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Optimization of Sliding Wear Characteristics of Aluminium Based Metal Matrix Composite Reinforced With Silicon Carbide Particles

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***Abstract*— Metal matrix composites (MMCs) are widely used nowadays due to its low cost and higher performance as compared to un-reinforced metals. Recently composite become an interesting field of research, especially Al-SiC composite are being use in electronics, aerospace, automobile industries. SiC have high thermal conductivity, electric field breakdown strength, surface hardness and maximum current density due to these properties its composite are widely used in electronics based industries. In the present research work, experiments were conducted to find out the wear property of Al-SiC composite synthesized using two step mixing process with the help of stir casting. The specimens were prepared by using 5%, 10% and 15% SiC by weight in aluminum matrix and test the wear property of composites by sliding wear test. The optimum set of SiC % Vs load is obtained to minimize the wear. The focus on better wet-ability and gravity segregation of reinforcement with the aluminum matrix were also carried out with the help of a constant speed stirrer. The magnesium 5% by weight is added to enhance the wet-ability of particles with the matrix phase. The results obtained in this work were compared with the published literature.**

***Index Terms* — Metal Matrix Composite, Al-SiC, dry sand abrasion.**

I. INTRODUCTION

Metal Matrix Composites (MMCs) are composed of a metallic matrix (aluminium, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase. The main advantages that MMCs possess over CMCs are the usability at high temperatures, and resistance to corrosion by organic fluids. MMCs are used in industries like automobile and aerospace. Mainly Aluminium and Copper are used as the metal matrix. MMCs are used for Space Shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs and a variety of other applications. From a material point of view, when compared to polymer matrix composites, the advantages of MMCs lie in their retention of strength and stiffness at elevated temperature, good abrasion and creep resistance properties. Most MMCs are still in the development stage or the early stages of production and are not so widely established as polymer matrix composites.

MMCs in general, consist of at least two components, the metal matrix and the reinforcement. In all cases the matrix is defined as a metal, but pure metal is rarely used; it is generally an alloy. The two most commonly used metal matrices are based on Aluminium and Titanium. Both of these metals have comparatively low specific gravities and are available in a variety of alloy forms. Although Magnesium is even lighter, its great affinity for oxygen promotes atmospheric corrosion and makes it less suitable for many applications. Beryllium is the lightest of all structural metal and has a tensile modulus higher than that of steel. However, it suffers from extreme brittleness, which is the reason for its exclusion as one of the potential matrix material. Nickel and Cobalt based super alloys have also been used as matrices, but the alloying elements in these materials tend to accentuate the oxidation of fibres at elevated temperatures.

Aluminium and its alloys have the most attention, as matrix materials for MMCs and the most common reinforcement is Sic. Aluminium (commercially pure having an assay of 99% of

Aluminium) and Sic particulates have been used for the MMC fabrication in the present investigation. Metal Matrix Composites, alternatives to conventional materials, provide the specific mechanical properties necessary for elevated as well as ambient temperature applications. The performance advantages of these materials include their tailored mechanical, physical and thermal properties in light of their low density, high specific modulus, high strength, high thermal conductivity, good fatigue response, control of thermal expansion, high abrasion and wear resistance, etc. Some of the typical applications of MMCs include their use in fabrication of satellite, missile, helicopter structures, structural support, piston, sleeves and rims, high temperature structures, drive shaft, brake rotors, connecting rods, engine block liners various types of aerospace and automotive applications etc. [5].

MMCs reinforcement can be generally divided into five major categories; continuous fibres, discontinuous fibres, whiskers, wires, and particulates (including platelets). With the exception of wires, which are metals, reinforcements are generally ceramics. Typically these ceramics are oxides, carbides and nitrides that are used because of their excellent combination of specific strengths and stiffness at both ambient as well as elevated temperatures. MMCs reinforcement can be generally divided into five major categories; continuous fibres, discontinuous fibres, whiskers, wires, and particulates (including platelets). With the exception of wires, which are metals, reinforcements are generally ceramics. Typically these ceramics are oxides, carbides and nitrides that are used because of their excellent combination of specific strengths and stiffness at both ambient as well as elevated temperatures.

However, it must be clearly understood and appreciated that though a ductile metal matrix (such as Aluminium) when impregnated by a significant volume fraction of a stiff non-metallic phase (such as silicon carbide) results in phenomena that are specific to reinforced metals, the associated issues that need to be addressed to and answered satisfactorily are the following: Interfacial bonding between the reinforcement and the matrix, Residual stresses, Matrix dislocations generated by the thermal mismatch between phases and Reinforcements and alterations in matrix precipitation kinetics.

II. ABOUT THE MATERIAL

Commercially pure Aluminium of IE–07 grades from National Aluminium Company (NALCO), Angul of Orissa was collected and used for experimental purpose. The composition analysis along with other test results such as hardness, density & tensile strength are presented in tables 1& 2.

Fig 1 Specimen for Experiments

TABLE I Compositional analysis of Aluminium

component	Weight %
Si	00.080
Fe	00.150
Ti	00.001
V	00.007
Cu	00.001
Mn	00.003
Al	99.760

TABLE II Mechanical property of Aluminium.

Property	Value
Density	02.70 gm/cc
Hardness	40.80 VHN
Tensile strength	67.00 MPa

III. EXPERIMENTAL SETUP

The machine used for the purpose of calculating wear rate is shown in the fig.2.

Fig 2 Sliding wear test machine

TABLE III Technical Data and Specification of the machine:

Pin	Diameter	006 mm
	Length	030 mm
Disk	Diameter	100 mm
	Thickness	6-8 mm
	Rotation	480 rpm
Frictional force	Make	Any load, Model 108 AA, 5 kg
	Range	0-30 N
	Least count	0.10 N
	Accuracy	(0.1±2 % Measured frictional force) in N
Wear	Sensor Spac.	LVDT,make: Syscon
	Range	±2 mm
	Least count	1 micron
	Accuracy	(1±0.25 % measured wear) micron
Wear track data	50 mm to 80 mm	
Normal load	5 N to 30 N	

IV. OPERATION PROCEDURE

A. Machine Preparation For The Test:

Connecting the power input cable to 230V, 50Hz, 5 Amps supply.

B. Clamping Wear Disk

Thoroughly clean wear disc holder, place wear disk over it and tightened the screws on opposite ends, this ensures wear disk is parallel. It required use a dial indicator with magnetic base for checking run out over wear disc.

C. Clamping Specimen:

Thoroughly clean specimen, remove bars from the circumference of using even paper. Inserting the pure aluminum, aluminum alloy, and casted composite specimen pin in to the specimen holder and set the height of the pin approximately 4 mm above the wear disc. Tighten two clamping screws on the holder to clamp the specimen pin firmly.

D. Setting Wear Track Radius:

Set required track radius (62mm) by moving the sliding plate between 50-80 mm over graduated scale on base plate. Tighten the sliding plate clamping screws and assembly is clamped firmly.

E. Setting LVDT for Test:

Switch on machine loosen LVDT lock screw, rotate thumbscrew to bring LVDT plunger visually to mid position by observing the wear digital. When wear display is within ±50 micro meters, lock the position.

F. Appling Normal Load:

Normal load is applied by placing dead weights over loading pin; a set of weight of 0.5 to 3 kg can be applied for the purpose. After completing the experiment on different samples, we calculate the weight loss of different specimens at different loading condition by a weighing machine.

G. Dry Sliding Wear:

The specific wear rate for dry sliding is given by:

$$\text{Specific wear rate} = \frac{\Delta m}{\rho l F}$$

Where, Δm = mass loss, ρ = density, l = sliding distance and

F = normal load applied.

V. RESULTS AND DISCUSSION

Sliding wear behaviour of different sample of pure Al and casted composite was studied with different parameter like applied load. Based on tabulated result, various graphs are plotted and presented in figure below for fixed percentage of reinforcement under different test conditions.

TABLE IV SPECIFIC WEAR RATE AT VARYING LOAD

S.No	Load	Specific wear rate			
		Pure Al	5% SiC	10% SiC	15% SiC
1	10	0.3990	0.1804	0.1299	0.4068
2	20	1.3917	1.2132	1.0799	1.3894
3	30	1.4634	1.3870	1.1666	1.4192

The plot of various readings of the above table is shown in Fig. 3. The plot shows that the increase in specific wear rate for composite at lower value of load is less as compared to a higher load thus showing better wear resistance at lower load this is because sliding characteristics of SiC particles at a lower load playing a significant role in reducing mass loss but at higher load values, SiC particles are eroded from the matrix more quickly and easily, thus not providing as good wear resistance as they provided at lower load

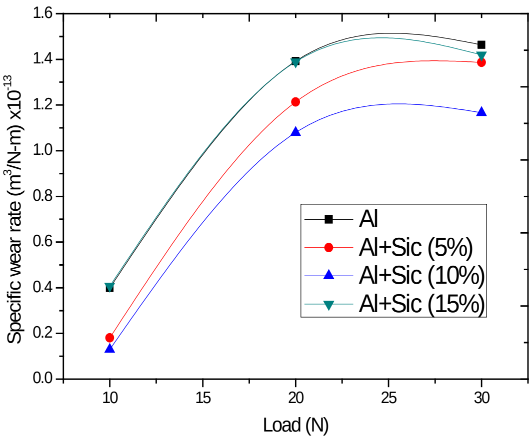

Fig. 3 Specific wear rate Vs. Load in dry sliding wear rate

This observation also sheds light on the wetting characteristic of SiC particle, as a composite with better wetting characteristic would have better wear resistance up to a higher value of load. This is due to the fact that matrix would have a better bonding with particles in good wetting condition, thus avoiding the erosion of particle at a lower load value.This observation predicts the suitability of the composite to the low loads application.

REFERENCES

[1]. B. Craig, "Limitations of Alloying to Improve the Threshold for Hydrogen Stress Cracking of Steels Hydrogen Effects on Material Behaviour," Moran, Wyoming, USA, 12-15 Sept. 1989, pp. 955-963.
[2]. S.Bandyopadhay, T.Das , and P.R.Munroe ,Metal Matrix Composites - The Light Yet Stronger Metals For Tomorrow, A Treaise On Cast materials, p-17-38.
[3]. T.W.Clyne, (2001), Metal Matrix Composites: Matrices and Processing, Encyclopedia of Materials: Science and Technology, p- 8
[4]. Composite Materials: Engineering and Design by F.L.Matthews and R.D.rawlings, Chapman & Hall publication.
[5]. Fundamentals of Metal-Matrix composites, copyright, 1993 by Bufferworth-Neinemann.
[6]. K.U. Kainer. Prasad. "Composite material Technology", Vol. 37, 1991, pp.191.
[7]. W. D. Callister, Jr., "Materials Science and Engineering", (2008), John Wiley &Sons, page 400-736.
[8]. Kamal Sethi ―Investigation of damaged glass fibre reinforced polymer composites in 3-point bending.
[9]. Mathews, F.L. and Rawlings, R.D., Composite Materials; Engineering and Science,Chapman and Hall, 1994.
[10]. Fundamentals of Metal-Matrix composites, copyright, 1993 by Bufferworth-Neinemann.
[11]. K. U. Kainer. Prasad."Composite material Technology", Vol. 37, 1991, pp.191.
[12]. Richards Demeis, "New life for Aluminium", Aerospace America, March1989, pp. 26-29.
[13]. R. Mehrabian, R.G. Riek and M. C. Flemings, "preparation and casting of Metal-Particulate Non-Metal Composites," Metal. Trans, Vol. 5A, 1974, pp 1899-1905.
[14]. M.G. McKimpson and T.E.Scott, "Processing and Properties of MMCs Containing Discontinuous Reinforcement", Mat. Sci. and Engg., Vol. 107A, 1989, pp 93-106. 16 H.J. Rack, "Metal Matrix Composites", Adv. Mater. Processes, Vol. 137 (1), 1990, pp 37-39.
[15]. M. Taya & R.J.Arsenault, "Metal Matrix Composite thermo mechanical behavior", 8Pergamon press, 1989.
[16]. R.L. Trumper, Met. Mater, Vol. 3, 1987, p p. 662.71.
[17]. J. Lock; Prof. Engg. , April 1990, Vol. (21). 168.
[18]. K. U. Kainer. Prasad."Composite material Technology", Vol. 37, 1991, pp.191.
[19]. D. H. Kim, E.J. Lavernia and J. C. Earthman, " Fatigue Crack growth behavior of a continuous alumina fibre reinforced Magnesium alloy", High performance Composites for the 1990's eds. S.K. Das, C. P. Ballard and F. Marikar, TMS-NewJersey, 1990, pp 117-126.
[20]. P.J. Meachter and J.E. Oneil, "Communication: Rapid Solidification Processing of Magnesium-Lithium Alloys", Metall. Trans., Vol. 15A, 1984, pp 237-240
[21]. J.E. Hack, R. E. Page and G.R. Leverant, "Tensile and Fatigue Behaviour of Aluminium Oxide Fibre Reinforced Magnesium Composites: part I. Fibre Fraction and Orientation", Metall. Trans., Vol. 15A, 1984, pp 1389-1396.
[22]. PradeepRohatgi, IUNIDO's State-of-the-art series: "Advances in Materials Technology: MONITOR", compiled by the Industrial Technology Development.
[23]. Division Department of Industrial Promotion, Vienna, Austria, No.17, Feb. 1990.
[24]. R. R. Irving, "Composites Go After Commercial Markets", Iron Age, Sept.5th, 1986, pp 35-38.
[25]. D.L. McDanels and C.A. Hoffman, "Microstructure and orientation effects on properties of discontinuous Silicon Carbide/ Aluminium Composites" NASA Tech. Pap. 2303, Cleveland, OH, 1984, pp 1-29.
[26]. J.L. Cook and Walter R. Mohan, "Whisker-reinforced MMCs' Metal, Carbon /Graphite and Ceramic Matrix Composites", 1987, pp 896-902.
[27]. D. L. McDanels and A. R. Signorelli, "Evaluation of low cost AluminiumComposites for Aircraft engine Structural Applications", NASA Tech. Memo. No. 83357, Washington, DC, 1983.
[28]. Alan L, Geiger and J.Andrew walker, "The processing and properties of discontinuously reinforced Aluminium Composite", JOM, August 1991, pp 8-15.
[29]. R. A. Higgins, "Properties of Engg. Materials", Holder & Stoughton, 1986.
[30]. M. Taya&R.J.Arsenault, "Metal Matrix Composite thermo mechanical behavior", Pergamon press, 1989.
[31]. "Advances in Materials Technology Monitor", Butter Worth, London, 1995, pp 68.
[32]. S.C. Tjong, S.Q. Wu, and H. Liao:"Wear behavior of an Al–12% Si alloy reinforced with a low volume fraction of SiC particles." Journal of composite science and technology, Vol–57, Issue–12, Dec 1997, pp 1551-1558.
[33]. S.C.Tjong, H.Z.Wang and S.Q.Wu "Wear Behavior of Aluminium based Metal Matrix Composites Reinforced with a Perform of Alumino silicate Fibre" Metallurgical and Materials Transactions A, Vol 27A, (1996) 2385-89.
[34]. J. Zhang, R.J. Perez, M. N. Gungor and E.J. Lavernia, "Damping Characteristics of Graphite Particulate Reinforced Aluminium Composites", Developments in Ceramics and Metal Matrix Composites.KamleshwarUpadhya, ed., Warrendale, PA: TMS Publication, 1992, pp 203-217.
[35]. T.S. Chester, "Non-metallic Materials for Gas Turbine Engines: Are They Real?" Adv. Mater. Processes, Vol. 139(6), 1991, pp 32-39.
[36]. Deonath and P.K.Rohatgi, 'Fluidity of Mica Particle Dispersed Aluminium Alloy: J. Mat. Sci., Vol. 15, 1980.pp 2777-2784.
[37]. Deonath, R.T.Bhat and P.K.Rohatgi, "Preparation of Cast ALLOY-Mica Particle Composites": J. Mater. Sci., Vol. 15, 1980, pp.1241-1251.
[38]. M.S.Zedalis, J.D.Bryant, P.S.Gilman and S.K.Das, 'High-Temperature Discontinuously Reinforced Aluminium. JOM, Vol.43 (8), 1991. pp. 29-31.