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Full Length Article

Effect of flyash particles with aluminium melt on the wear of aluminium metal matrix composites

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ABSTRACT

The present work deals with the fabrication and tribological testing of an aluminium flyash composite. The metal matrix selected was aluminium and flyash contents in different percentages were reinforced in it to fabricate the required metal matrix composite (MMC). Stir casting method was used to fabricate the MMC with 2–4–6% weight of flyash contents in aluminium. Tribological analysis of the tribo pairs formed between the smooth surfaces of cast iron disc and smooth MMC pin has been considered and friction force and wear of the MMC were investigated by using a Pin-on-disc setup. It was observed that the MMC with 6% weight of flyash content in aluminium matrix results in less wear (0.32 g) and 4% weight of flyash content gives the low coefficient of friction (0.12) between the tribopairs of cast iron surface and MMC surface.

1. Introduction

The metal alloys and composite materials have a vast application in the automobile, aircraft and allied industries. Reinforcement used in the metal matrix affects the strength and durability of the material in comparison to their constituent parent materials. Present scenario directly links the mechanical field and its research with the automobile and aircraft industries. It is the need of the society to decrease the rate of consumption of the fossil fuel (exhaustible) Mazaheri and Shabani [7], Shabani et al. [12]. In order to achieve it, the efficiency of the automobile needs to be improved. This can be done by reducing the total weight of the automobile whose major components are the engine and the frame. Aluminium in its alloy form is currently being used for the manufacturing of various engine parts. The limitation of aluminium is that it is prone to scratches and indentations very easily. So, a need arises to fabricate an aluminium-based composite which will be wear resistant in nature by the addition of suitable reinforcements in defined proportion. Aluminium matrix composites have excellent ability to bear tensile as well as compressive forces Shabani and Mazahery [13]. Research has been going on by attempting different reinforcement materials into the aluminium matrix to improve and enhance the properties of the composite. For the fabrication of the composites, casting, powder metallurgy, friction stir processing, ball milling and hot rolling and vacuum hot pressing are some of the techniques which are used by researchers. However casting process is largely used because of its low cost and high production rate Faraji et al. [4], Baghani et al. [3], Shabani et al. [14], but formation of clusters and agglomeration of reinforced particles in the base metal is one of the main problems of casting process Mazahery and Shabani [7]. Recently Shamsipour et al. [17] proposed a semi-solid-metal (SSM) processing for the fabrication of the composites. Widespread research has been done to study the wear behavior of the aluminium MMCs as it provides better wear resistance as compared to the alloy.

Boron carbide Mazahery and Shabani [8], Al_2O_3, TiC, SiC, are the most used reinforcement material for MMCs. Recently non-metallic components like rock dust particles, rice husk ash (RHA), few-layer graphene (FLG) are used as reinforcement and these all resulted in improvement in mechanical properties of the composites.

TiC nanoparticles were reinforced into the matrix of Al-Si alloy by Shamsipour et al. [17], Shamsipour et al. [16]. The addition of TiC particles enhances the hardness of the aluminium alloy and hence decreases the wear rate. Mazahery and Shabani [9] and Shabani et al. [14] used the TiB_2 coated B_4C particulates in Al-Si matrix and tested it against a hardened steel disc on a pin on disc machine. It was reported by authors that as the volume fraction of the coated B_4C increases wear rate decreases. Some iron parti-

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cles from the hardened steel disc were also got transfer to the composite. In another research by Shamsipour et al. [17] optimum combination of the different inputs of the compocasting was found out and used for the fabrication of the Aluminium metal composites using TiC particles as reinforcement. Rahimipour et al. [11] used the technique of artificial neural network algorithm to predict that Al-20% B_4C provides better wear resistance as compared to other percentages of the B_4C reinforcement.

The size of the reinforcement particles also affects the tribological properties of the composites. Tofigh and Shabani [21] investigated the effect of the different size of B_4C particles on the aluminium composite. It was reported that large B_4C particles showed better wear resistance during the abrasive wear. Also, the surface roughness of Al-B_4C composite material decreases with increase in particle size of B_4C in an aluminium matrix. Similarly, Al_2O_3 in different volume percentages were reinforcement in the aluminium matrix by Shabani and Mazahery [13], Shabani et al. [15]. The Al_2O_3 helps in reducing the wear rate, however the friction coefficient increases with the addition of Al_2O_3 in the matrix of the aluminium. Steel machining chips of the order of 105 μm were reinforced in different wt.% in the copper matrix by Alaneme and Odoni [1]. In was reported that the hardness, strength along with wear resistance of the copper improved with the addition of steel chips. Kumar et al. [5] developed an Al5052/ZrB_2 composite with different percentage of (0, 3, 6, 9 and 10 vol%) ZrB_2 particles by reaction of molten AA5052 with using two inorganic salts K_2ZrF_6 and KBF_4. It was reported that with the increase in the percentages of the reinforcement the hardness and density of the composite also get increased. The strength of the formed composite also got improved with increasing the amount of ZrB_2 till 9% of ZrB_2 and then it started decreasing.

Sharma et al. [18] focuses on the production of aluminium (Al6082-T6) matrix composites reinforced with various weight percentages of silicon nitride particles by conventional stir casting route. The percentage of reinforcement is varied from 0 wt% to 12 wt% in a stage of 3 wt%. The ductility of the aluminium composite decreases with the increase in silicon nitride, however, hardness and ultimate strength increases.

In the recent time, the focus of the researchers has been on the use of non-metallic particulates. Prakash et al. [10] used the technique of powder metallurgy for the fabrication of composite of Aluminium 6061 T6 with rock dust particles. The excess of rock dust particles decreases the hardness of the aluminium composite but the low amount of in the range of 10% helps in improving the wear resistance of the composite. A combination of ball milling and the hot rolling process was adopted by Shin and Bae [20] to produce a composite of aluminium alloy 2024 Al2024) with few-layer graphene FLG). Microstructure and mechanical properties were tested by the authors for the developed composite. At 7% vol of FLG the aluminium showed improved tensile strength properties. Sharma et al. [19] focus on the effect of graphite particles on the microstructure of Al6082 metal matrix composites. Authors used conventional casting Stir) process for the production of the composite material. The addition of graphite as reinforcement in the aluminium matrix is not desired as it decreases the hardness of the composite. Almost same findings were reported by Alaneme and Sanusi [2] for the hardness of the aluminium-graphite-rice husk ash (RHA) composite. However, strength and toughness of the 0.5% graphite and up to 50% RHA got increased. Authors also reported that with graphite component the composites resulted in greater susceptibility to wear however as it is increased from 0.5 to 1.5% the wear resistance decreases. Based on the previous research articles it could be concluded that metallic as well non-metallic reinforcement is being used to fabricate the aluminium matrix composites. The amount of reinforcement is generally very low for non-metallic reinforcement. So as a non-metallic reinforcement in the form of flyash was selected as the reinforcement into the aluminium matrix. Flyash is produced as a by-product from the burning of pulverized coal in power generation plants. It is harmful to humans if inhaled through the air. So by looking at harmful effects and to reduce the flyash contents from the atmosphere, it was decided to use flyash in a positive way to enhance the mechanical properties of the aluminium composites. In this paper, the influence of flyash contents on the aluminium matrix was studied and a potential composite material is proposed for various mechanical applications like engines and bearings.

2. Experimentation

MMC was manufactured with the help of a stir casting process. Stir-casting is the process of melting the material with continuous stirring and immediately pouring the melt into a preformed cavity, then cooling it and allowing it to solidify. In stir-casting, the particles often tend to form agglomerates, which can be only dissolved by vigorous stirring at high temperature. The stir casting set up (Fig. 1) consists of a furnace, crucible and a rotor attached to the motor. The aluminium metal was melted in the crucible which was heated to a temperature of about 900 °C, while the reinforcement material (flyash) was added externally in a fixed proportion of 2–4–6% weight. Aluminium and flyash were mixed with the help of a specially designed stirrer, at a rotational speed of 100 rpm with the aid of the rotor for uniform mixing. The stirrer used had a length of 95 cm and exactly plus sign blade having zigzag angle 90° of each side. The length of every side of stirrer blade was 9 cm each.

The molten mixture of aluminium with flyash was poured in the predefined cavity of required dimensions. After subsequent cooling and secondary machining processes, different specimens were made for testing of wear and coefficient of friction. The percentages of different elements of the composite were analyzed and represented in Table 1.

A pin on disc setup (Fig. 2) was used to measure the wear and frictional force. For the pin-on-disc wear test, two specimens are required. One, a cylindrical pin which is positioned perpendicular to the flat circular counter disc. In this work, the disc rotates at some rotational speed and pin specimen was pressed against the disc at a specified load by means of a lever with attached weights. The amount of wear is determined by weighing pin specimens before and after the test.

A cast iron specimen of 165 mm diameter and 8 mm thickness was used as a counter disc. Surface grinding and lapping processes were used on the disc to make it smooth. The surface roughness value achieved on disc specimen was 0.2 μm Ra.

Aluminium flyash composite material was used as pin specimen of 30 mm length and 10 mm diameter. The bottom surface of the

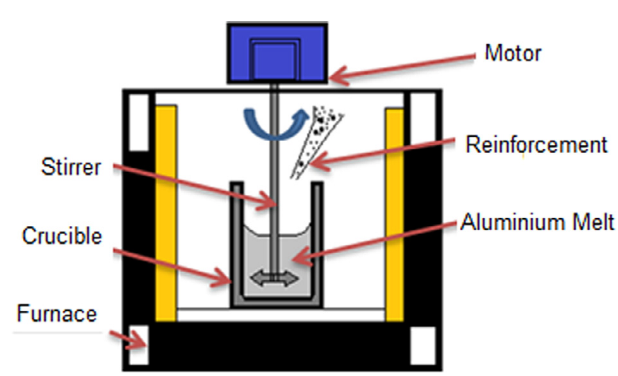

Fig. 1. Stir Casting setup representation.