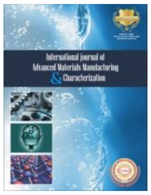

Advanced Materials
Manufacturing & Characterization

journal home page: www.ijammc-griet.com

Abrasion Wear Characterization of Al-Al_2O_3 in-situ Particulate Composite Synthesized in Open Hearth Furnace with Manually Controlled Stirring Method

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ARTICLE INFO

Received 24 Dec 2012
Accepted 26 Dec 2012

Keywords:

Pmmcs,
Al Matrix Composite,
In-Situ,
Abrasion Wear,
Mno_2.

ABSTRACT

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. PMMCs contain different variety of the particles either hard or soft or their mixtures in a ductile metal or alloy matrix. Therefore, PMMCs combine metallic properties (ductility and toughness) with the characteristics of reinforcement particles, often leading to greater strength, higher wear resistance and better properties at elevated temperature depending on the nature of particles. In the recent past researchers are concentrating on the easy low cost techniques for the synthesis of PMMCs, like stir casting.In the present work cast particle reinforced composites containing in-situ generated reinforcement Alumina particles have been synthesized by solidification of slurry obtain by dispersion of externally added Manganese Dioxide (MnO_2) particles in the molten aluminium. Alumina particles have been generated by the reaction of the Manganese Dioxide with molten Aluminium. The chemical reaction also releases Manganese in to molten Aluminium which increases the strength of the matrix. Magnesium is added to the melt in order to help wetting of alumina particles in molten Aluminium and to retain the particles inside the melt. The present work also investigates the abrasion wear properties of the resulting cast in-situ composites. In the present work the Aluminium alloy (Al + 5% Mg) matrix composite reinforced with Alumina particles have been synthesized in the open hearth furnace with the hand stirring method. The present work shows the effect of the reinforcement on the abrasion wear properties of casted alloy and casted composites. The present work also compares the abrasion wear properties of pure Aluminium, the casted alloy and the casted composites.

Introduction

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.

Axen et al. [1] have noted that, in a variety of wear conditions, the particulate reinforced composites perform better than the fibre-reinforced composites. Now a day's researchers all over the world are focusing mainly on aluminium [2] because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. 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, good dimensional stability, and high temperature operability [3]. In abrasive wear there is ploughingof localized surface contacts by a softer mated material

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- Doi: http://dx.doi.org/10.11127/ijammc.2013.02.041

[4]. 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 scratchesand 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. 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 equipments, 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. 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. The wear resistance of materials is related to its microstructure may take place during the wear process and hence, it seems that in wear research emphasis is placed on microstructure [7].

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 (1260 gms) 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 MnO_2 (5%) powder, 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 (5%) was added to the melt [8]. 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 Aluminium alloy 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 Abrasion wear testing.

Fig. 1 Stir casting setup

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 2 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 2 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 3 shows a 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 3 Tested Specimen of Casted Composite

Results and Discussion:

Dry sand wear behaviour of different sample of pure Al, casted Al-Mg Alloy, and the casted composite was studied with different parameter like rotating rubber wheel speed, and the load applied. There result and discussion are given in the following subsections;

Fig 4 shows the graph between the Wear rate of different samples and the rotational speed of the rubber wheel. Fig 5 shows the graph between the Wear rate and load of different samples.

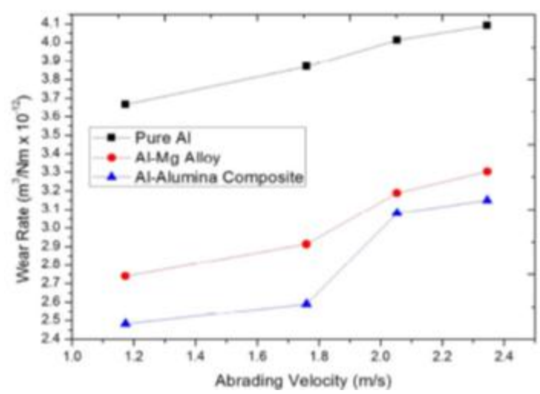

Fig 4: Wear rate Vs Abrading Velocity

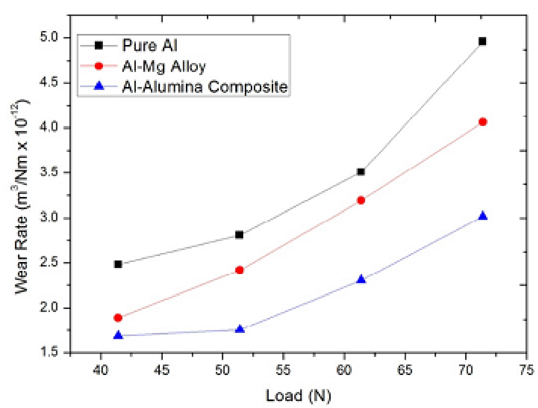

Fig 5 : wear rate Vs load

It is clearly understood from the graph 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 two materials (pure Al and casted alloy). This is due to some factors which are;

- The in-situ alumina particles generated inside the casted composite from thereaction of molten aluminium and the manganese dioxide.
- The alumina particles are hard which increase the hardness and the Tribological properties of the composite.
- Good wettability.
- Processing temperature.
- Stirring time.
- Amount of reacted MnO2 with the molten metal.
- Amount of Mg in to the molten Al.

Conclusions

In the present study, cast in-situ Al (Mg, Mn) - Al_2O_3 (MnO_2) composite have been synthesized by stirring MnO_2 particles in to molten aluminium alloy. The stirring of the casted composite has been done by hand running stirring method at a speed of around 250 to 300 RPM. An Al- Mg (5%) alloy also fabricated at the same processing parameters.

The following conclusions may be drawn from the project work:

- MnO_2 up to 5% 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 8 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 manganese dioxide and the molten Al, producing in-situ finer particles of complex oxides.
- The oxide particles and the unreacted particles of manganese give sufficient improvement in strength and hardness of the composite. The releases manganese also reacts with the melt and forms $MnAl_6$ which is hard and brittle.
- Strengthening of composites is due to particle reinforcement, dispersion strengthening and solid solution strengthening.
- Addition of Mg improves the wettability of manganese dioxide with aluminium melt and thus increases the amount of reinforcing phase in the composite.
- The abrasion wear resistance has improved significantly by addition of manganese dioxide.
- The metal matrix composites shows better abrasion wears resistance due to its superior load bearing capacity.
- Increase in normal load and rubber wheel velocity increases the magnitude of wear.
- Different wear readings were observed at different loads, abrading velocities.

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