Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

IMPROVEMENT IN TRIBOLOGICAL BEHAVIOR OF ALUMINUM 356 HYBRID METAL MATRIX COMPOSITES

M.Mariyappan[1*], P.Sarangapani[2], G. Perumal[3] and A.Sathiyamoorthi[4]
1.PG Scholar, Department of Mechanical Engineering, V.R.S College of Engineering and Technology Villupuram, Tamilnadu, India. 7418338746, mariyappa690@gmail.com.
2.Assistant Professor, Department of Mechanical Engineering, V.R.S College of Engineering and Technology Villupuram, Tamilnadu, India. 9994956549, maheshpancity@gmail.com.
3.Professor, Department of Mechanical Engineering, V.R.S College of Engineering and Technology Villupuram, Tamilnadu, India. 9976248394, perumal_harish@yahoo.com.
4.Professor, Department of Mechanical Engineering, Pondicherry Engineering College, Puducherry
***Corresponding author: Email: mariyappa690@gmail.com**

ABSTRACT

This paper deals with the fabrication and mechanical investigation of aluminum alloy, Zirconia (zro2) and silicon carbide metal matrix composites. Aluminium356 is the matrix metal having properties like light weight, more strength and ease to machine. Zirconia which has better wear resistance, high strength, hardness and silicon carbide which has excellent hardness and fracture toughness are added as reinforcements. Here, the fabrication is done by liquid state processing which involves mixing the required quantities of additives into stirred molten aluminium356 matrix. After solidification, the samples are prepared as per the ASTM standard and tested to find the various mechanical properties like tensile and hardness. The microstructure of the composite is observed using Scanning Electron Microscope (SEM).

Key words: Hybrid Metal Matrix Composites; Zro2SiC; Al356; Stir casting; Scanning Electron Microscope

INTRODUCTION

Metal Matrix Composites are most preferred among the fastest growing families of new materials and have potential properties like more strength, toughness. There is a continuous development and usage of particulate composites in the making of appliances such as engine parts, cylinder liners, etc., which are regarded as high performance components, due to their superior mechanical and tribological properties. The MMCs are attractive materials for use in structural applications because they combine favorable mechanical behaviors such as better wear resistance and lower thermal expansion Particle-reinforced metal matrix composites(PMMCs) are very promising materials for structural applications due to their isotropic material properties, and metal forming processes to yield the finished products. However, the heterogeneous material systems in various forms of composites, precipitation- hardened alloys, and dispersion-strengthened alloys are not known well their macroscopic indentation responses are affected by the mechanical properties of the matrix and reinforcement material as well as the type of form, aspect, geometric arrangements, and weight fraction of the reinforcement. Particulate-reinforced metal matrix composites have paved a new path to produce high strength and high wear-resistant materials by introducing hard ceramic particles and solid lubricant in the metal matrix. Addition of reinforcements such as SiC, B4C, Al2O3, ZrO2 and TiC, these ceramics improves hardness and thermal shock resistance of the Metal Matrix.

Aluminium alloys are mostly applicable in space and automobile industries because of their high Specific strength, modulus and high thermal conductivity. These materials display poor tribological properties that lead to seizure under adverse conditions. Hence there was a need to develop new materials with greater resistance to wear and good tribological properties which ultimately led to the development of aluminium metal matrix composites. A good number of works have been carried out on using SiCp, Al2O3 and soft graphite particles as reinforcements individually. The wear resistance and mechanical properties of MMCs increased with the increase in the content of hard ceramic particles, but the machining property was decreased. Tjong et al. studied on the addition of a low volume fraction of SiCp from 2-8 vol. % to Al- Silicon alloys. He observed that the significant increase in wear resistance with increase in content of reinforcement. Miyajima et al. investigated the different volume fraction of reinforcements such as SiC whisker of 5-29 %, Al2O3 fibers of 3-26 %, and SiC particles of 2-10 % with Al-2024 matrix materials and investigated the dry sliding wear behavior by using pin-ondisk apparatus. Improvement in wear behavior was observed with reinforcement by particles. Pramila Bai et al. observed that wear resistance improved with the addition of SiCp when compared with non-reinforced aluminium alloy.

The increase of SiCp from 15 to 25 wt. % does not change any mechanisms and only quantitative improvement was observed. Ravikiran et al. carried out the effect of sliding speed on wear behavior of A356 aluminium reinforced with 30 wt. % SiCp. The wear rate reduced continuously with increasing speed. Prasad and Asthana reported that reinforcement of aluminum alloys with graphite solid lubricants and hard ceramic particles were used in automotive applications. Deonath et al revealed that cast aluminium−mica particulatecompositesand copper-coated groundmica particles have enoughstrength andthey are used as bearingsin several applications. Jha et al reported that the addition of talc particles in the composite improves the wear resistance in the range of 22%−30% compared with the matrix alloy. Raj mohan et al found that hybrid aluminum/ceramic–mica composites showed better machinability in terms of reduced tool wear, thrust force and inflection height compared with aluminum/ceramic composites. 10% (volume fraction) SiCp/Al−Mg composites with different Mg contents were successfully fabricated by semi-solid mechanical stirring technique under optimum treating conditions.

The effect of Magnesium content on micro structural studies and mechanical properties were studied by Scanning Electron Microscopy (SEM), X-ray diffractometry (XRD) and transmission electron microscopy. It was found that the wear rate of 11% SiC MMC is higher on SiC abrasives compared with the 50% SiC MMC due to wear of the Al matrix. This tendency is retreated on diamond abrasives due to pulling-out of the irregular shaped composite particles. The tensile and yield strength increase, but the elongation decreases when increasing the weight fraction of the SiC particles there view of literature left the scope for the researcher to study the mechanical properties and wear loss of ceramic–Zirconia reinforced hybrid composites. Furthermore, sufficient investigations have not been carried out to find the mechanical properties of hybrid Al/SiC−Zirconiacomposites. In thisstudy, SiC reinforcement is added to the Al356/SiC/Zirconia composite to form stronger hybrid composites. The mechanical and wear properties of Al356/SiC/Zirconia composites are studied and presented in detail.

EXPERIMENTAL SECTION

Materials: Aluminium alloy, Al356, was used as a matrix material and its chemical composition is presented in Table1.

Table 1 Chemical composition of Al356

%	Cu	Si	Mg	Mn	Fe	Ti	Zn	Al
Elements	0.05	7.2	0.41	0.02	0.12	0.08	0.05	Bal.

The mechanical properties ofAl356 alloy is presented in Table 2.

Table 2 Mechanical properties of Al356

Density in (g·cm−3)	Ultimate tensile strength in MPa	Yield tensile strength in MPa	Elongation in %	Modulus of elasticity in GPa	Poisson ratio
2.67	234	167	3.7	72.1	0.33

The silicon carbide particles with size of 25μm and Zirconia with average size of 45μm were used as the reinforcement materials. The composites were fabricated with the Zirconia particles of 1)2.5% Sic, 2% Zr, and 2) 5% Sic, 4% Zr, 3) 7.5% Sic, 6% Zr

The composites were fabricated by stir casting method to ensure uniform distribution of the reinforcements. The Al 356 alloy, initially in the form of ingot, which was cut into small pieces then it is placed in the Teflon coated crucible, Aluminum alloy was first melted in an electric furnace. Zirconia and SiC, pre heated to a temperature of about 600°C, were added to the molten metal at 850°C and stirred continuously. The stirring was carried out at 100 r/min for 10min. Magnesium was added in a small quantity during the stirring in order to get better interfacial bonding. Then the preheated reinforcement was poured into a permanent metallic mold. Casting setup is presented in Fig.1

Fig.1 Experimental setup used for stir casting Fig 2.Tensile test work piece

Experimental procedure: A Mechanical and Micro structural study of the composites leads to following discussions. A Micro structural study is prepared using SEM. The sample size for SEM study was 10mm dia and 10mm length and then polished the samples with emery paper upto1200 grit size, followed by polishing with Alumina suspension on a grinding machine using velvet material. Micro structural specimens of the composites were prepared for SEM observation by grinding up to600grits with SiC abrasive paper and then consecutively polishing by diamond pastes of numerous dimensions. The following mechanical properties such as tensile properties of the specimen were measured by using a tensile testing machine at room temperature based on American Society for Testing Materials (ASTM) standard.Tensile test sample size was 260mm length and 20mm dia. The tensile test work pieces are shown in Fig 2.

Hardness tests were done on composites to know the effect of Zirconia particles in the matrix materials. The composite specimens were tested for their hardness In the brinell test, a hardened steel ball indenter is forced into the surface of the metal to be tested. The diameter of the hardened steel indenter is 10mm the standard loads are maintained as a constant for 10-15 seconds. Brinell hardness measurements were carried out on the base metal and composite samples by using standard Brinell hardness tester. Hardness test results are investigated in order to find out the influence of particulate weight fraction on the matrix hardness. Load applied was 500 kgf and indenter was a steel ball of 1/10 mm diameter, Five sets of readings were taken at various places of the specimen and an average value was used for analysis.

The sliding experiments were conducted at room temperature in a pin on disc wear testing machine (Wear and Friction monitor TR-201). The pins were loaded against the disc by a dead weight loading system. The pin specimen size was flat ended with 10mm diameter and 20mm length .The disc test piece was 55mm in diameter and 10mm in thickness. They slide on track diameter 20mm. The material of the disc is steel of EN31 with 65HRC.Wear test on composite specimen (AL 356+SiC & Zro2) were carried out under dry sliding condition under applied loads of 29.43N (3Kgf), for a total sliding distance 188.49m at a constant sliding speed of 0.314 m/s for all samples. During the test the relative humidity and temperature of the surrounding atmosphere was about 50% and 25°c respectively. The test duration was 10 minutes at a constant disc speed of 300 rpm for the entire test.

The vertical height (displacement) of the specimen was continuously measured using linear variable differential transformer (LVDT) of accuracy 1μm during the wear test and the height loss was taken as wear of the specimen. The photographic view of the pin on disc wear tester as shown in Fig 3.

Fig 3 Photo graphic view of pin on disc wear testing machine

RESULTS AND DISCUSSION

Tensile strength: The results obtained from the tensile tests of Zirconia reinforced composites are shown in Fig 4. From the Figure it is clear that there reinforced with 2.5%Sic, 2% Zr particle have the highest tensile strength of 164MPa. At the same time, the tensile strength of composite reduced with increased weight percentage of Zirconia reinforcement

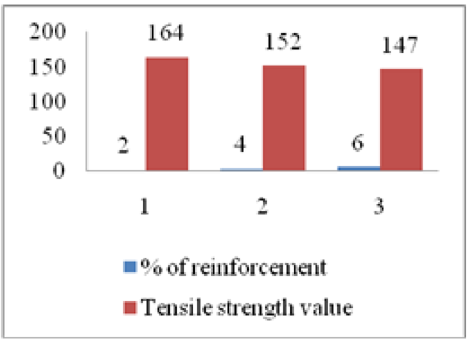

Fig.4 Tensile strength of composites with different contents of Zirconia

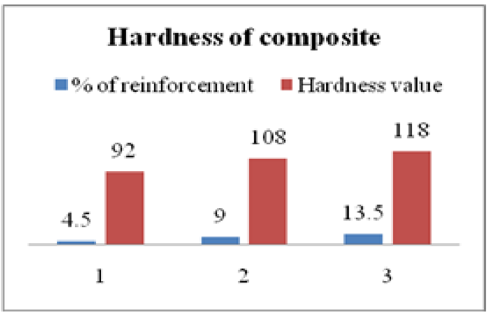

Fig.5 Hardness of composites with different contents of Zirconia

Hardness: The results of hardness of the composites reinforced with different weight fractions of Zirconia particles are shown in Fig.5 The hardness of the MMCs increases more or less linearly with the weight fraction of particulates in the alloy matrix due to the increasing ceramic phase of the matrix alloy.

Wear characteristics: The wear rate of as-cast hybrid composites was carried out on pin-on-disc technique to verify the wear resistance characteristics, wear rate of as-cast composites as a function of constant sliding distance 188.49m, at sliding speed of 0.314m/s, and applied load of 30 N. The difference in the weights of the specimen

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

between before and after the test, gives the weight loss of the specimen. All these experiments were conducted at room temperature.

Effect of Sliding Distance on Wear Rate: The wear rate increased linearly with the increase in sliding distance. This is due to improper precipitation to form good hardening characteristics in composite and alloy materials. The increase in the hardness and also increase in wear resistance.

Table 3 Test parameters for wear test

Test Parameters	Units	Values
Weight fraction of composites	%	4.5,9,13.5
Load (L)	N	29.43
Sliding Velocity	m/s	0.314
Sliding distance	m	282.74
Track radius (r)	mm	10
Temperature	°C	25°c

Effect of load and sliding distance on wear rate: The wear rate of the composite specimen increases with increasing sliding distance and load. The fig 6.graphs shows that the reinforced alloy specimen increases more rapidly with applied load compared with the composite specimen. The graph exhibit two regions which is 'running in' and 'steady state' periods. During running-in period the wear rate increased very rapidly with increasing sliding distance. During steady state period, the wear progressed at a slower rate and linearly with increasing sliding distance. The higher wear rate at the initial stage is due to the adhesive nature of the sample to the sliding disc. The results show that the particulate reinforcement SiC and Zro2 has a marked effect on the wear rate .The wear rate of the composite specimen decreases with the increasing weight percentage of particulate reinforcement.

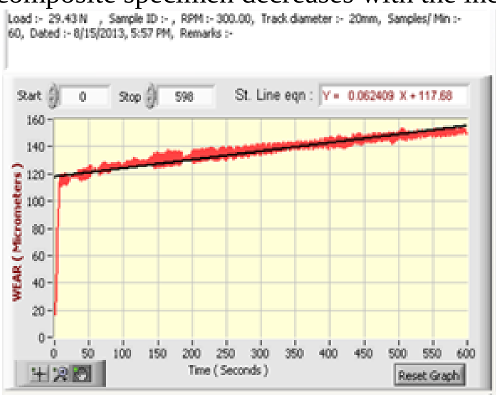

Fig.6 Wear rate graph for 4.5% of Reinforcement

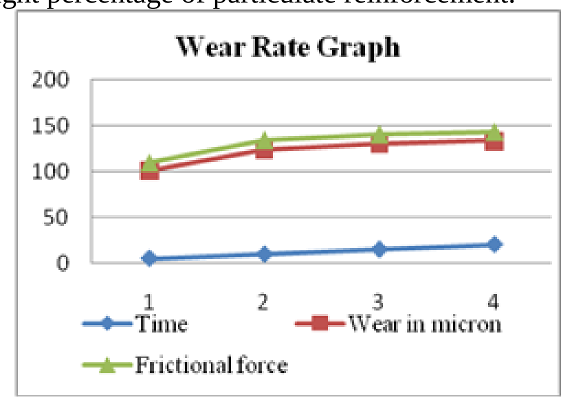

Fig.7 Wear rate graph for 4.5% of Reinforcement

The below Table 2 reveals that as the percentage of reinforcement SiC and Zro2 increases there is reduction in the percentage of weight loss of the composite material in pin on disc wear tester. The wear resistance increases with the increases in the weight percentage of the reinforcement.

Table 2 Weight loss of AL 356 composite material in pin on disc wear tester

Aluminium composite material		Specimen pin size 10mm dia and 20mm length			
Particulate reinforcement	Load applied in Kgf	Weight in grams			% in weight loss
		Before wear test	After wear test	Weight loss	
SiC = 2.5% Zro_2= 2%	3	2.520	2.450	0.070	2.85
SiC = 5% Zro_2 = 4%	3	2.670	2.625	0.045	1.71
SiC = 7. 5% Zro_2 = 6%	3	2.700	2.670	0.030	1.12

Effect of sliding time on wear rate: When the sliding time increases respectively the wear rate also increases, we have conducted the experiments with the sliding time of 15min and 10min. the wear rate for the sliding time of 15min leads to the higher wear rate than the sliding time of 10min.Fig 7 shows the wear rate of the composites.

Examination of Worn surfaces

Figures 7−8 show SEM images of wear surface of the Zirconia-reinforced composites. These micrographs show numerous long grooves and craters on worn surfaces with the increase of load to 30N at sliding speed of 0.314m/s. As the load increases, the wear behavior of the composites changes from abrasion to delamination as evident from the SEM micro graphs. The rows of furrows and delamination are the signs of plastic deformation, as seen in Figs.7-8. The wear track shows clearly the presence of oxide layer, leads to the relative motion between disc surface and pins generates frictional heat, which considerably affects the wear rate of pins

Fig 7. SEM photograph of the worn surfaces of composites with 4.5% (SiC &ZrO2)

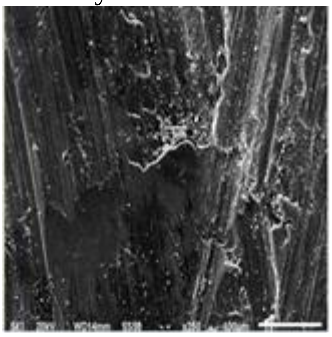

Fig 8. SEM photograph of the worn surfaces of composites with 9% (SiC &ZrO2)

The particle pull out is due to the poor particle /matrix bonding. This indicates the abrasive wear mechanism of the composite material while resisting the delaminating process. The wear resistance is more in case of composite material.

CONCLUSION

1. From the experiments, it is clear that the hardness of the composites was reviewed and finally, it is revealed that as the reinforcement contents increased in the matrix material, the composites hardness also increased. Tensile strength decreased with increased amount of reinforcement.
2. The wear rate of the composites reduced with increased weight percentages of the reinforcements.
3. The detailed SEM image analysis was done on worn out surfaces of composites for characterizing wear mechanism. The abrasive, adhesive and plastic deformation are found to be a predominant wear mechanism in sliding on steel disc and Abrasive wear and pull out of particle is a predominant wear mechanism.
4. The reinforcements of SiCp and Zirconia improve the tribological property of the material.

Acknowledgments

We are extremely thankful to manufacturing department, annamalai university Chidambaram for allowing as to the wear test and SEM tests.

REFERENCES

B.M. Viswanatha a, M.P. Kumar b, S. Basavarajappa c, T.S. Kiran "Effect of Ageing on Dry Sliding Wear Behavior of Al-MMC for Disc Brake Published on Tribology in Industry Vol. 36, No. 1 (2014) 40-48

RajmohanT, Palanikumar K. Evaluation of Mechanical and wear behavior of Aluminum Hybrid composites Transactions of Non ferrous Metal.Society of.China, 2012, 22: 1286−1298.

Leeja,Mykkanendl. Metal and polymer matrix composites [M].Park Ridge: Noyes Data Corporation.

Jung S W, Nam H W, Jung C K, Han K S. Analysis of temperature depend on thermal expansion behavior of SiCp/Al2O3f/Al composites [J].Journal of KSCM, 2003,16(1):1−12.

Matam,Alcalaj.The role of friction on sharp indentation[J].Journal of the Mechanics and Physics of Solids, 2004,52: 145−165.

Zhany,Zhangg.Graphite and SiC hybrid particles reinforced copper composite and its tribological characteristic Journal of Mater Science Letters, 2003, 22: 1087−1089.

Liangyh,Wanghy,Yangyf,Wangyy,Jiangqc. Evolution process of the synthesis of TiC in the Cu−TiC−C system Journal of Alloy of Compounds, 2008, 452: 298−303.

Matsunagat,Kimjk, Hard castles,Rohatgipk.Casting characteristics of aluminium alloy, fly ash composites [J]. Transactions of AFS, 1996, 104: 1097−1102.

Thakur SK, Kwee G T, Gupta M. Development and characterization of magnesium composites containing Nano-sized silicon carbide and carbon nano tubes as hybrid reinforcements [J]. Journal of Material Science, 2007,42: 10040−10046.

Prasadr,Asthana.Aluminum metal-matrix composites for automotive applications 'tribological considerations Tribol Letters, 2006, 17: 445–453.

Deonath,Rohatgipk.Cast aluminum alloy composites containing copper-coated ground mica particles [J]. Journal of Material Science, 1981, 16:1599−1606.

Jhaak, Dantk, Prasadsv, Rohatgipk.Aluminium alloy solid lubricant talc particle composites [J]. Journalof Material Science, 1986, 21: 3681−3685