Study on Tribological Characteristics of Self-lubricating AA2218-Fly ash-White graphite Composites

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***Abstract* -** In the present scenario composite materials are extensively used for structural applications in automobile and aerospace industries. Composite material exhibits a high strength to weight ratio, improved hardness, reduced weight and low coefficient of friction. Because of their enhanced tribological properties helps to achieve low manufacturing cost and superior performance. The present research is primarily focused on the development of self-lubricating hybrid metal matrix composites. Self-lubricating composite materials gives better results where it is very difficult to maintain lubrication effect consistently. An attempt has been made to explore the possibility of using white graphite for synthesizing AA2218 based self lubricating composite through metal stir casting route. In this study 4 wt. % of white graphite (hBN) used as a first phase reinforcement and as in the case of second phase reinforcement, 5 wt. %, 10 wt. %, 15 wt. % of fly ash particles were added into the matrix melt by creating the vortex with the help of mechanical stirrer. The self-lubricating composite characterized in terms of density, dry sliding wear, coefficient of friction and micro structural properties.

KEYWORDS: AA2218, Fly ash, hBN, MMC, Stir casting process, Pin-on-disc.

I. INTRODUCTION

In the recent years there has been an emerging trend to use solid lubricants over a wide range of applications. The self-lubricating composites are suitable for application requires improved hardness, wear resistance and low coefficient of friction with lower density. These properties enhance the usage of self-lubricating composites in automotive and tribological applications. In the field of automobile and tribo industry [1], hybrid self-lubricating composites are extensively used for cylinder liner, piston, valve stem guide, and plain bearings. Self-lubricating composites have found wide application in many special machine parts; yet oil or grease cannot lubricate inaccessible parts and contamination is not acceptable. On the other hand, limited information is available about the characterization of this AA2218-fly ash-hBN composite [2].

Lot more methods are available to fabricate metal matrix composite. But wettability and the dispersion of reinforcement particles with the matrix alloy is the main problems. Many methods have been proposed to overcome this situation. Like, blending, consolidations, vapour deposition, stir casting, pressure infiltration technique, and spray deposition method. However, stir casting is the simplest and most economical method [3]. It has been suggested to develop composite materials have the capacity to achieve low friction and wear at the contact interface without any external supply of lubrication during the sliding [4].

The boron nitride (hBN) gets non-wetting property, as a result of non-wetting it is very difficult to achieve better interfacial bonding strength. The previous reports suggest that, addition of magnesium improves the wettability of composite and it was observed from SEM micrographs [5].

This paper clarifies the influence of a fly ash weight percent and hBN on dry sliding wear condition. Furthermore, the formation of a tribochemical layer at the interface was investigated through SEM micrographs.

II. EXPERIMENTAL DETAILS

A. *Materials*

1) *Aluminium*

AA2218 aluminium alloy (Fig. 1) is a very useful material and over the years its range of application has widened immensely. It was selected as the base material as it possesses good formability, machinability, and corrosion resistance, with high mechanical strength after heat treatment compared to other grades of aluminium alloys. AA2218 alloy is a heat treatable wrought alloy. Its nominal chemical composition is shown in Table 1.

TABLE 1: CHEMICAL COMPOSITION OF AA2218 ALLOY IN WEIGHT PERCENTAGE

Cu	Ni	Mg	Si	Fe	Ti	Al
3.87	1.90	1.47	0.51	0.16	0.02	Balance

Fig. 1 AA2218 aluminium alloy

Fig. 2 Fly ash

Fig. 3 Hexagonal Boron Nitride

2) *Fly ash*

Fly ash (Fig. 2) is one of the residues generated in combustion, and comprises the fine particles that go up with the flue gases. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gas reaches the chimney of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata [6]. Its nominal chemical composition is shown in Table 2.

TABLE 2: CHEMICAL COMPOSITION OF FLY ASH IN WEIGHT PERCENTAGE

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	LOI*
64.80	24.01	5.23	2.76	0.90	0.50	0.87-1.33

** Loss on Ignition*

3) *Hexagonal Boron Nitride*

Boron nitride (Fig. 3) is often referred to as “white graphite”, has similar (hexagonal) crystal structure as graphite. This hexagonal crystal structure provides excellent lubricating properties [7].

In this present study, white graphite and three different weight percent of fly ash were incorporated in the AA2218 based self-lubricating composite synthesized by metal stir casting route in order to get the low wear rate and coefficient of friction over a wide range of loading conditions.

TABLE 3: MECHANICAL AND THERMAL PROPERTIES OF WHITE GRAPHITE (hBN)

Density (g cm^{-3})	Bulk modulus (GPa)	Poisson's ratio	Coefficient of thermal expansion at 300K	Melting temperature (K)
2.1	36.5	0.05	$1.2x10^{-6}$	2973

B. Composite Preparation

The self lubricating AA2218-based composites with 4 wt. % of hBN-5, 10, 15 wt. % of fly ash were fabricated by metal stir casting (Fig. 4) method. Table 4 gives the compositions of the liquid metallurgy samples. An electrical melting furnace with stirring assembly was used for the continuous dispersion of preheated reinforcement particles into liquid aluminium alloy. hBN and fly ash was preheated at 400°C for one hour to increase the surface reaction. The heat treated particles were then added into the melt through the vortex, which was formed by continuous stirring. The speed of the stirrer has maintained at 300-400 rpm and continued about 10 minutes to get properly mixing and low porosity [8]. Non-wetting behavior of hBN cause low interfacial bonding with matrix alloy. To overcome this effect 0.5 wt. % of magnesium also incorporated with hBN into the matrix alloy. Solidified specimens (Fig. 5) were machined with the specification of 10mm diameter and 30mm in length for wear test.

Fig. 4 Electrical Furnace

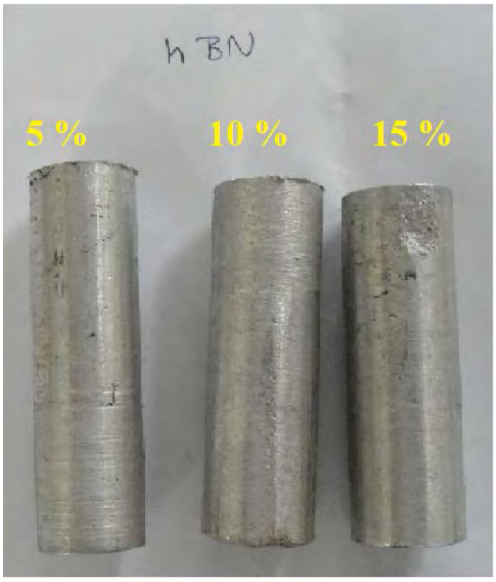

Fig. 5 Wear test specimens

TABLE 4: TO CARRY OUT THE STUDY, THREE DIFFERENT COMBINATIONS ARE

Specimen-1	AA2218-4% hBN-5% fly ash
Specimen-2	AA2218-4% hBN-10% fly ash
Specimen-3	AA2218-4% hBN-15% fly ash

III. RESULTS AND DISCUSSION

A. Density

The density of composites has been calculated by the "Rule of mixture". The Fig. 6 shows the effect of fly ash wt. % with density of self-lubricating composites. Because of low density, a large agglomerate of fly ash particles in the composite consistently reduces the density of the composite.

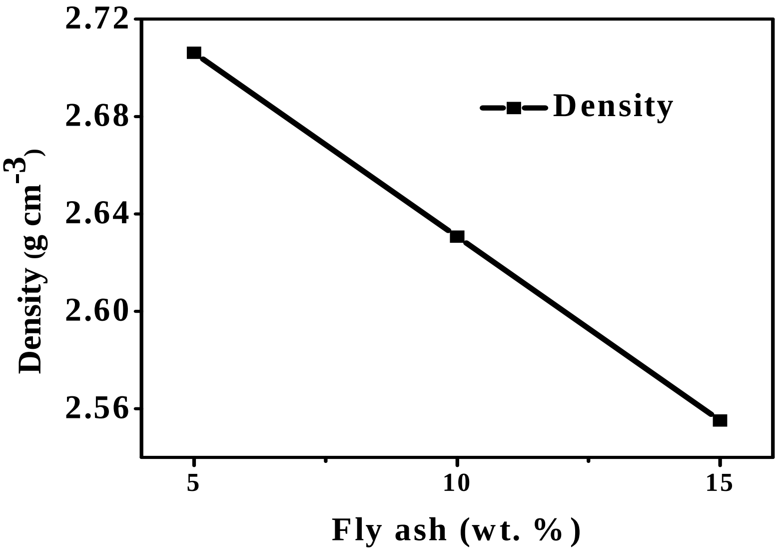

Fig. 6 Density versus weight percent of fly ash

B. Effect of Reinforcement on Wear and Friction Properties

To study the dry sliding wear behavior of the self-lubricating composite, a pin-on-disc apparatus used was manufactured by DUCOM friction Wear Monitor, Bangalore, India. Metallurgically polished and cleaned test specimens were loaded against the disc with a dead weight [9]. The disc is fabricated by 0.95-1.20% Carbon (EN31) hardened steel disc with hardness of 62 HRC having diameter 165mm. Prior to the test, the surface of the test specimens and the disc was cleaned with acetone.

A single pan digital balance with 0.001g of precision was used to measure the volume loss of the specimen before and after the wear test. Wear rate is calculated by the ratio between volume loss (mm^3) and sliding distance (m). A ratio between tangential forces (FT) and the normal force (FN) is known as the coefficient of friction (μ).

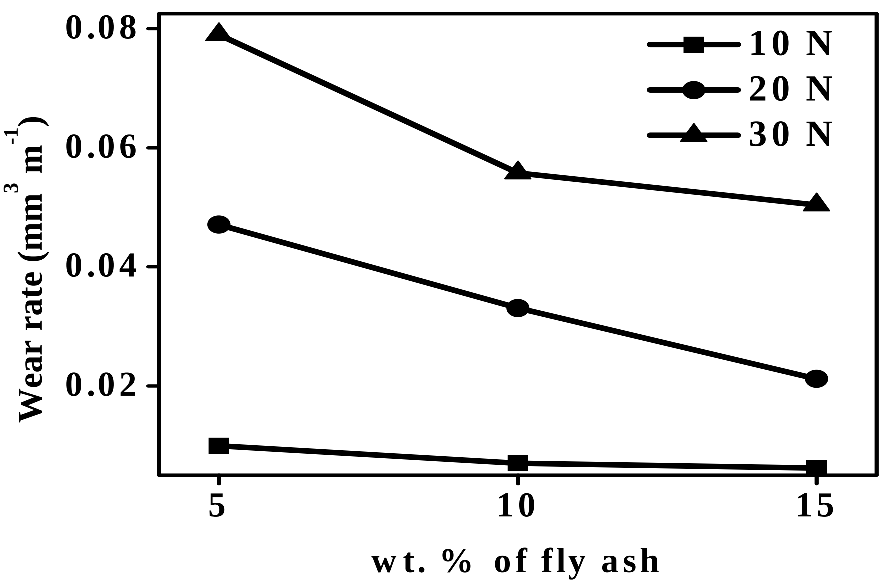

Fig. 7 Wear rate versus weight percent of fly ash

Fig. 7 shows the variation of wear rate is the function of adding fly ash into the matrix alloy and applied load. It can be seen that as the weight percentage of fly ash increases with decreases the wear rate of self lubricating composites, indicating that spherical shaped hard fly ash particles provides better load bearing capacity and also protects the matrix alloy effectively during dry sliding wear. At the same time accumulation of hBN in to the matrix could reduce the wear by providing the transition layer at sliding interface.

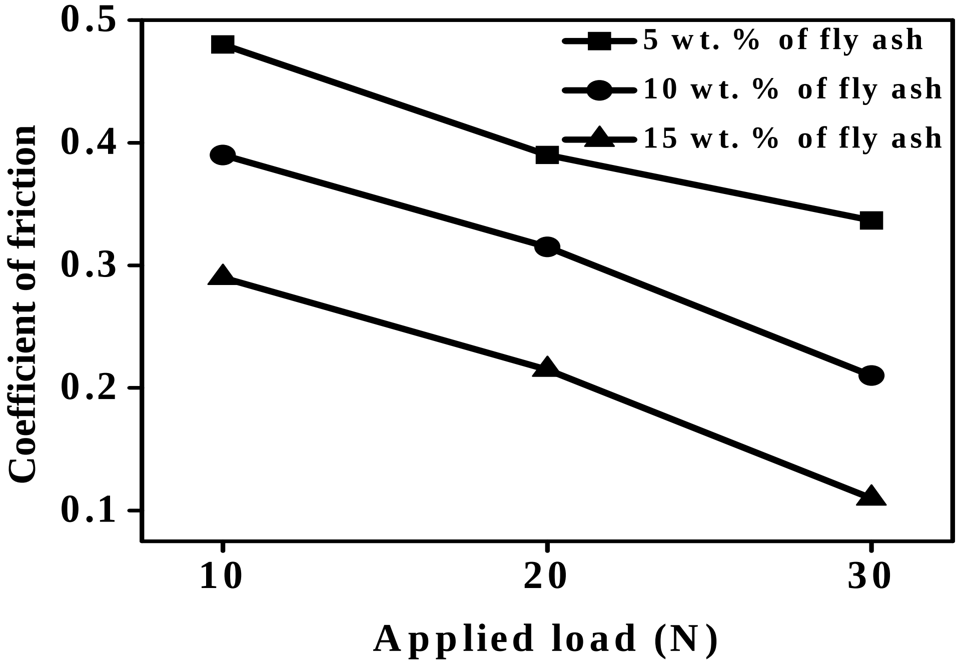

Fig. 8 Coefficient of friction versus applied load in Newton

Fig. 8 illustrates the effect of load on the friction coefficient. Friction coefficient reduces with increase in applied load. Moreover, the effect of applied load on friction coefficient was inverse nature when compared with its effect on wear rate.

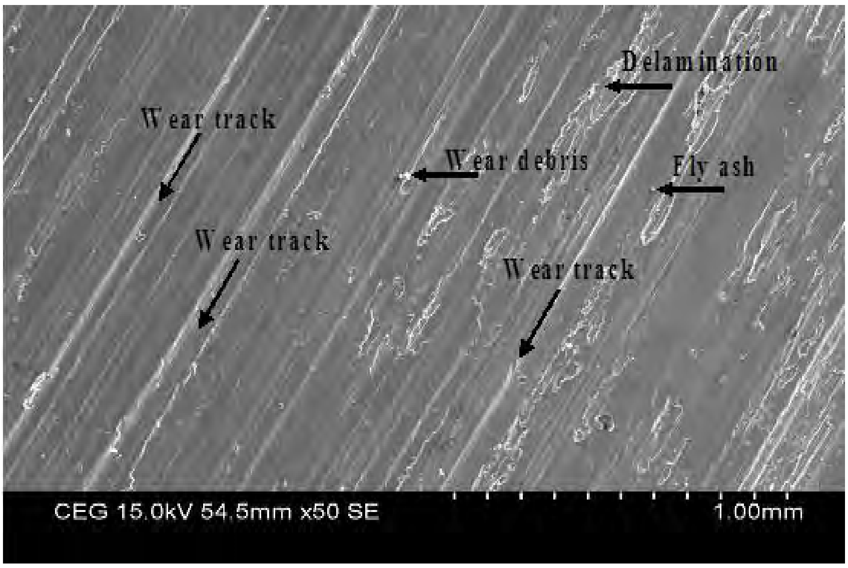

Fig. 9 worn surface morphology of self-lubricating composite after wear test

The results correlated well with the observations from SEM image (Fig. 9), which suggested that the hBN tribochemical layer was present on the worn surface, providing some lubrication and wear resistance. In the same way the formation of the tribochemical layer at the sliding interface reduces the friction coefficient significantly by increasing the applied load.

IV. CONCLUSIONS

The present investigation, AA2218- Fly ash- hBN self-lubricating composite was produced by liquid metal stir casting technique and the tribological characteristics were studied. The following observations can be drawn:

1. Dispersion of low density fly ash particles significantly reduces the density of self-lubricating composite.
2. Accumulation of both fly ash and hBN particles into the matrix improves the wear resistance of aluminium composite.
3. The wear resistance of the hybrid composite containing 15 wt. % fly ash and 4 wt. % hBN is marginally higher to that of the other hybrid composites.
4. Even at higher load 4 wt. % of hBN exhibits better lubricity and the formation of hBN sacrificial layer at the interface was rich in worn surface, which was examined through SEM micrographs. It played an important role in reducing the friction coefficient and wear rate.

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