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Tribological Characterization of Aluminium Functionally Graded Materials using different Reinforcing Elements

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Abstract— *The processing of Functionally Graded Material (FGM)in today scenario is complicated and time consuming because of its exploring areas. In this paper we not only give the introduction regarding the processing of FGM but also its tribological characterisation such as wear rate, coefficient of friction and the frictional force parameters on the fixed parameters of pin on disc speed, wearing time and the track diameter. The functionally graded material is a superior quality material which in present days is not only replacing the conventional materials but also fiber reinforced and metal matrix composites, In this research paper we have considered the pure aluminium of 98% purity with ASTM standards is considered as the matrix material and reinforcing elements such as alumina and magnesium oxide are taken to process the FGM. The FGM is processed through powder metallurgy technique and Zinc sterate is taken as the binding agent with the aid of rule of mixtures (5%,10% & 15%) of matrix and reinforcing elements .The FGM specimens are tested extensively on pin on disc tester with EN31 disc material and tested for 125 rpm,225 rpm and 425 rpm with wear period of 15 minutes,30minutes and 45 minutes. Plots for wear rate, coefficient of friction and frictional force with respect to time are performed and different characteristics are identified for different compositions of FGM with increasing reinforcing element in volume.*

Keywords— *FGM, wear rate, aluminium, rpm.*

I. INTRODUCTION

Functionally graded materials (FGM) are prepared by placing the matrix element in the bottom most layer and thereby decreasing the matrix element and increasing the reinforcing element over the increasing layer and thereby eliminating the matrix material to the top most layer. The methods used to process the FGM are very low and they are not fully explored due to the undefined standards of the functionally graded materials. The powder metallurgy process is initiated in the initial stages and later on modified to a larger extent to produce different materials and sub steps to remove the wastage and decrease the manufacturing time. The FGM are unique variety of materials extensively used in wear resistant materials as to have more resistant materials in various heated and tough operating conditions. This research work aims at the preparation of functionally graded metal matrix composites (MMCs), considering pure Aluminium as matrix material and silicon carbide, alumina and magnesium oxide as the reinforcing agents using the powder metallurgy methodology with some advancements. FGM are extensively used in different components used in automobile to space craft industries because of their superior material properties along the volume rate. These materials not only possess high stiffness, high hardness, and high compressive strength but also possess excellent tribological properties. Due to their high stiffness to weight ratio they are used in crankshaft preparation in super cars manufacturing. These materials not only gives sufficient load bearing capability but also increase the life period hence they are used in different functional and operational requirements than that of alloying materials. Even though they produce extensive superior properties they possess a difficulty of brittleness of the structure when left over a period of time without any usage and also could be subjected to crack propagation and enhancement. The compacts of FGM are synthesized by taking pure Aluminum with no reinforcements in the bottom most layer and subsequently the second layer with pure aluminum and silicon carbide as the bonding agents and the next subsequent layer is by aluminum, alumina and the third layer is aluminium, alumina and magnesium oxide and the top most layer is alumina and combination of magnesium oxide. in different weight fractions (5%, 10%, 15%, & 20%)[3]. The tribological properties of these compacts are then assessed at different speed time and track diameter of the pin on disc tester. The wear characteristics are not only to determine the effectiveness of the synthesized process but also to choose correct combination of the matrix and the reinforcing elements.

II EXPERIMENTAL WORK

2.1 **Materials:**

The pure aluminium powder with 98% purity with 200 microns particle size is taken as the matrix constituent due to its extensive application in aeronautical and automotive applications. The reinforcements mainly silicon carbide (SiC),magnesium oxide of respective densities 3.21 and 3.58 g/cm3 are selected due to their high hardness and wear resistance. The content of the reinforcing agents with an mass fraction of 15% with their average size of 50 microns is chosen to study their dry abrasive action. The chemical composition of the pure aluminium is displayed in Table 1.

Table 1 shows the Chemical composition of pure aluminum with respective to % of mass fraction of elements.

Si	Fe	Mn	Mg	Ti	Al
0.41	0.15	0.023	0.38	0.016	99.021

2.2 Development of functionally graded materials:

After selection of the materials the next process is to develop fine mixture of the matrix and the reinforcing agents with the help of ball milling of ASTM standards using the rule of mixtures methodology. The FGM consists of four layers starting from the bottom most layer (100% pure aluminium) and the subsequent layer consists of (90%Al+10%SiC),the third layer consists of (90%Al+5%SiC+5%Mgo2) and the top most layer consists of 85%Al+5%SiC+10%Mgo2).After ball milling the powders are ready for the compaction process which is not processed in a simple compaction machine but it is processed systematically in compression testing machine of capacity 100KN

Specin	Composition	Matrix wt (gm)	Reinforcem (gm)
1	100%Al	25.00	0
2	90%Al+10%SiC	20.00	5.00
3	90%Al+10%Al_2O_3	20.00	5.00
4	85%Al+7.5%SiC+ 7.5%Al_2O_3	21.25	4.75

Table 2 shows the composition of matrix and reinforcements

The FGM are manufactured by using above composition by adopting the rule of mixtures and we have taken special care that the compacts of the FGM are perfectly bonded leaving no sharp edges and unwanted material at the surfaces. The compaction is performed on universal compression testing machine according to ASTM standardization with standard compression load of 18.75KN and the ejection load of 9.75KN.The compaction is done in two stages because of layer by layer deposition of the material by this two stages we will achieve layer by layer deposition of the material at an uniform rate.

The compacted FGM'S are made to sintered specimens by allowing them to pass through the tubular furnace where it is specially designed to increase the hardness and sustainable strength to the material we have considered a temperature of 623 centigrade temperature for a time period of four hours and we cooled the specimens at very low rate. The specimens are also subjected to furnace cooling for 24 hours such that there is no flaws in the sintering operation which is very vital in the preparation of FGM.s because even though how strong the compaction is done but it is not sintered properly the specimens are easily damaged and subjected to sharp interfaces and low strength in the micro and macro structural level.

The FGM's are now successfully ready for the testing on pin on disc wear test apparatus of EN 31 disc material and standardized according to ASTM 356 standards. The wear tester is equipped with 4, 6, 8, 10& 12 mm pin holders to hold the different types of circular, rectangular and triangular specimens onto the disc which is connected to the micro controller which is manually controlled for the initial setting of the wearing time and resetting the values of wear rate and frictional force to zero such that the obtained values are without errors and flaws.

3. Results & Discussions:

Specimen 1: left hand side layers

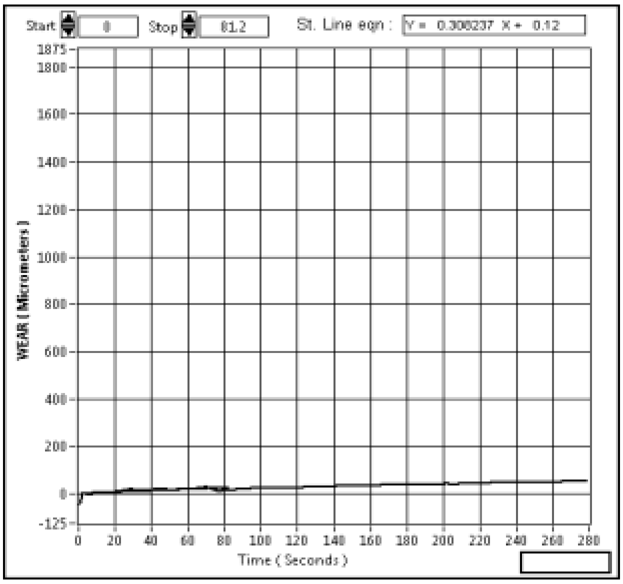

Fig 1 : variation of wear with respect to time

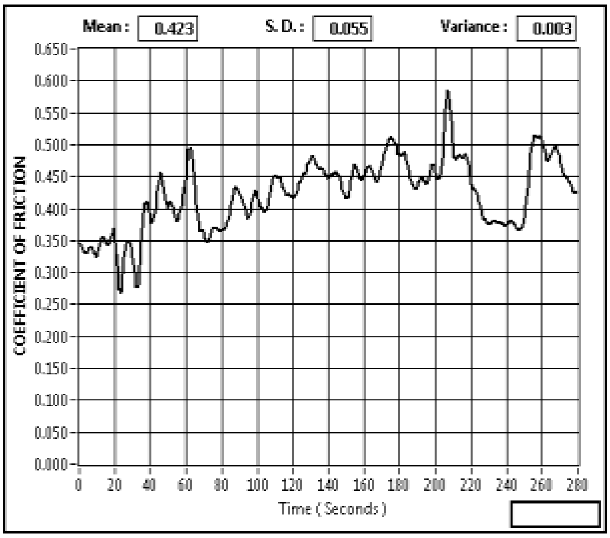

Fig 2: variation of friction coefficient with respect to time

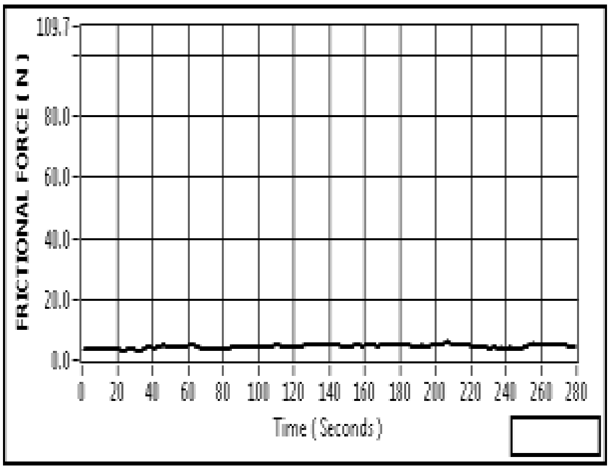

Fig : variation of frictional force with respect to time

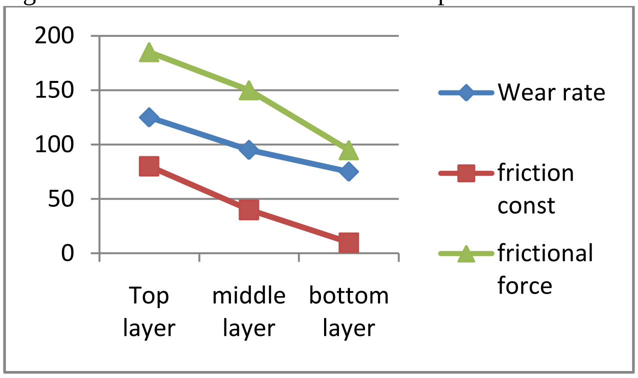

Fig 3:Variation of tribological parameters w.r.t layers

From the above graphs we can observe that the wear rate at the initial time is below zero and it increased at very slow rate of 15 microns and increase very low rate due to the high bonding of elements and finally it reached a value of 125 microns which is very low when compared to alloys and metal matrix composites. Similarly when we shift to the frictional constant it is 0.055 which is very low and also the frictional force is subjected to 8.5KN.

Specimen 1: Right hand side layers

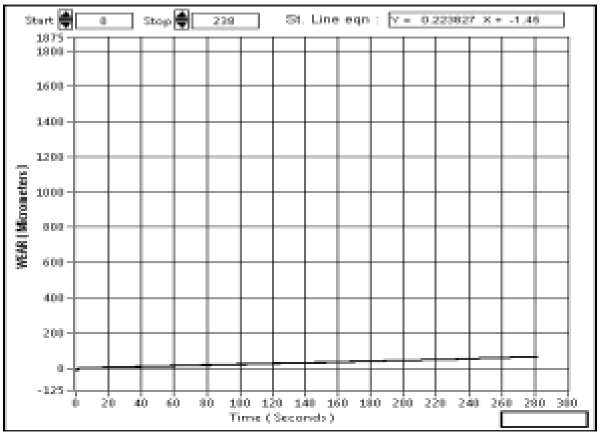

Fig 4: variation of wear with respect to time

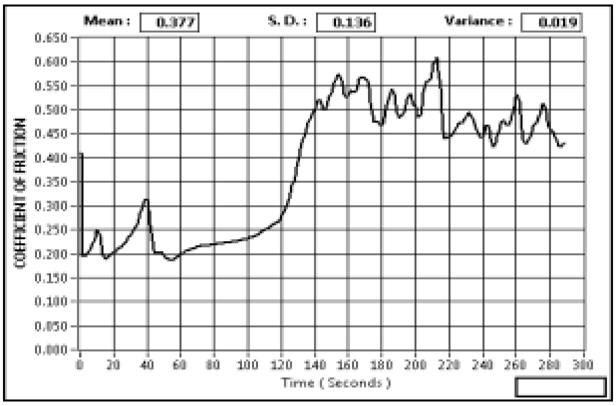

Fig 5: variation of friction coefficient with respect to time

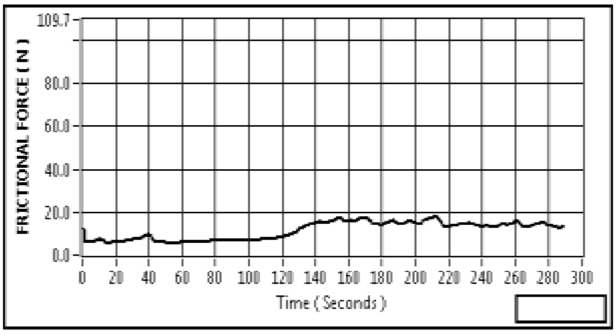

Fig 6 : variation of frictional force with respect to time

Now in order to validate our tribological properties we had shifted to the right side and now this side is subjected to rigorous wear and tearing of the EN 31 material and now we observe the wear rate to be 18 microns, coefficient of friction to be 0.136 and the frictional force to be 18.5N which is well below the approximation and error percentage of 5%.This validates our both FGM sides result according to the standards.

Specimen 2: left hand side layers

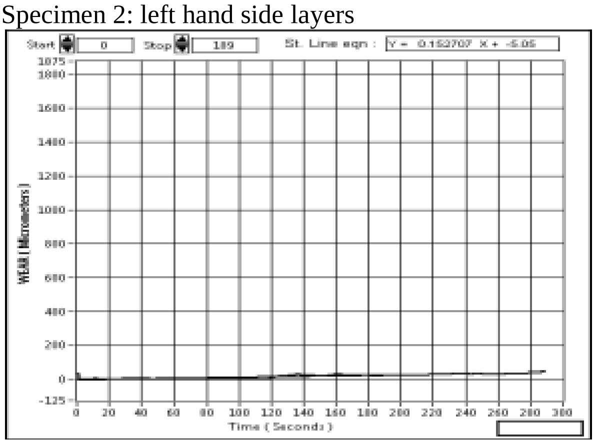

Fig 7 : variation of wear with respect to time

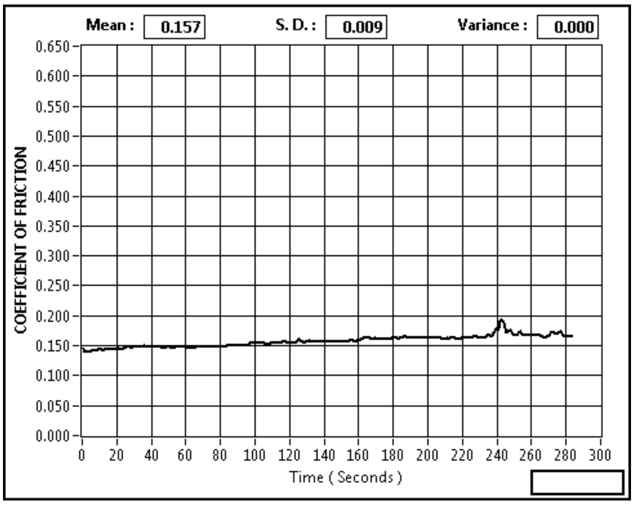

Fig 8: variation of friction coefficient with respect to time

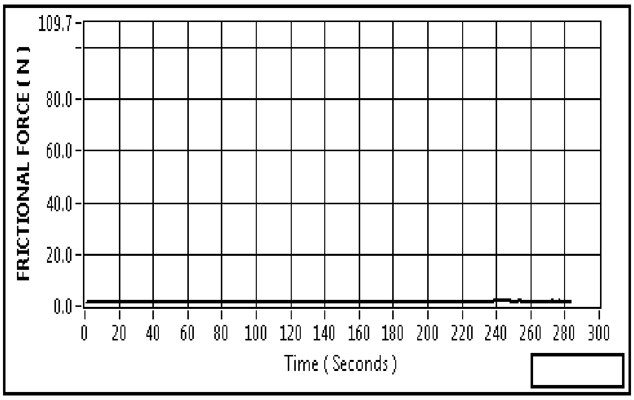

Fig 9 : variation of frictional force with respect to time

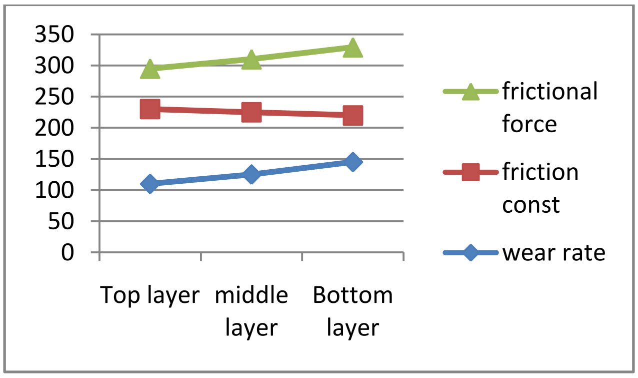

Fig 10:Variation of tribological parameters w.r.t layers

Specimen 2: Right hand side layers

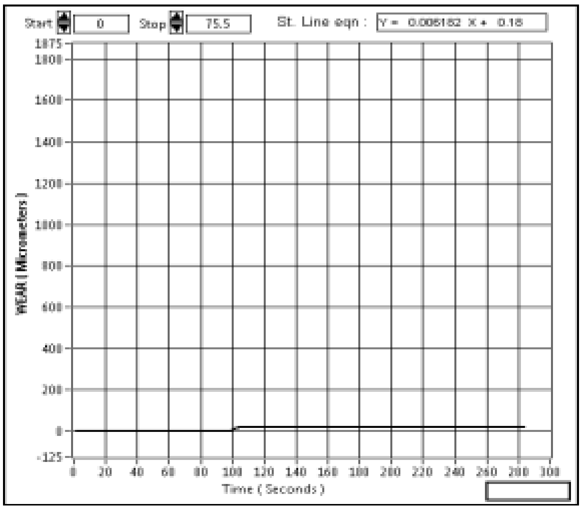

Fig 11 : variation of wear with respect to time

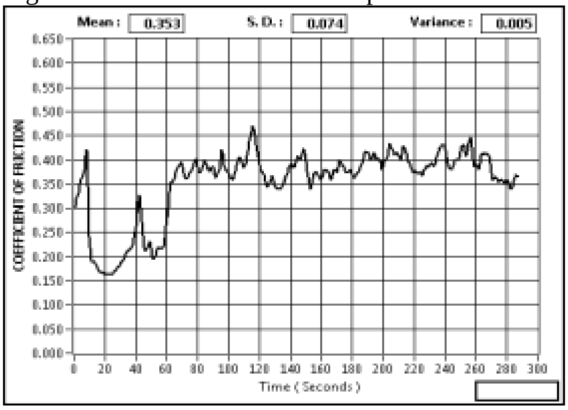

Fig 12 : variation of friction coefficient with respect to time

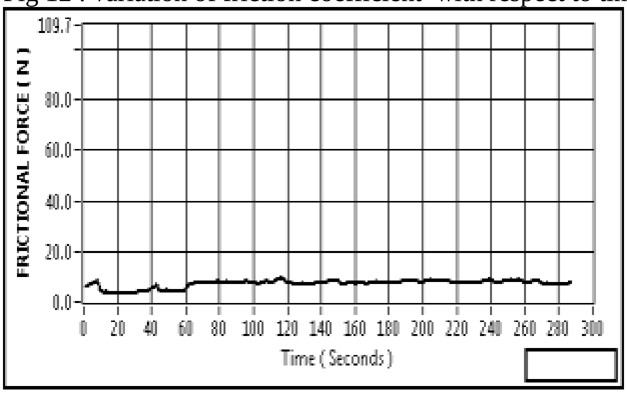

Fig 13 : variation of frictional force with respect to time

We have now selected another specimen and tested for the parameters of wear rate, coefficient of friction and frictional force and we have successfully found the parameters through the graphs as the wear rate is 65 microns and the frictional constant 0.074 and the frictional force as 12.25N.The reason of increase in frictional force is due to the high resistance offered by the silicon carbide elements making the specimens to have increase in frictional force.

From these graphs we can successfully infer that the FGM exhibit better tribological parameters when compared to ordinary alloying agents and the composite materials.

4. Conclusions:

1. The FGM are synthesized successfully by using layer by layer compaction process.
2. The layer by layer bonding is very well enhanced by sintering operation.
3. The specimen are tested successfully on pin on disc wear testing apparatus and the evaluating graphs for the wear rate, coefficient of friction and the frictional force are successfully evaluated.

4. The FGM of composition 85%Al+7.5%SiC+7.5% alumina showed less wear rate and coefficient of friction when compared to 100% aluminum matrix element and the 90%Al+10%(silicon carbide, alumina) compositions.
5. The increase in frictional force is observed in the second most layer subsequent to the bottom most layer due to the less molecular bonding of aluminum with the silicon carbide elements.

References

[1] Amir Arifin, Abu Bakar Sulong, Norhamidi Muhamad, Junaidi Syarif, Mohd Ikram Ramli "Material Processing of Hydroxyapatite and Titanium Alloy (HA/Ti) Composites as Implant Materials using Powder Metallurgy: A Review", Materials and Design 55, Pages 165-175, 2013.

[2] Al6061 Hybrid Metal Matrix Composite Reinforced with Alumina and Molybdenum

[3] Disulphide. G. Pitchayyapillai, P. Seenikannan, K. Raja, and K. Chandrasekaran

[4] Gaurav Mahajan, Nikhil Karve, Uday Patil, P. Kuppan* and K. Venkatesan "Analysis of Microstructure, Hardness and Wear of Al-SiC-TiB_2 Hybrid Metal Matrix Composite "Indian *Journal of Science and Technology, Vol 8(S2), 101-105, January 2015*.

[5] Arindam Ghosh and Subrata Chatterjee "Effect of Al2O3 Content and Process Variables on Structure and Properties of Al-Al2O3 Compacts

[6] Yasuyoshi, Fukui & Watanabe, Yoshimi. (1996)., Analysis of thermal residual stress in a thick-walled ring of Duralcan-base Al-SiC functionally graded material, Metallurgical and Materials Transactions A. 27. 4145-4151. DOI: 10.1007/BF02595662.

[7] M. M. Nemat-Alla1, M. H. Ata, M. R. Bayoumi, and W. Khair Eldeen, Powder metallurgical fabrication and microstructural investigations of Aluminium/Steel functionally graded material, Materials Sciencesand Applications, vol. 2, (2011), pp. 1708-1718

[8] P.G. Mukunda, A. Shailesh Rao, Shrikantha S. Rao, "Influence of Rotational Speed During Centrifugal Casting on Sliding Wear Behaviour of the Al-2Si Alloy", Frontier Material Science of China, Page 339-344, 2009.

[9] Garrett E. Ryan, Abhay S. Pandit, Dimitrrios P. Apatssidis, "Porous Titanium Scaffolds Fabricated using a Rapid Prototyping and Powder Metallurgy Technique", Biomaterials, Page 3625-3635, 2008.