Available Online at http://www.recentscientific.com

ISSN: 0976-3031

International Journal of Recent Scientific Research
Vol. 6, Issue, 5, pp.4197-4203, May, 2015

International Journal of Recent Scientific Research

RESEARCH ARTICLE

SLIDING BEHAVIOUR OF ALUMINIUM METAL MATRIX COMPOSITE REINFORCED WITH TITANIUM OXIDE

Ganesh Khandoori[1], Dr. K.K.S Mer[2] and Chandraveer Singh[3]

[1]Faculty of Technology, Dehrdun
[2]I.T Gopeshwarchamoli
[3]G.B.P.E.C Ghurdauri Uttarakhand India

ARTICLE INFO

Article History:

Received 2nd, April, 2015
Received in revised form 10th, April, 2015
Accepted 4th, May, 2015
Published online 28th, May, 2015

Key words:

MetalMatrix composite, Aluminium and titanium oxide, Stir casting, Sliding test,

ABSTRACT

During the last two decades, metal matrix composites (MMCs) have emerged as an important class of materials for structural, wear, thermal, transportation and electrical applications. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. Aluminium Metal Matrix Composites (MMCs) sought over other conventional materials in the field of aerospace, automotive and marine applications owing to their excellent improved properties. These materials are of much interest to the researchers from few decades. These composites initially replaced Cast Iron and Bronze alloys but owing to their poor wear and seizure resistance, they were subjected to many experiments and the wear behaviour of these composites were explored to a maximum extent and were reported by number of research scholars for the past 25 years.

In the present investigation, we have chosen aluminium as a matrix phase and titanium oxide as a reinforcement phase. The aim of our project is investigate the wear behaviour of aluminium metal matrix on different amount of reinforcement. The titanium oxide, 5%, 10%, and 15% weight of aluminium was used to make three different specimen. Among all the fabrication process we choose stir casting because stir casting process are simplest and cheapest. Magnesium (4% by weight) was added in molten aluminium to improve the wettability. After fabrication; the composites have been characterized for their wear behaviour to see the suitability as a wear resistant material. Wear test was performed as a function of sliding distance, applied load, sliding velocity with the help of Pin-On-Disc wear test machine.

INTRODUCTION

In the present life metals are used for the variety of applications like automobile, aerospace, daily using utilities and for other infrastructure [Attia.A.N, 2000]. These metals have influenced the human life very much. So, there is a need of new metals or composition of metals which satisfy the requirement and characteristics. These metal mostly used in because of their high temperature applications such as in automobile engines and in other rotating and reciprocating parts such as piston, drive shafts, brake rotors and in other structural parts which require light weight but high strength material [A. Ibrahim *et al*,1991]. One of the main drawbacks of this material system is that they exhibit poor tribological properties. Hence the desire in the engineering community to develop a new material with greater wear resistance and better tribological properties, without much compromising on the strength to weight ratio led to the development of metal matrix composites [I. Sinclair *et al*,1997and A. P. Sannino and H.J. Rack1995]. The composite materials have various applications in the fields like industrial, automobile, marine and aerospace etc.

Composite can be generally defined as combination of two or more dissimilar materials having a distinct interface between them such that the properties of resulting material are superior to the individual constituting components. There are three main groups of composite material Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC), Polymer Matrix Composites (PMC) [Kaczmara *et al*, 2000].

Metal Matrix Composites are being increasingly used in aerospace and automobile industries owing to their enhanced properties such as elastic modulus, hardness, tensile strength at room and elevated temperatures, wear resistance combined with significant weight savings over unreinforced alloys [R. Dwivedi]. The commonly used metallic matrices include Al, Mg, Ti, Cu and their alloys. These alloys are preferred matrix materials for the production of MMCs. The reinforcements being used are fibres, whiskers and particulates [T. Miyajima *et al* 2003]. The advantages of particulate-reinforced composites over others are their formability with cost advantage [Mortensen *et al*]. Further, they are inherent with heat and wear resistant properties [Y.M. Pan *et al*, 1990]. For MMCs SiC, Al_2O_3 and Gr are widely used particulate reinforcements.

Corresponding author:* **Ganesh Khandoori
Faculty of Technology, Dehrdun

Compositionally, MMCs have at least two components, viz. the matrix and the reinforcement. The matrix is essentially a metal, but seldom a pure one. Except sparing cases, it is generally an alloy. The most common metal alloys in use are based on Aluminium and Titanium. Both of them are low density materials and are commercially available in a wide range of alloy compositions. Other alloys are also used for specific cases, because of their own advantages and disadvantages. Beryllium is the lightest of all structural materials and has a tensile modulus greater than that of steel, but it is extremely brittle, rendering it unsuitable for general purpose use. Magnesium is light, but is highly reactive to Oxygen. Nickel and Cobalt based super alloys have also found some use, but some of the alloying elements present in the matrices have been found to have undesirable effect(promoting oxidation) on the reinforcing fibres at high temperatures.

The reinforcements for MMCs can be broadly divided into five major categories, viz. Continuous fibres, discontinuous fibres, whiskers, wires and particulates. Except the wires being metals, the reinforcements are generally ceramic; which can be oxides, carbides and nitrides which are used because of their excellent combination of specific strengths and stiffness at both ambient and elevated temperatures. MMCs offer designers benefits as they are particularly suited for applications requiring good strength at high temperature, good structural rigidity, dimensional stability and light weight. The present day trend is towards safe usage of the MMC parts in the automobile engines, which work particularly at high temperature and pressure environments [Ranganath, *et al,* 2001]. The increase in demand for lightweight, stiff and strong materials has led to the development of MMCs reinforced with ceramic dispersoids. These MMCs possess excellent mechanical and tribological properties and are considered as potential engineering materials for various tribological applications. Several researchers have worked on sliding wear mechanism of MMCs reinforced with ceramic particulates like SiC, $Al_2O_3$and garnet particles etc. and have observed improvement in wear and abrasion resistance [Kumar *et al,* 2006]. [Rohatgi, 1993] reviewed theworld-wide upsurge in metal-matrix composite research and development activities with particular emphasis on cast metal-matrix particulate composites. [Bandyopadhyay *et al,* 2007] highlighted the development and processing of new generation metal matrix composites. [Chou *et al,* 1985] reported a review on fibrereinforced metal matrix composites. They studied the fabrication methods, mechanical properties, secondary working techniques and interfaces of those MMCs. Some researchers reported on the finite element modelling of metal matrix composites [Avila *et al,* 1998].

There are number of processing techniques which have been developed in recent years for processing metal matrix composites. According to the type of reinforcements, the fabrication techniques also vary considerably. The different techniques employed for metal matrix composites are powder metallurgy, spray deposition, liquid metal infiltration, squeeze casting, stir casting, etc. [S.M.L. Nai *et al,* 2002]. All of them have their own advantages and disadvantages. Among the various processing techniques available for particulate or discontinuous reinforced metal matrix composites, stir casting is the technique which is in use for large quantity commercial production. This technique is most suitable due to its simplicity, flexibility and ease of production for large sized components. It is also the most economical among all the available processing techniques. The principle tribological parameters that control the friction and wear performances of reinforced aluminium composite can be classified into two categories. One is mechanical & physical factors and the other arematerial factors [A.P. Sannino *et al,* 1995]. The mechanical &physical factors has been identified as sliding velocity and normal load, whereas, with regards to the material factors they are volume fraction and type of reinforcements. The volume fraction reinforcement has the strongest effect on the wear resistance and this has been studied by many researchers [M.K.Surappa *et al,* 1982]. Lot of research has been carried out to prepare MMCs by different type of reinforcements [M.Singh *et al,* 2003]. The outcome of all these findings is that wear properties are improved remarkably by introducing hard intermetallic compound in to the aluminium matrix.

The present investigation has been focused on the wear behaviour of aluminium metal matrix composite (MMCs) reinforced with different composition (5%, 10% and 15% by weight of aluminium) of titanium oxide (TiO_2) and stir casting is used to produce this composite. Dry sand abrasion test and sliding wear test was performed on these MMCs.

Material Selection For Mmcs

The structural efficiency of metal matrix composites is directly related to the density, elastic modulus and tensile strength of the reinforcing phase. The chemical and thermal stability of the reinforcements and compatibility with the matrix phase are important not only for the end application but also during material fabrication [M.G.Mc Kimpson *et al,* 1989].Concerning alloying element addition one very thing to be noted is that the added element should not form inter-metallic compounds with the matrix elements and should not form highly stable compounds with the reinforcements. To get best properties in a composite system, the reinforcement and matrix should be physically and chemically compatible.

Aluminium (Al) As A Metal Matrix

Aluminium is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. Aluminium matrix composites (AMCs) have been widely studied since the 1920s and are now used in sporting goods, electronic packaging, armours and automotive industries. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix. They are usually reinforced by Al_2O_3, SiC, C, TiO_2 but SiO_2, B, BN, B_4C may also be considered [P .K. *et al,* 1988].

In addition, literature also reveals that most of the published work has considered Aluminium-based composites with their attractions of low density, wide alloy range, heat treatment capability and processing flexibility.

Titanium Oxide (Tio_2) As A Reinforcement

The reinforcing phase is the nominal constituent of a composite. It is the principal load bearing component in the system. Hence the reinforcements with better mechanical properties than the matrix materials are chosen while designing a composite. The matrix is responsible for holding the load-carrying reinforcement together and retaining the bulk shape of the composite.

Since most ceramics are available as particles, there is a wide range of potential reinforcements for particle-reinforced composites. Alumina [M.V Ravichandran *et al,* 1992] and other oxide particles like TiO_2 [P.K.Balasubramanian *et al,* 1989]etc. have been used as the reinforcing particles in Al-matrix. Alumina has received attention as reinforcing phase as it is found to increase the hardness, tensile strength and wear resistance [M.V Ravichandran *et al,* 1992] of aluminium metal matrix composites. Rohatgi and co-workers [Deonath *et al,* 1980] have studied mica, alumina, silicon carbide, clay, zircon, and graphite as reinforcements in the production of composites. Numerous oxides, nitrides, borides and carbides were studied by [Zedalis *et al,* 1991] as reinforcements for reinforcing high temperature discontinuously reinforced aluminium (HTDRA). It has been inferred from their studies that HTDRA containing TiC TiB_2, B_4C, Al_2O_3, SiC and Si_3N_4 exhibit the highest values of specific stiffness. [Kaataih *et al,* 1988] found that the addition of TiO_2 particles has significant effect on mechanical properties of the MMCs because with increase in reinforcement content the ultimate tensile strength, yield strength and hardness of the composite increase while the ductility of the composite decreases. Increase in hardness is due to the hard TiO_2 particles acting as barriers to the movement of dislocation and contribute positively to the hardness of the composites and decrease in ductility can be attributed to the embrittlement effect of hard TiO_2 particle which causes increased local stress concentration sites. So there is a necessity of a compromise with the amount of reinforcement in the composite to enhance the mechanical properties.

Interface

It has characteristics that are not depicted by any of the component in isolation. The interface is a bounding surface or zone where a discontinuity occurs, whether physical, mechanical, chemical etc. The matrix material must "wet" the fibre. Coupling agents are frequently used to improve wettability. Well "wetted" fibres increase the interface surfaces area. To obtain desirable properties in a composite, the applied load should be effectively transferred from the matrix to the fibres via the interface. This means that the interface must be large and exhibit strong adhesion between fibres and matrix. Failure at the interface (called de-bonding) may or may not be desirable.

Wettability

The nature and characteristics of the interface region formed between the matrix and the reinforcing phase determine load transfer and crack resistance of the metal matrix composites during application. It is well known that by promoting wetting, controlling chemical reactions and minimizing oxide formation, interfacial bond strength can be increased. When the interfacial bond strength between a solid and a liquid exceeds the surface tension of the liquid, wetting is said to be achieved. Molten metals have generally very high surface tension hence, wettability is very low in molten metal ceramic systems. Wetting can be increased in these systems by promoting a decrease in the contact angle by increasing the surface energy of the solid, Decreasing the solid-liquid interfacial energy and Decreasing the surface tension of the liquid metal.

Addition of surface and interfacial active elements (e.g. Mg, Ti), Dispersion of uncoated graphite particles in a semi-solid alloy and Application of pressure during the casting procedures are the various method to improve the wettability.

Fabrication Method Of Mmcs

Metal matrix composite materials can be produced by many different techniques. The focus of the selection of suitable process engineering is the desired kind, quantity and distribution of the reinforcement components (particles and fibres),the matrix alloy and the application. By altering the manufacturing method, the processing and the finishing, as well as by the form of the reinforcement components it is possible to obtain different characteristic profiles, although the same composition and amounts of the components are involved.

Normally the liquid-phase fabrication method is more efficient than the solid phase fabrication method because solid-phase processing requires a longer time. The certain main manufacturing processes which are used presently in laboratories as well as in industries are diffusion bonding, the powder metallurgy route, liquid-metal infiltration, squeeze casting, spray co-deposition, stir casting and compo casting.

Stir Casting

Stir-casting is the simplest and most commercial method of production of MMCs. This approach involves mechanical mixing of the reinforcement particulate into a molten metal bath and transferred the mixture directly to a shaped mouldprior to complete solidification. In this process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal. Microstructure inhomogeneity can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. Inhomogeneity in reinforcement distribution in these cast composites could also bea problem as a result of interaction between suspended ceramic particles and moving solid liquid interface duringsolidification. This process has major advantage that the production costs of MMCs are very low.

Experiemental Aspects

The weighted quantities (1000gms) of pure aluminium were melted to desired superheating temperature of around 750^0 C in graphite crucible open furnace. After melting was over the required quantity of TiO_2(5% by weight) powder, preheated to around 400^0C were then added to the molten metal at a rate of about 0.5 gm/sec and stirred continuously by using mechanical stirrer. The stirring time was maintained between 6 to 8 minutes at an impeller speed of 250 rpm. To fulfil the stirring requirement we use hand running stirrer shown in fig.4.2. During stirringenhance the wettability small quantities of Magnesium (4% by weight) was added to the melt. The melt with the reinforced particulates were then poured to a prepared cylindrical sand mould. After pouring is over the melt was allowed to cool and solidify in the mould. For the purpose of comparison, the amount of TiO_2 (10% and 15% by weight) was also cast under similar processing conditions. After solidification the casting were taken out from the mould and were cut to require shape and sizes for wear testing.

Open hearth furnace with stirring arrangement

Wear Test

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

Sliding wear machine

Sliding wear test equipment shown in the fig 4.2 is built by Ducom Instruments Pvt. Ltd. established in 1979. With the help of this machine we can find out the sliding wear rate of any material. The technical data and specification of the machine is given in to the table 4.3. Technical Data and Specification

Wear Operation

The operation of wear monitor ED – 201 is made simple and user friendly by arranging controls on the front panel. The controls of operation are:

Wear - To be present to zero before start of operation.

Speed - speed of the disk is constant at 480 rpm.

Timer - to control test duration or revolution of the disk.

Composite specimen

Table 4 Technical data

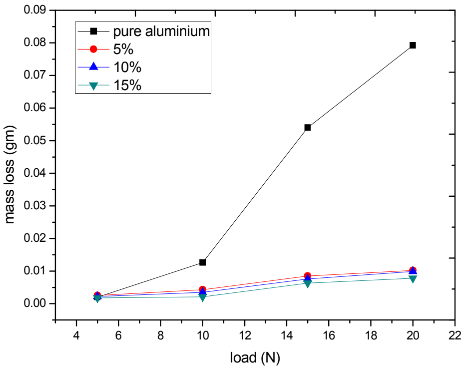
Parameter		Min	Max
Pin	Diameter	6 mm	
	Length	30 mm	
Disc	Diameter	100 mm	
	Thick	6 & 8 mm	
Wear track Data		50 mm	80 mm
Disc		480 rpm	
Normal load		5 N	30 N
Frictional force	Make	Any load, Model 108AA, 5 kg	
	Range	0-30 N	
	Least count	0.1 N	
	Accuracy	(0.1± 2% measured frictional force) in N	
Wear	Sensor Spec.	LVDT, make: Syscon	
	Range	±2 mm	
	Least count	1 micron	
	Accuracy	(1± 0.25% measured wear) micron	
Pulley ratio for speed		1:3	
Machine element specification			
Overall size		400 X 350 X 700 mm	
Base plate height from floor		415 mm	
Max height above base plate		270 mm	
Base plate size		350 X 260 X 12 mm	
Loading lever length		160 mm	
Total machine weight			
Electrical specification & power requirement			
Electricity required		230/1/50, 5 A	
Power consumption		0.2 kw	
AC motor Spec.		Make: SPG, S9190STCE, 220v, 50 Hz 0.68 A, 1350 rpm, 9W	
VF drive Spec.		230V, 0.2Kw, Make: HITACHI, Model No.: WT200.002SF	

Applying Normal Load

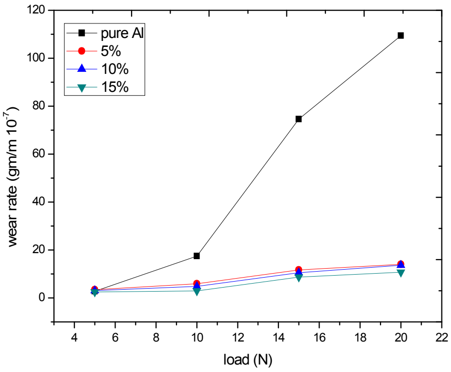
Normal load is applied by placing dead weights over loading pin; a set of weight of 0.5 to 3 kg can be applied for the purpose. Here we applying load from 500gms, 1000gm, 1500gm, and 2000gm for different specimen of pure aluminiumand the casted composite. After completing the experiment on different samples, we calculate the weight loss of different specimens at different loading condition by a weighing machine.

CALCULATION

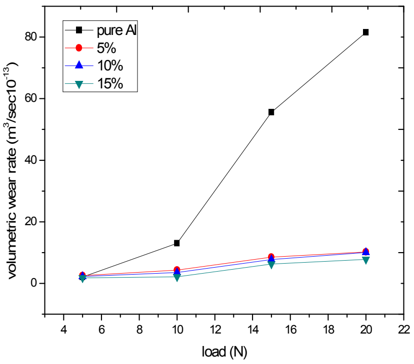
Wear rate was estimated by measuring the mass loss in the specimen after each test and mass loss, Δm in the specimen was obtained. Cares have been taken after each test to avoid



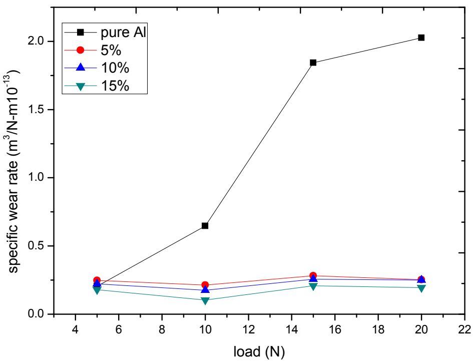
Mass loss vs. load in dry sliding wear test



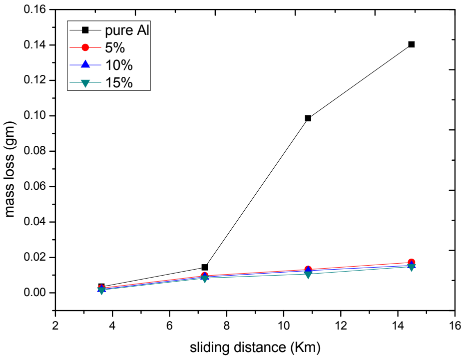
Wear rate vs. load in dry sliding wear test



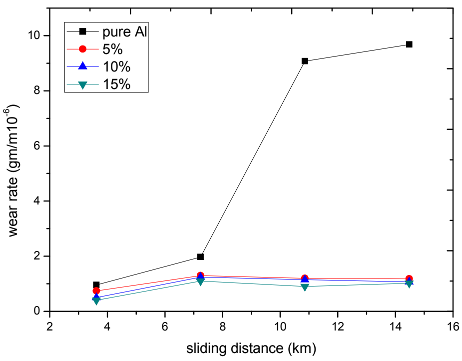
Volumetric wear rate vs. load in dry sliding wear test



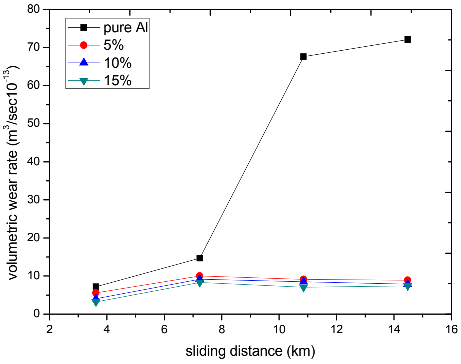
Specific wear vs. load in dry sliding wear test



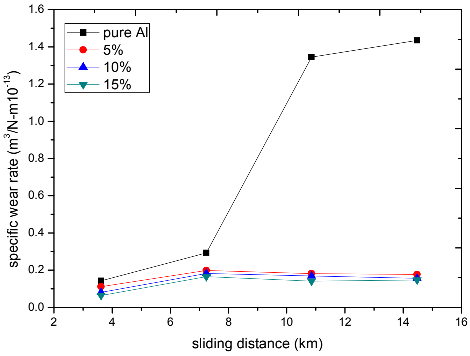
Mass loss vs. sliding distance in dry sliding wear test



Wear rate vs. sliding distance in dry sliding wear test



Volumetric wear rate vs. sliding distance in dry sliding wear test



Specific wear rate vs. sliding distance in dry sliding wear test entrapment of wear debris in the specimen. Wear rate which relates to the mass loss to sliding distance (L) was calculated using the expression,

$W_r = \Delta m/L$

The volumetric wear rate W_v of the composite is relate to density (ρ) and the abrading time (t), was calculated using the expression,

$W_v = \Delta m / \rho.t$

For characterization of the abrasive wear behaviour of the composite, the specific wear rate is employed. This is defined as the volume loss of the composite per unit sliding distance and per unit applied normal load. Often the inverse of specific wear rate expresses in terms of the volumetric wear rate as

$W_s = W_v / V_s F_n$

Where V_s is the sliding velocity

Calculated results of the wear test of different test pieces (Pure Al, and three different casted composite) at different test conditions are tabulated and presented in table;

The theoretical density of composite materials in terms of weight fraction can easily be obtained as for the following equations given by Agarwal and Broutman;

$$\rho_c = \frac{1}{\frac{W_f}{\rho_f} + \frac{W_m}{\rho_m} + \frac{W_p}{\rho_p}}$$

RESULT AND DISCUSSION

Curve between mass loss and load during dry sliding wear test plotted under different condition of varying load and fixed sliding velocity, for the specimen of pure aluminium, aluminium metal matrix composite having reinforcement of weight percentage of aluminium as 5%, 10% and 15%. it is clear from the graph that mass loss of three specimen increase as the load value increases but with different rate. It can be clearly seen that as the TiO_2 composition increases themass loss decreases i.e. more mass loss has occurred for the sample of pure aluminium. This indicates that mass loss of the composite decrease with increase in the percentage of TiO_2.The relationship between wear rate and applied load at constant sliding velocity 2.0106 m/sec.It is seen that at lower load the wear rate is low in case of composite then it increases slowly. The rate of wear in case of pure aluminium sample is extremely high in comparison to composite. The relationship with volumetric wear rate and applied load at constant sliding velocity (2.0106 m/sec). The volumetric wear has low value for the specimen having higher weight percentage of TiO_2. The above figure shows the relationship between the specific wear and normal load applied. The specific wear rate of composite at some point increased due to the porosity. The wear rate of cast in situ composites containing relatively higher reinforcing particle, increases slightly with increasing volume fraction of porosity possibly due to relatively smaller effect on porosity.

The relationship between mass loss and sliding distance at constant load (25N) and constant sliding velocity (2.0106 m/sec). Mass loss increase as the sliding distance increased. The curve of mass loss (in gram) for all the three specimens shows an increasing trend with an increase in sliding distance (in kilometre). Thus, as the sliding distance or sliding time for a sample increases the material erodes easily. It is obvious from the fact that sliding wear occurs when the material is repetitively being subjected to a constant erosive force for a period of time and the wear would be easier if the sliding continues for a longer time (or we can say, for higher values of sliding distance).The relation between sliding distance and wear rate of the composites at a constant load of 25 N. The above figure clearly shows that change of wear rate initially high and after a certain sliding distance the change of wear rate almost becomes constant. Like variation of wear rate with load in the in the present case also increase in dispersed phase reduces the wear rate.

The specific wear rate vary with sliding distance as same as volumetric wear rate. Initially there is rapidly increased in wear rate with sliding distance and after certain sliding distance the wear rate is almost constant.

CONCLUSION

1. The wear resistance has improved significantly by addition of titanium oxide. The effect of increased reinforcement on the wearbehaviour of the metal matrix composites is to increase the wear resistance and to decrease the wear rate.
2. Addition of Mg improves the wettability in aluminium melt and thus increases the amount of reinforcing phase in the composite.
3. The wear rate decreases with increase in the percentage of TiO_2 in the aluminium matrix i.e. wear resistance of the composite increases with increase in TiO_2 content.
4. As the sliding distance increases, the specific wear rate of the composite also increases but at higher distance values, it tends to become constant.
5. The wear properties of the composite depend on many factors, such as sliding or abrading velocity, sliding or abrading distance and applied load.
6. 6.The cumulative volume loss and wear rate in composite decreases considerably compared to those observed either in purealuminium, particularly at higher normal loads.

References

Attia.A.N “New phase reinforcement for composite materials”,2000.

Ibrahim, F.A. Mohamed, E.J. Lavernia, Metal matrix composites- a review, *Journal of material science*, 26 (1991) 1137–1157.

I. Sinclair, P.J. Gregson, Structural performance of discontinuous metal matrix composites, Material science technology, 3 (1997) 709–725.

A. P. Sannino, H.J. Rack, Dry sliding wear of discontinuously reinforced aluminiumcomposites: review and discussion, Wear 189 (1995) 1– 19.

Kaczmara .J. W, Pietrzakb. K, Woosinski. W “The production and application of metal matrix composite materials" *Journal of Materials Processing Technology*, pp.106, 2000.

R. Dwivedi, "Performance of MMC Rotors in Dynamometer Testing", SAE Technical Paper Series, 940848, Warrendale, PA, USA.

T. Miyajima, Y. Iwai; "Effects of reinforcements on sliding wear behaviour of aluminium matrix composites", Wear 255 (2003) 606–616.

Mortensen A, Wong T. Metall Trans A; Vol 21 A: pp 2257–63.

Y.M. Pan, M.E. Fine, H.S. Chang, "Wear mechanism of aluminium based meal matrix composite under rolling and sliding contraction in technology of composite materials", P.K. Rothagi, P.J.B. Ian, C.S. Yune (Eds.), ASM International, 1990, pp. 93–101.

Ranganath, G., Sharma, S.C. and Krishna, M., (2001). Dry sliding wear of garnet reinforced zinc/aluminium metal matrix composites, Wear 251, 1408–1413

Kumar, M. P., Sadashivappa, K., Prabhukumar, G. P. and Basavarajappa, S.(2006). Dry Sliding Wear Behaviour of Garnet Particles Reinforced Zinc-Aluminium Alloy Metal Matrix Composites, ISSN 1392–1320, materials science, Vol. 12, No. 3.

Rohatgi, P. K., (1993). Metal - matrix Composites, *Defence Science Journal*, Vol. 43, No 4, 323-349.

Bandyopadhyay, N. R., Ghosh, S. and Basumallick, A., (2007). New Generation Metal Matrix Composites, Materials and Manufacturing Processes, 22: 679–682.

Chou, T.W., Kelly, A. and Okura, A.(1985). Fibre - reinforce metal-matrix composites, COMPOSITES. VOLUME16. NO 3, 187-206.

Avila, A. F. and Tamma, K.K.(1998) Analysis of Laminate Metal Matrix.

S.M.L. Nai, M. Gupta, Influence of stirring speed on the synthesis of al/sic based gradient materials, Compos. struct.57 (2002) 227–233.

A.P. Sannino, H.J.Rack, "Dry sliding wear of discontinuously reinforced aluminium composite: review and discussion", Wear, Vol.189, 1995, pp 1-19.

M.K.Surappa, S.V.Prasad, P.K.Rohatgi, "Wear and abrasion of cast Al-alumina particle composites", Wear Vol. 77, 1982, pp 295-302.

M.Singh, D.P.Mondal *et al*. "Development of light-weight aluminium alloy hard particle composite using natural minerals for wear resistance application. National conventions on Emerging materials on wear applications. paper no TS- 4/5, 2003, Bhopal.

M.G. McKimpson and T.E.Scott, "Processing and Properties of MMCs ContainingDiscontinuous Reinforcement", Mat. Sci. and Engg., Vol. 107A, 1989, pp 93-106.

P .K. GHOSH and S .RAY, *Indian J. Technol*.26(2) (1988) 83.

M.V Ravichandran. R.Krishna Prasad and E.S.Dwarakadasa, *J. Mater. Sci. Letts;* Vol-11, 1992, p.452.

P.K.Balasubramanian, P.SrinivasaRao, *et al.J.Mater.Sci.Letts*., Vol-8, 1989, p.799.

Deonath and P.K.Rohatgi, 'Fluidity of Mica Particle Dispersed Aluminum Alloy: *J. Mat. Sci*., Vol.15, 1980.pp 2777-2784.

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

Kataiah, G. S., (2010). The mechanical properties and fractography of aluminium 6061-TiO2 composites, *International journal of pharmaceutical studies and research*, vol-1, 17-25

How to cite this article:

Ganesh Khandoori *et al.,* Sliding Behaviour Of Aluminium Metal Matrix Composite Reinforced With Titanium Oxide. *International Journal of Recent Scientific Research Vol. 6, Issue, 5, pp.4197-4203, May, 2015*

****