Mechanistic Studies on Dry Sliding Wear Behavior of Aa6026 Composite Strengthened By Lanthanum Oxide

K.Chithambaram[1], Dr.P.K.Palani[2], B. Rajeswari[3]
[1, 2, 3] Dept of Mechanical Engineering
[1, 2, 3] Government College of Technology, Coimbatore

Abstract- *The aim of the project is to investigate the mechanical behavior of AA6026, lanthanum oxide (La_2O_3) aluminum matrix composite prepared using Stir casting machine. Investigation on the dry sliding wear behavior by means of pin-on disc apparatus at room temperature has been carried out. The variations in the micro structure and mechanical properties were observed for composite with varying proportions of La_2O_3. The mechanical properties were studied using tensile test, density test, Vicker and Brinell hardness test. The micro structural properties were analyzed using optical microscopy. It is observed that the mechanical properties improved when the lanthanum oxide reinforcement addition is 4% weight. Tests were done to find the sliding distance and sliding speed to study the wear characteristics of the composite. The results show that La_2O_3 particles refined the grains of the aluminum matrix and improved the wear resistance of the composite. The study also indicate that La_2O_3 particulate improved the wear resistance of the composite and reduced the damage on the wear surface. These results show that the promising trends on utilizing this aluminum metal matrix composite in various engineering applications such as breaking system, decorative anodizing, dielectrics and photo optics.*

Keywords- Composite, metal matrix, optical analysis, wear behavior, pin-on disc and wear surface.

I. INTRODUCTION

Aluminium is an element in the boron group with atomic number 13 and symbol Al. It is the third most abundant element on the earth crest only after Silicon and Oxygen. It is the most abundant metallic element, making up about 8% of the earth's crust, and is produced in a quantity second only to that of iron. Pure aluminum has a silvery - white appearance. It is soft and ductile in nature. It has very high conductivity and high corrosion resistance. Aluminium atoms are arranged in face centered cubic structure.

Properties of aluminium

- **Density-** The main beneficiary property of aluminum is its low density which accounts for its good strength to weight ratio. It has a density of 2700 kg/m^3 which is one third of that of iron.
- **Strength-** The strength of aluminium alloy ranges from70 MPa to 700 MPa. The strength of aluminum increase in low temperature .This nature it more preferable than steel in low temperature applications since steel become brittle at low temperature.
- **Thermal Conductivity and Electrical conductivity-** The thermal conductivity of aluminium is 205 (W/mK) °C at a range of 0-100°C which is about three times greater than that of steel. This makes it suitable material for both cooling and heating applications such as heat exchanger.
- **Corrosion Resistance of Aluminium -** There will be an instantaneous formation of a layer of aluminium oxide forms on the surface of aluminium if it is exposed to air. This layer has excellent resistance to corrosion which enables aluminium to have high corrosion resistance. It is fairly resistant to most acids but less resistant to alkali.
- **Linear expansion** - The co-efficient of linear expansion of aluminium is 23.5 x10^{-6}/°C for temperature range of 0°C to 100°C which is relatively large compared to other metals
- **Machining -** Aluminium can be subjected to most of machining methods such as drilling cutting punching bending etc. with comparably less energy.

Composites

A composite can be termed as any multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a superior combination of properties is achieved. Most composites have been designed to enhance mechanical characteristics such as stiffness, toughness, and ambient and high temperature strength.

Types of Composites

According to the matrix phase composites are classified as following

Polymer Matrix Composite

Polymer Matrix composites (PMC) are made of polymer as matrix and fibers as reinforcement. Polymers are used as matrix materials to induce some ductility to composite. The reinforcements used are glass fiber, aramid fiber and carbon fiber.

Ceramic Matrix Composite

Ceramic Matrix composite has a ceramic matrix reinforced by resilient particulates, fibers, or whiskers of one ceramic material that have been embedded into a matrix of another ceramic and thereby improving fracture toughness . Phase transformation may help to arrest the propagation of cracks.

Metal-matrix composites

In the matrix is a ductile metal and the reinforcement may be in the form of particulates, continuous and discontinuous fibers and whiskers. The concentrations reinforcement of normally range between 10 and 60 percentage volume. Continuous-fiber materials are generally made of carbon, silicon carbide, boron, aluminum oxide, and the refractory metals.

II. METHODOLOGY

The literature review has given an insight of the alloy research work and the gaps found in it enabled to identify problem areas find solution through the experimental methodology fulfilling the objective.

Stir Casting

In stir casting we use stirrer to agitate the molten metal matrix. The stirrer is generally made up of a material which can withstand at a higher melting temperature than the matrix temperature. Generally graphite stirrer is used in stir casting. The stirrer is consisting of mainly two components cylindrical rod and impeller. The resultant molten metal is then poured in die for casting. The distribution of particle in the molten metal matrix is also affected by the velocity of stirrer, angle of stirrer, vortices cone etc. In this method first the matrix metal is heated above its liquid temperature so that it is completely in molten state.

Factors affecting the process

Information collected through various research papers show the following factors which affect the stir casting process the most. They are

A.Speed of stirring
B.Time duration of stirring
C.Stirring temperature

III. EXPERIMENTAL WORK

Fabrication of Composite

The experimental setup of stir casting essentially consists of an electric furnace and a mechanical stirrer. The electric furnace carries a crucible of capacity 2kg. The maximum operating temperature of the furnace is 1000°C. The current rating of furnace is single phase 230V AC, 50Hz.

Fig.2 Stir Casting Machine

Experimental plan

Material requirement

Diameter of die (D) = 30 mm
Length of die (L) = 240 mm
Volume (V) = $A = \pi r^2 \times h$
= 3.14 X 15^2 X 250
(V) =176625.24 mm^3material Required

AA6026:

Mass = Density × Volume [Density of AA6026 = 2.72g/cm^3]
=$2.72\times10^{-3}\times$ 176625.24
= 480.42 g

La_2O_3:

Mass = Density × Volume [Density of La_2O_3 = 6.51g/cm^3]

= $6.51\times10^{-3}\times$ 176625.24
= 1149.83 g

TOTAL MASS CALCULATION OF SAMPLES :

SAMPLE I :

MASS = 100% AA6026
= 480.42 g

SAMPLE II :

MASS = 99% AA6026 + 1% La_2O_3
=(99%*480.42)+(1% *1149.83)
= 475.61 + 11.98= 487.59 g

SAMPLE III :

MASS = 98% AA6026 + 2% La_2O_3
= (98%*480.42)+(2% *1149.83)
= 470.81 + 22.99
= 493.80 g

SAMPLE IV :

MASS = 97% AA6026 + 3% La_2O_3
= (97%*480.42)+ (3% *1149.83)
= 466 + 34.49
= 500 g

Stir casting

The aluminium alloy AA6026 bricks were cut in power hacksaw machine to the small pieces to feed the materials in to the crucible. The required proportion of the pieces as per experimental plan is fed in to crucible and melted by heating in the induction furnace at the temperature of 650-700°C for 1 to 2 hours and melt the La_2O_3 pieces above its liquid temperature to make it in the form of semi liquid state around 1000°C.

Preheated die is heated to a temperature of 200°C for proper solidification. During the reheating process of aluminium alloy at 750°C stirring is done by means of a mechanical stirrer as shown in figure 2 which rotates at a speed of 600 rpm. Then the reinforcement powders are added to semi liquid aluminium alloy in the furnace. Argon gas is passed in to the molten metal to remove the soluble gases present in the liquid state metal. Stirring of molten metal is carried for 3 minutes duration.

The aluminium composite material reaches completely liquid state at the temperature of about 900°C and the completely melted aluminium hybrid composite is poured in to the permanent metal die and subjected to solidification to produce the required specimen. Thus, all samples were casted as per experimental plan.

Testing Of Mechanical Properties

Tensile test

The tensile properties of the sample was analyzed using digital testing machine. The samples were prepared as per given dimensions and the sample was loaded in the machine. The ultimate and yield strength, strain rate and applied force were recorded using machine software and the stress strain graphs was plotted.

Vickers hardness test

The Vickers hardness test method or micro hardness test method is used to measure hardness for small parts, thin sections, or case depth work. It will only impart a very small indentation on the test material so that the surface finish is not much affected. This enables testing very thin materials like foils or measuring the surface of small parts or areas. It will also help to measure the depth of case hardening by sectioning a part and making a set of indentations to mention the profile of change in hardness. The indentation is made using a square base pyramid shaped diamond indenter which is measured by an optical measurement system. The load applied are very light, ranging from 10gm to 1kg. The sample has to be well polished for accurate measurement.

Table 1.Hardness testing parameter

Load applied	100gf
Dwell time	10s
No of readings	3

Density Testing

The density was tested using the density testing machine. Here the sample is weighed in a tray and another tray that is immersed in water. The difference in weight in gram will indicate the volume in cubic centimeter. The density can be computed easily using above values.

Charecterization Analysis

Optical Microscopy

The microstructure of the samples was observed by optical microscope .The microstructure of the top surface front surface and side surface were taken .The steps for sample preparation is as follows

30mm X 20mm 15mm block is prepared from bottom portion of riser and three adjacent surfaces of this block were smoothened by surface grinding.

- These surfaces were further polished by using emery paper of grit size 400, 600, 800, and 1000 respectively.
- Then mirror finish is given to the surface using alumina polishing.

IV. RESULTS AND DISCUSSION

Cast samples of alloy and composite

The as cast samples were made and was visually examined for soundness and porosity. It was noted that the castings with 0%, 1% and 2%reinforcement had negligible amount porosities and pinholes. Very small porosities was observed for sample with 3% which had a depth of roughly 1mm to 2mm.This may be due to the changes in solidification rate. Pinholes may occur due to the increase in localised nucleation sites. This is due to the increase in solidification rate caused by increase of reinforcement.

Optical images of microstructre

The optical images of microstructures three adjacent side of the samples were taken using Optical Microscopy. On the top surface for pure alloy the coarse grains are formed. The dendrite starts to form in sample composite with 1% of reinforcements. The presence of the dendrites are increased when the percentage of reinforcements. Many dendrites are breaking and finer grains are forming when the reinforcement percentage is increased to 3%. These effects may be due to the grain refinement nucleation and change in solidification rates and caused by the presence of alumina particles.

The microstructure in the top and the side surfaces has finer grains compared to the top surface. This may be due to the grain refinement due to increase in cooling rate. Since the side surfaces are closed to the walls the heat dissipation is increased. There is a ripple like orientation of grains for the microstructure of the side surface of the sample with 1% reinforcement. These ripple formation become feeble and disappears as reinforcement increases. The ripple formation may be due to the laminar flow occurring in the riser part due to the slow rise of molten metal in the riser followed by solidification. These ripples may disappear due to the turbulence caused by the alumina particles.

Fig.2Image of AA6026(Top Surface)

Fig.3Image of AA6026(Side Surface)

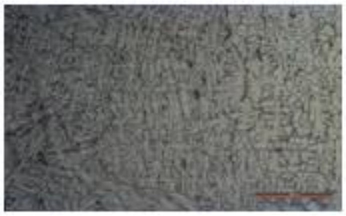

Fig.4Image of AA6026-1% La_2O_3 (Top Surface)

Fig.5 Image of AA6026-1% La_2O_3 (Side Surface)

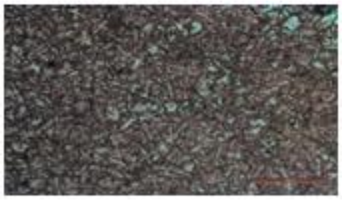

Fig.6 Image of AA6026-1% La_2O_3 (Front Surface)

Fig.7 Image of AA6026-2% La_2O_3 (Top Surface)

Fig.8 Image of AA6026-2% La_2O_3 (Side Surface)

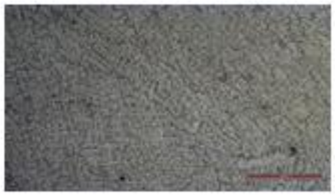

Fig.9 Image of AA6026-3% La_2O_3 (Top Surface)

Testing of Mechanical Properties

Hardness test

Vickers hardness test was conducted for all samples with using hardness testing apparatus applying 100gf of load with 10s dwell time. It was observed that the hardness value was increasing according to the increase of percentage of added reinforcement. The hardness value tend to stabilize at composite having 3% of alumina.

Table 2 Vickers Hardness Values

Trial No	Sample with 0% La_2O_3	Sample with 1% La_2O_3	Sample with 2% La_2O_3	Sample with 3%La_2O_3
1	81.4	92.6	93.3	94.2
2	82.3	91.4	92.2	93.1
3	82.7	92.7	93.2	94.1
Average in HV	82.13	92.23	92.9	93.8

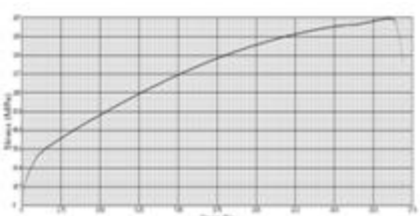

Fig.10 Tensile test stress strain graph of aa6026 - 0% la_2o_3

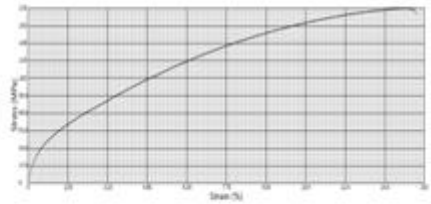

Fig.11 Tensile test stress strain graph of aa6026 - 1% La_2o_3

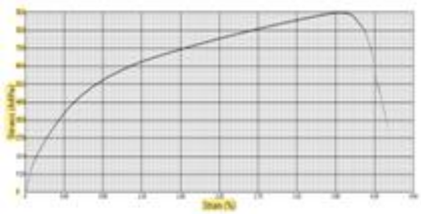

Fig.12 Tensile test stress strain graph of aa6026 - 2% la_2o_3

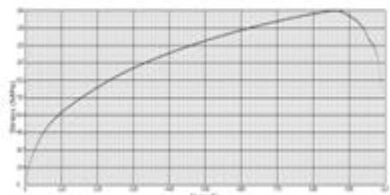

Fig.13 Tensile test stress strain graph of aa6026 - 3% la_2o_3

Tensile test

The tensile values were measured using micro tensile testing apparatus. The tensile value was observed to have a gradual increase till the specimen having 2% of alumina. The tensile he seems to decrease for sample having 3% of alumina as reinforcement. This may be due to the increase of brittleness caused by the change in the grain structure properties of the specimen having 3% alumina.

Table 3 Tensile Strength results of as cast samples

Trial No	Specimen 0% La_2O_3	Specimen 1% La_2O_3	Specimen 2% La_2O_3	Specimen 3% La_2O_3
Ultimate Stress in MPa	91.9	167	170	153

V. CONCLUSION

Dendrites were developed grain refinement occurred by the increase of the amount of reinforcement or alumina in the composite.The microstructure of the surface near to the die wall showed finer grains compared to the microstructure in the top surface .This may be due to the increased cooling rate caused by heat dissipation at side wall of the die.The hardness test shows the gradual increase of the hardness value with respect to the increase in the percentage of alumina added in the composite .The maximum hardnessvalue is 93.8 HV.The tensile test shows that the specimen with 2% alumina had maximum tensile strength of 170 MPa.The maximum density is 3.94 g/cc for composite with 3% alumina.The results show that La_2O_3 particles refined the grains of the aluminum matrix and improved the wear resistance of the composite. The study also indicate that La_2O_3 particulate improved the wear resistance of the composite and reduced the damage on the wear surface. These results show that the promising trends on utilizing this aluminum metal matrix composite in various engineering applications such as breaking system, decorative anodizing, dielectrics and photo optics.

REFERENCES

[1] Moustafa M. M. Mohammed, Omayma A. Elkady, Abdel hameed Wazeer Abdel hameed (2013), Effect of Alumina Particles Addition on Physico-Mechanical Properties of AL-Matrix CompositesOpen Journal of Metal, 2013, 3, pp 72-79.

[2] S.A. Sajjadi, H.R. Ezatpour, H. Beygi (2011) Microstructure and mechanical properties of Al–Al_2O_3 micro and nanocomposites fabricated by stir casting .Materials Science and Engineering A 528 (2011) pp 8765– 8771.

[3] ASTM E384 -17 “Standard Test Method for Micro indentation Hardness of Materials (Metric)”, ASTM International, United States.

[4] J. Allwyn Kingsly Gladson, I. Dinaharan(2017), Dry Sliding Wear Behavior of AA6061 Aluminium Alloy Composites reinforced Rice Husk Ash Particulates Produced Using Compocasting. Open Journal of Metal, 2017.

[5] Nosa Idusuyi, John I. Olayinka, “Dry Sliding Wear Characteristics of Aluminium Metal Matrix Composites: A brief Overview”, Open Journal of Metal, 2019.

[6] Bharath V, Madev Nagaral V Auradib and S. A. Kori (2014)Preparation of 6061Al- Al_2O_3 MMC’s by Stir Casting and Evaluation of Mechanical and Wear PropertiesProcedia Materials Science 6 (2014)pp 1658 – 1667.

[7] S. Senthil Murugan . V. Jegan1 . M. Velmurugan (2017)Mechanical Properties of SiC, Al_2O_3 Reinforced Aluminium 6061-T6 Hybrid Matrix Composite. The Institute of Engineers India DOI 10.1007/s40033-017-0142-3.

[8] K. Hemalatha V. S. K.Venkatachalapathy, N.Alagumurthy (2013) Processing and Synthesis of Metal Matrix Al 6063/Al_2O_3 Metal Matrix Composite by Stir Casting Process International Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 3, Issue 6, pp.1390-1394.

[9] Carlo Bruni, Daniele Ciccarelli (2020), “Characterzation, modeling and microstructure of composite aluminium alloy specimens after ECAP”, Procedia Manufacturing, Volume 50, 749-756.

[10] Chrominski W, Olejnik L, Rosochowski A (2015), “Grain refinement in technicall pure aluminium plates using incremental ECAP processing”, Mater Sci Eng A, 636,pp.172-180.

[11] Estrin , Vinogradov A (2013), “Extreme grain refinement b severe plastic deformation: A wealth of challenging science”, Acta Mater, 61, pp.782-817.

[12] V. M. Ravindranath, G. S. Shiva Shankar, N. G. Siddesh Kumar, “Dry sliding wear behavior of hybrid aluminium metal matrix composite reinforced with boron carbide and graphite particles”, Materials Today: Proceedings, Volume 4,pp 11163-11167.

[13] T. N. Baker, H. C How (1997), “Dry sliding wear behavior of saffil-reinforced AA6061 composites”,War,10, pp. 263-272.

[14] S. Basvarajappa, G. Chandramohan (2005), “Wear studies on metal matrix composites: A Taguchi approach”, Journal of Material Science Technology, 21(6), pp. 845-850.

[15] C. Brain, D. Fionn, S. Ian (2003), “ Metal and ceramic matrix composites”, IOP Publishing Ltd, UK Cornwall.

[16] A. Martin, J. rodrigues, J. Llorca (1999), “Temperature effects on the wear behavior of particulate reinforced Al-based composites”, Wear, 225, pp. 615-620.

[17] P. K. Rohatgi, Y. Liu, S. Ray (2004), “Friction and wear of metal matrix composites”, ASM Hand book, 18, pp. 801-811.

[18] DiptikantaDas, Swati Patanaaik (2017),“Dry sliding wear behaviour of SiCp reinforced Zn-Mg-Cu based aluminium matrix composite”, Materials Today Proceedings, Volume 4, Part A, pp.2965-2974.

[19] J. Rodriguez, A. Rico (2007), “Dry sliding wear behaviour of aluminium-lithium alloys reinforced with SiC particles”, Wear, Volume 262, pp.292-300.