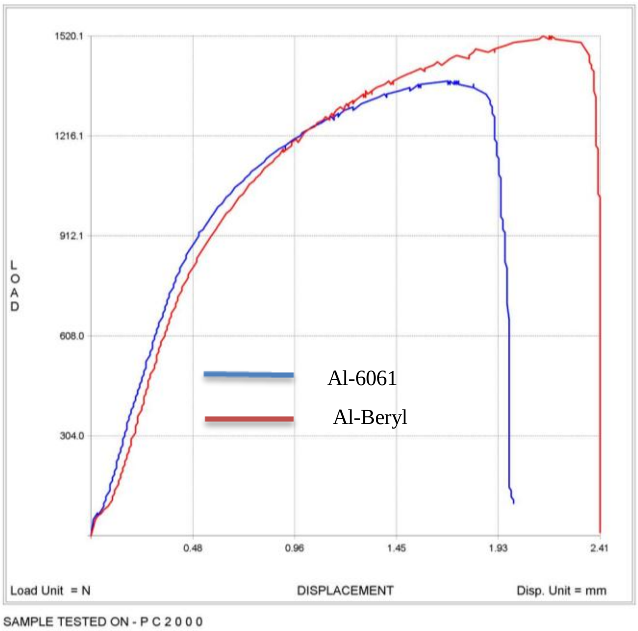
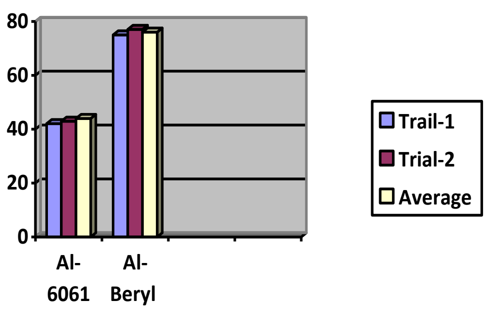


Fig. 4. Fig. 4. Load Vs Displacement curves

The engineering ultimate tensile stress of Al-beryl is found to be 120.9 N/mm^2 as opposed to 110 N/mm^2 for pure Aluminium 6061.

B. Hardness Test

The hardness test was conducted on Brinell hardness testing machine. If was found that on average the Al-beryl composite outperformed its competitor Al 6061 with BHN of 76 and 44 respectively. The trail are shown in the graph below



Graph 1: Comparison of hardness in BHN

C. Wear Test

Sliding tests using Al-Beryl as pin were conducted using pin-on-disc wear testing machine. The normal loads applied were 4.905N, 9.81N, and 14.715N. Experiments were repeated three times at each level of normal loads for three different speeds of disc namely, 382, 477 and 572 RPM (9 experiments in total). The friction co-efficient was monitored and captured with respect to sliding time on a computer. The typical dependencies of co-efficient of friction with sliding time are shown below.

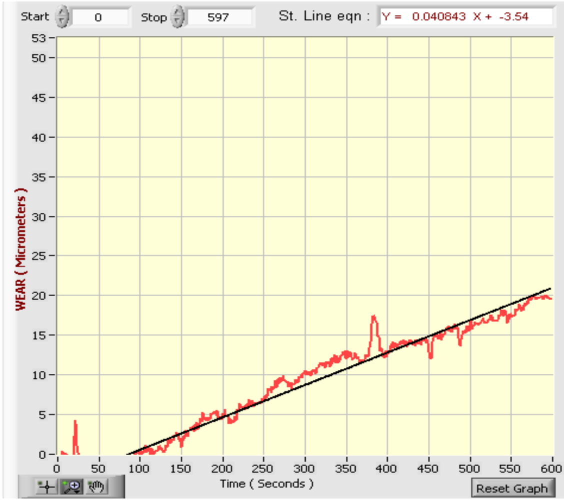


Fig. 5. Wear Vs Time graph for 0.5 Kg and 382 RPM

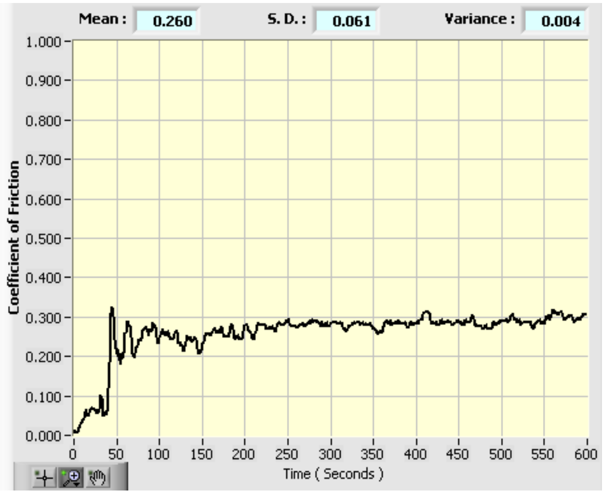
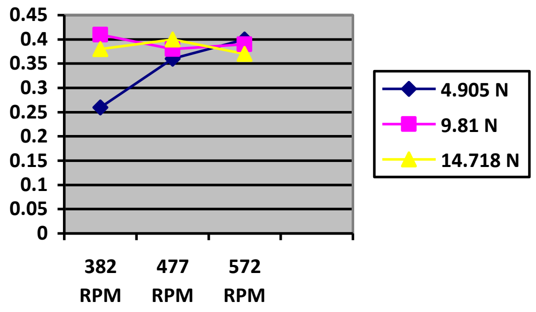


Fig. 6. Coefficient of friction Vs time graph for 0.5 Kg and 382 RPM

Fig 5 and fig. 6 shows wear vs. time graph and the dependency of friction co-efficient on sliding time respectively, when normal load is 4.905 N. The co-efficient of friction achieved all most steady state after initial running time of approximately 5 sec. The friction co-efficient was found to be steady throughout the rest of the sliding time. From fig 6 to shows the dependency of co-efficient of friction with time for normal load of 4.905N. The friction co-efficient reached a steady state after initial running time of about 5 sec. The friction was found to be steady throughout the running time except a small kink over a running time between approximately 15 sec to 30 sec.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 04, April-2017



Graph 2: Comparison of co-efficient of friction of various RPM and loads

The average co-efficient of friction was found to be minimum which is 0.26 when normal load was 4.905 N. The average co-efficient of friction was found to be maximum which is 0.41 when normal load was 9.81 N.

The plot average co-efficient of friction on corresponding normal load indicates that the co-efficient of friction drastically increases when normal load changes from 4.905 N to 9.81 N. The co-efficient of friction was found to decrease when normal load changes from 9.81 N to 14.718 N.

The plot average co-efficient of friction on corresponding normal load indicates that the co-efficient of friction drastically increases when normal load changes from 4.905 N to 14.718 N.

The plot average co-efficient of friction on corresponding normal load indicates that the co-efficient of friction drastically decreases when normal load changes from 4.905 N to 14.79 N.

An attempt has been made to understand the possible mechanism which contributed dependency of average co-efficient of friction with normal load.

VI. DISCUSSIONS

The conclusions derived from the results and discussions of experiments are as follows:

- The co-efficient of friction was found to depend on state of stress which was in turn dependent on normal load.
- The state of stress influences the co-efficient of friction and found to be at maximum when the state of stress is not severed. This is because of the increased surface roughing and a large quantity of wear debris.
- The co-efficient of friction was found to reduce when the state of stress found to become very sever.

ACKNOWLEDGMENT

The authors acknowledge, to Dr. H C Nagaraj, Principal. Nitte Meenakshi Institute of Technology for providing the support and infrastructure to carry out our research. We would also like to acknowledge Dr. Kiran Aithal S., HOD, Department of Mechanical Engineering, Dr. P. G. Mukunda and Dr. Desai Gowda H.S. of Nitte Meenakshi Institute of Technology for their valuable suggestions and support.

REFERENCES

[1] Nature's Building Blocks: An A-Z Guide to the Elements by John Emsley pp. 23-58

[2] Progress in Materials Science Research By Antonio C. Venetti pp. 65-70

[3] Biswajit Das, Susmita Roy, R.N. Rai, S.C. Saha, Priyanko Majumder. "Effect of in-situ processing parameters on microstructure an mechanical properties of TiC particulate reinforced Al–4.5Cu alloy MMC fabricated by stir-casting technique – Optimization using grey based differential evolution algorithm"

[4] Alok Manas Dubey, Ajay Kumar, Ashok Kumar Yadav. "Wear behavior of friction stir weld joint of cast Al (4–10%) Cu alloy welded at different operating parameters"

[5] N.Ch. Kaushik n, R.N. Rao. "Effect of grit size on two body abrasive wear of Al 6082 hybrid composites produced by stir casting method". Tribology international 102 (2016) 52-60.

[6] Shivraman Thapliyal, Dheerendra Kumar Dwivedi. "Microstructure evolution and Tribological behavior of the solid lubricant based surface composite of cast nickel aluminum bronze developed by friction stir processing".

[7] Kenneth Kanayo Alaneme, Olusola Joseph Ajayi. "Microstructure and mechanical behavior of stir-cast Zn–27Al based composites reinforced with rice husk ash, silicon carbide, and graphite".

[8] S. Gopalakrishnan, N. Murugan. "Production and wear characterization of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method". Composites: part B 43 (2012) 302-308.

[9] Hossein Abdizadeh, Reza Ibrahim ifard, Mohammad Amin Baghchesara. "Investigation of microstructure and mechanical properties of Nano MgO reinforced Al composites manufactured by stir casting and powder metallurgy methods". Composites: part B 56 (2014) 217-221.

[10] Rupinder Singh, Gagandeep Singh. "Investigations of Al–SiC AMC prepared by vacuum moulding assisted stir casting".

[11] S. Suresh N. Shenbaga Vinayaga Moorthi. "Process development in stir casting and investigation on microstructures and wear behavior of TiB2 on Al6061 MMC". Procedia engineering 64 (2013) 1183-1190.

[12] K.Umanath, S.T.Selvamani, K.PalanikumarK and D.Niranjanavarma. "Metal to Metal Worn Surface of AA6061 Hybrid Composites Casted by Stir Casting Method". Procedia engineering 97 (2014) 703-712.

[13] Shashi Prakash Dwivedi, Satpal Sharma, Raghvendra Kumar Mishra. "Microstructure and Mechanical Properties of A356/SiC Composites Fabricated by electromagnetic Stir Casting".

[14] Bharath V, Madev Nagaral, V Auradi and S. A. Kori. "Preparation of 6061Al-Al2O3 MMC's by Stir Casting and Evaluation of Mechanical and Wear Properties". Procedia materials science 6 (2014) 1658-1667.

[15] Vishnu Prasad K, K R Jayadevan. "Simulation of stirring in stir casting". Procedia technology 24 (2016) 356-363.

[16] S. Aravindan, P.V. Rao, K. Ponappa. "Evaluation of physical and mechanical properties of AZ91D/SiC composites by two step stir casting process".

[17] Nagaraj M. Chelliah, Harpreet Singh, M.K. Surappa. "Correlation between microstructure and wear behavior of AZX915 Mg-alloy reinforced with 12 wt% TiC particles by stir-casting process".