Dry sliding and sand Abrasion Wear Characterization of Al-SiC, in-situ Particulate Composite Synthesized in Open Hearth Furnace with Manually Controlled Stirring Method

[1]Neetu Saini, [2]Vivek Kumar Sharma
Assistant Professor
Mechanical Engineering Department., Quantum University India, Roorkee, Uttarakhand India,

---

Abstract - Metal matrix composite (MMCs) are next generation materials. MMCs add higher strength and stiffness than the matrix alloy or aluminium, excellent wear resistance and lower coefficient of thermal expansion (CTE). One of the important objectives of metal matrix composites is to develop a material with a judicious combination of toughness and stiffness. It decreases the sensitivity to cracks and flaws and at the same time increases the static and dynamic properties. Reinforcement effect occurs due to the extraordinary high strength of whiskers with diameters below a few micrometers. In general, Metal matrix composites consist of at least two components. One is the metal matrix and the second is reinforcement. Particle- Reinforced Metal Matrix Composites (PMMCs) are a special category of practically isotropic composites, which have either hard or soft particles, or their mixtures embedded in to a ductile metal or alloy matrix. Therefore, PMMCs combine metallic properties (ductility and toughness) with the characteristics of reinforcing particles, often leading to the greater strength higher wear resistance and better properties at elevated temperature depending of the nature if the particles. Particulate metal matrix composites (PMMCs) have proved their viability as good alternatives to conventional alloys in high strength and stiffness applications but they are still long away from high-volume commercial production. PMMCs are a special category of virtually isotropic composites. In the present work cast particulate composites, with different weight percentages of Silicon carbide (2.5%, 5%, 7.5% and 10%) and Magnesium was added to the melt in order to help wetting of silicon carbide in to the molten Aluminium and to retain the particles inside the melt. The present work aims to understand the wear properties of the resulting cast Insitu composites. In the present work the pure Aluminium matrix composite reinforced with silicon carbide particles have been synthesized in the open hearth furnace with the hand stirring method. Stir casting method was used with two step mixing method. The present work also investigates the dry sliding and abrasion wear properties of the resulting cast in-situ composites. The present work shows the effect of the reinforcement on the dry sliding and abrasion wear properties of pure aluminium and casted composites. The present work also compares the dry sliding and abrasion wear properties of pure Aluminium, and the casted composites.

Index terms: PMMCs, Al matrix composite, in-situ, dry sliding wear, abrasion wear, SiC, two step mixing method.

I. INTRODUCTION:

Aluminium matrix composite material systems offer superior combination of properties in such a manner that today no existing monolithic materials can arrival. Aluminium based metal matrix materials have a combination of different, superior properties to an unreinforced matrix which are; increased strength, higher elastic modulus, higher service temperature, improved wear resistance, low coefficient of thermal expansion and high vacuum environmental resistance. Rohatgi et al. [1] have noted that, in a variety of wear conditions, the particulate reinforced composites perform better than the fibre-reinforced composites [2]. Now a day's researchers all over the world are focusing mainly on aluminium because of its unique combination of good corrosion resistance, durability, machinability, high strength, low density and excellent mechanical properties. And cost is very attractive compared to competing materials. The unique thermal properties of aluminium composites such as metallic conductivity with coefficient of expansion that can be tailored down to zero, add to their prospects in aerospace.

The matrix phase for a MMC is a metal often which is ductile. MMCs are manufactured with aims to have high strength to weight ratio, high resistance to abrasion and corrosion, resistance to creep, very good dimensional stability, and high temperature operability [3]. Wear is the progressive loss of material from the operating surface of a solid occurring as a result of relative motion between two surfaces [4]. In Adhesive wear is caused between two metallic components which are sliding against each other under an applied load and in an environment where no abrasives are present. The name "adhesive" is given due to the forming of a strong metallic bond between the asperities in the surface of the contacting materials. Wear rates are high for high load application on the surface. This kind of wear is generally seen in sliding components in a valve, conveyor belts, fasteners, etc. In abrasive wear there is ploughing of localized surface contacts by a softer mated material [5]. Abrasive wear can be caused by both metallic and non-metallic particles but mostly non-metallic particles cause abrasion. If the particle is harder than the material then serious scratching or abrasion can occur. Abrasive Wear can be further subdivided into three types namely high stress, low stress and gouging. High stress abrasion is caused due to high stress which results in more work hardening. Few examples are abrasion caused due to by rolling-contact bearings, gears, pivots and cams. In low stress abrasion there is light rubbing activity of the abrasive particles with the metal surface which causes scratches and there is no work hardening. Gouging abrasion also results due to high stress that forms grooves or gouges on the affected surface. Some examples where this can occur are impact hammers in pulverisers, parts of crusher liners, etc. Factors that can affect the resistance from abrasion are hardness, microstructure and for steel carbon content is also a factor.

Wear causes an enormous annual expenditure by industry and consumers. Most of this is replacing or repairing equipment that has worn to the extent that it no longer performs a useful function. And For many machine components this occurs after a very small percentage of the total volume has been worn away. For some industries such as agriculture, as many as 40% of the components replaced in equipment, fail by abrasive wear. Other major sources of expenditure are losses in production consequential upon lower efficiency and plant shutdown, the need to invest more frequently in capital equipment and increased energy consumption as equipment wears. Estimates of direct cost of wear to industrial nations vary from 1 to 4 % of gross national product and Rigney [5] has estimated that about 10% of all energy generated by man is dissipated in various friction processes.

Wear is not an intrinsic material property but characteristics of the engineering system which depend on load, speed, temperature, hardness, presence of foreign material and the environmental condition [6].Widely varied wearing conditions causes wear of materials. It may be due to surface damage or removal of material from one or both of two solid surfaces in a sliding, rolling or impact motion relative to one another. In most cases wear occurs through surface interactions at asperities [7]. During relative motion, material on contacting surface may be removed from a surface, may result in the transfer to the mating surface, or may break loose as a wear particle [8].

II. MATERIALS AND METHODS OF FABRICATION

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

Table 1: Compositional analysis of aluminium

S.No.	Si	Fe	Ti	V	Cu	Mn	Al
1	0.08	0.15	0.001	0.007	0.001	0.003	99.76

Table 2: Density, Hardness & Tensile Strength of Aluminium

Density	2.7 gm/cc
Hardness	40.8 VHN
Tensile strength	67 MPa

The weighted quantities (1000 gms) of pure aluminium were melted to desired superheating temperature of around 750^0 C in graphite crucible open furnace. Than molten metal are cools at room temperature between its liquidus and solidus temperature. After cooling or semi- solid state mixed the required quantity of Silicon carbide particles, preheated to around 400^0 C were then added to the molten metal at a rate of about 0.5 gm/sec and stirred continuously by using manual 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.1. During stirring to enhance the wettability small quantities of Magnesium (4%) was added to the melt [9]. Then mixed slurry again melted at desired temperature. This is called two step mixing method in stir casting. 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 matrix material, and the other composite with different compositions of Silicon carbide particles cast under similar processing conditions. After solidification the casting were taken out from the mould and were cut to require shape and sizes for Dry sliding wear and Abrasion wear testing.

Fig. 1: Stir casting setup

III. DRY SLIDING WEAR TEST

Fig 2: Sliding wear machine

Sliding wear test equipment shown in the fig 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 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. Thoroughly clean specimen, remove bars from the circumference of using even paper. Inserting the pure aluminium 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. And now set required track radius (80mm) by moving the sliding plate between 50-80 mm over graduated scale on base plate. Tighten three sliding plate clamping screws and assembly is clamped firmly. switch on machine loosen LVDT lock screw, rotate thumbscrew to bring LVDT plunger visually to mid position by observing the wear digital. Test specimens are made of dimensions with 6 mm diameter cylindrical pin with 30 mm length (fig 3).

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 applied load from 500 grams, 1000 grams, 1500 grams and 2000 grams for different specimen of the casted composite. After completing the experiment on different samples, we calculated the weight loss of different specimens at different loading condition by a weighing machine.

After completing all experiments at varying load parameter we again prepared for the next experiments, in that we vary the time (or we can say that the sliding distance) from 30 to 120 minutes for one sample on different composite materials. After that the time is increased from 30 to 120 minutes with an interval of 30 minutes for different samples.

Fig 3: Composite specimen

IV. DRY SAND ABRASION TEST

The wear resistance of a material cannot be predicted reliably from simple properties such as bulk hardness, elastic modulus or tensile strength. There is therefore a need for a reliable and convenient approach to the study of abrasive wear properties.

Fig 4: Dry sand tester

A number of standard methods have been developed with the aim of producing test data that will reproducibly rank materials under a specified set of conditions. The most widely used are the sand/rubber wheel test in dry (ASTM G 65). These define tests under dry conditions with specified loads, wheel speeds and sand feed rate. In all cases the abrasive used is rounded quartz grain sand. Fig 4 shows a dry sand tester on which the abrasion tests were conducted.

The dry sand /rubber wheel abrasion test involves the abrading of a standard specimen with a grit of controlled size and composition. The abrasive is introduced between test specimen and a rotating wheel with a chlorobutyl rubber tyre of specified hardness. The test specimen is pressed against a rotating wheel at a specified force by means of a lever arm while a controlled flow of grit abrades the test surface. The rotation of wheel is such that the contact surface moves in the direction of sand flow. The pivot axis of lever arm lies in a plane which is approximately tangent to the rubber wheel surface, the normal to the horizontal diameter along which the load is applied. The test duration and force applied by the lever arm is varied. Specimens are weighed before and after test and the loss in mass is recorded. It is necessary to convert the mass loss to volume loss in cubic millimetres, due to wide difference in material density. Abrasion is reported as volume loss.

Typical specimen is rectangular shape 25 X 76 mm between 3.2 X 12.7 mm thicknesses. The size may be varied according to users need with the restriction that the length and width be sufficient to show the full length of scar as developed by the test. Fig 5 shows an abrasion tested specimen of casted composite.

The specimen should be smooth, flat and free of scale. Surface defects like porosity and roughness may bias test results, typical suitable surface are mill-rolled surfaces such as are present on cold rolled steel, electroplated and similar deposits, ground surfaces or finely machined surface. The specimens supplied along with machine have ground surface finish of approximately 0.8 micron Ra value.

Fig 5: Tested Specimen of Casted Composite

V. RESULTS AND DISCUSSION

Dry Sliding wear behaviour of different sample of the casted composite and aluminium was studied with different parameter like sliding distance, weight loss and applied loads. It is clear from the study that the dry sliding wear of different samples is increased with increasing the load applied. Volumetric wear rate and specific wear rate also increase with load applied and sometimes specific rate decrease because of load factor in varying load condition. In case of varying sliding distance condition, wear rate also increase with increase in sliding distance. Volumetric wear rate also as increase sliding distance and specific wear rate also increase but sometimes the reason behind of decreasing the specific wear rate is the unequal distribution of reinforcement in matrix.

Dry sand wear behaviour of different sample of pure Al, and the casted composite was studied with different parameter like rotating rubber wheel speed, and the load applied. It is clearly understood from the study that the dry sand abrasion wear of the different samples is increased with increasing the wheel rotation (RPM). If we compare the dry sand abrasion of different samples; we found that the wear rate of casted composite is less as compare to the others material (pure Al). This is due to some factors which are;

- The in-situ alumina particles generated inside the casted composite from the reaction of molten aluminium and the Silicon carbide.
- The alumina particles are hard which increase the hardness and the Tribological properties of the composite.
- Good wettability.
- Processing temperature.
- Stirring time.
- Amount of Mg in to the molten Al.

CONCLUSIONS

In the present study, cast In situ Pure aluminium and silicon carbide (800 mesh size) composite have been synthesized by stirring SiC particles in to molten aluminium. In stirring casting method used two step mixing method, in which first melt the aluminium in the graphite crucible and then it cools at room temperature between solidus and liquidus temperature. During process the silicon carbide particles mixed into it. Thereafter it is again melt to the desired temperature and then solidify. The stirring of the casted composite has been done by hand running stirring method at a speed of around 250 to 300 RPM. The other composite of Al- SIC also fabricated at the same processing parameters with different percentage of SiC.

The following conclusions have been drawn from the experimental work:

- SiC up to 10% by weight can be successfully added to molten aluminium at a rate of 0.5 gm/s. The stirring time is kept between 5 to 10 minutes. The slurry obtained by this method can be poured in to the sand mould or metallic permanent mould.
- There is appreciable reaction between the silicon carbide and the melted Al, producing Insitu finer particles of complex oxides.
- Strengthening of composites is due to particle reinforcement, dispersion strengthening and solid solution strengthening.
- Resistance to wear has increased with increased in SiC particles.
- Wear of complete specimen decreases with increase in SiC particles. As load is increased, increased in wear is observed. As reinforcement is increased, less material loss is observed.
- Addition of Mg improves the wettability of silicon carbide with aluminium melt and thus increases the amount of reinforcing phase in the composite.
- The metal matrix composites shows better wear resistance due to its superior load bearing capacity.
- Increase in normal load and sliding velocity increases the magnitude of wear.
- Different wear readings were observed at different normal loads, sliding velocities, sliding distance and operation time.
- Use of the two step mixing method, make composite with less defects.
- The wear rate, weight loss, VWR, and SWR were observed and found that the casted composite with more reinforcement by weight give appropriate results as compare to the less added percentage of reinforcement particles.

REFERENCES

[1]. Pradeep Rohatgi, IUNIDO's State-of-the-art series Advances in Materials Technology MONITOR Compiled by the Industrial Technology Development Division Department of Industrial Promotion, Vienna, Austria, No.17, Feb. 1990.
[2]. W. D. Callister, Jr., "Materials Science and Engineering", (2008), *John Wiley & Sons*, page400-736.
[3]. D. G. Teer and R. D. Arnell, Wear, Principles of Tribology, *J. Halling, Ed., Macmilan*. (1975).
[4]. ASM Handbook, „Friction, Lubrication, and Wear Technology, U.S.A. 18 (1992) 713.
[5]. D.A.Rigney, "Fundamentals of Friction and wear of materials", *American Society for Metals*, Metal park, Ohio.
[6]. [M.F.Ashby and S.C.Lim, 'Wear-mechanism maps', *Scripta Metallurgical et Materialia*, Vol.24, 1990, pp. 805-810.
[7]. Y. Wang, T.C. lei and C.Q. Gao, 'Influence of isothermal hardening on the sliding wear behaviour of 52100 bearing steel', *Tribology International*, 1990, Vol. 23(1), pp. 47-53.
[8]. S.D. Ridder, S.Kou and R.Mehrabian, "Effect of Fluid Flow on Macrosegation in Axi-Symmetric Ingots," *Metall. Trans.*, Vol. 12B, Sept.1981, pp 435-447.