Characterization and Performance Analysis of Graphite and Molybdenum disulphide based Hybrid Composite Materials

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Abstract. An attempt has been performed to observe the influence of heat treatment on composite specimen by dry sliding wear and hardness testing. The particulate reinforcements embedded with AA2218 Aluminium metallic element alloy with 4% constant weight proportion of Graphite, MoS₂, with a variable amount of hard reinforcement particulates. Availability of fly ash is abounded and it has to be utilized in any other way. Instead of carbides and nitrides, introducing fly ash as reinforcement satisfies the structural and thermal properties. 5%, 10% & 15% of fly ash added to the composite by liquid scientific discipline route. To get better mechanical properties of composite specimens are treated with ASTM T6 standard. Performance of heat-treated hybrid composite was investigated with a pin on disc with a constant load 2 kg sliding at 300 rpm. Hardness of the specimen at temperature was conjointly measured before and once the heat treatment is completed. The results were compared with base alloy and untreated composite specimens. Heat treated metal exhibits high hardness and wear resistance. This investigation reveals that AA2218 Aluminium matrix composites with high hardness and wear resistance will replace the traditional material employed in automobile elements to get improved performance and longer life.

Keywords- AA2218 Aluminium alloy, Graphite, MoS₂ & Heat treatment

1. Introduction

The world is trying to find the utmost doable optimisation in each field in recent times. With no exception in engineering, engineers are trying to find making the acute best from the most effective¹. Throughout these developments, in direct or opposite, the surroundings are affected. The composites strengthen with biodegradable material has been one in all the foremost modernizations within the field of material development in the past few decades. Metallic element alloys embedded with ash particles exhibit greater mechanical properties to reinforced metallic element and therefore hybrid materials are the possible way to achieve desired properties. Particle-reinforced Metal Matrix Composites (MMCs) containing set on AA2218 have agreeable attention within the past few decades due to their improvised wear resistance, improved hardness, dimensional stability, and enhanced strength compared to unreinforced metallic element alloys². Though they found a potential application in automobile and aerospace the applying base of those particulate MMCs is admissible by their low cost.

In recent times, inexpensive metallic element alloy MMCs strengthened with ash particles. Ash is the devastate consequence of coal combustion, has been built to act a substitute for typical particulate MMCs in many applications to broaden the applying basis of this category of MMCs. The addition of ash into metallic element MMCs could be an added initiative that lowers the disposal
value of ash, will increase energy savings by dropping the number of metallic elements made, and creates healthier surroundings. Fly ash could be a used as reinforcement which might be found profusely as solid waste derivative throughout coal incineration in power plants. It’s additionally terribly cheap. It’s being employed in forged and shaped metallic element alloys to create aluminium–alloy–fly ash (ALFA) composites. Hence, ash bolstered composites area unit a lot of probably to beat the value barrier for wide unfold applications. The stirring arrangement improves the distribution and wettability of composites\(^3\). Mechanical behaviour of Al-fly ash composites is investigated. Once the investigation of ash composites it’s been discerned that this material is appropriate for automobile. The general objective of this study is to develop and characterize the fabricated one distinctive from the normal metal or similar varieties of metal alloy. Once finishing the experimental work, it was ensured that the composites have a tendency to found increased in physical properties. These composites are used for enormous and advanced applications with low cost\(^4\). Besides, this sort of composites squares the property and setting friendly than traditional metal alloy.

### 2. Preparation of MMC using Stir Casting Method

#### 2.1 Matrix Material:

The alloys are widely utilized as matrices in aluminium are being engrossed on the A356, 2xxx and 6xxx series alloys\(^5\). Though very little experimentation have been depict on the 2xxx sequence materials embedded with solid lubricant and ash particles, much fewer concentration has been paid to the 2xxx Al alloy matrix composites, in which it gives the utmost potency of all marketable Aluminium alloy materials and used for structural application. The main intention of this learning is to explore the wear, friction and hardness of Fly ash and Graphite / Molybdenum disulphide reinforced aluminium matrix composite. Here AA2218 has been selected as structural material to get desired shape. The main constituent material of AA2218 is copper, second metal is magnesium, which is predominantly added to amplify the interfacial bonding between reinforcements and matrix material. Contents of aluminium AA2218 is tabulated in Table 2.1.

| Composition (wt. %) of Aluminium 2218 |
|--------------------------------------|
| Cu        | Ni     | Mg     | Si   | Fe   | Ti   | Al    |
| 3.870     | 1.900  | 1.470  | 0.510| 0.160| 0.020| Remaining |

#### 2.2 Reinforcement Material:

Fly ash is embedded with matrix to improve mechanical properties. The main purpose of adding Graphite and Molybdenum disulphide is to provide lubrication effect at the sliding interface\(^6\). Constituent particle size of fly ash varies from submicron to 500 μm. 2.1 to 2.6 of Specific gravity, whereas bulk density varies between 1 and 1.8 g/cm\(^3\). Density of Graphite is lies between 2.09 – 2.23 g/cm\(^3\).

| Reinforcements | Density(g/cm\(^3\)) | Melting Temperature (k) |
|----------------|---------------------|-------------------------|
| Fly ash        | 1.6                 | 1173                    |
| MoS\(_2\)      | 5.06                | 1458                    |
3. Composite Preparation and Characterization

3.1 Processing of Composites using Stir Casting Method:
Coal fired furnace slag powder of fly ash is strengthened with AA2218 by liquid metal processing methodology. Metal stir method was used to yield the required specimens. The structural material AA2218 was primarily raised the temperature higher than its solidifying temperature and consequently the required quantities of embedded particles are weighed accurately and fed into the chamber. Blending of metals was carried at 650 rpm about fifty seconds turn over the interface between the matrix alloy and then the particles promote wetting and consequently the particles were homogeneously distributed. The liquid metal in the furnace is poured in a cast iron mould and solidifies to get circular bar samples. Consequently three unrelated compositions were prepared as mentioned above through metal stir casting method. The stir casting setup used for the study and board for dominant the stirrer speed and therefore the temperature is portrayed in Figure 1.

![Figure 1. Stir casting set up](image)

The two set of specimens were prepared with ash particles as hard particles and Graphite and MoS₂ as second phase reinforcements. Developed specimen details are tabulated below.

| Specimen | Matrix | Reinforcement | Hardness(BHN) |
|----------|--------|---------------|---------------|
| 1        | 85%    | 15% of fly ash | 5% MoS₂       | 42            |
| 2        | 85%    | 15% of fly ash | 5% Graphite   | 58            |

3.2 Characterization of Composites by T6:
Coal fired furnace slag powder of fly ash is strengthened with AA2218 material by metal stir casting technique. The developed composite specimen is heated to 180°C for 6 & 8 hours subsequently cooled by air, brain solution and water to allow for precipitation hardening. This will enables the mixture of aluminium copper crystalline structures, the size of which will dictate the
strength. The effect of quenching with different agents and aging hours has been evaluated through harness and wear test.

**Table 3.2.** Characterization of Specimens

| Specimen No. | Composition            | Aging hours | Quenching Medium   |
|--------------|------------------------|-------------|-------------------|
| 1            | 15% of fly ash + 5% Graphite | 6           | Air               |
| 2            | 15% of fly ash + 5% Graphite | 6           | Brain Solution    |
| 3            | 15% of fly ash + 5% Graphite | 6           | Water             |
| 4            | 15% of fly ash + 5% Graphite | 8           | Air               |
| 5            | 15% of fly ash + 5% Graphite | 8           | Brain Solution    |
| 6            | 15% of fly ash + 5% Graphite | 8           | Water             |
| 7            | 15% of fly ash + 5% MoS₂  | 6           | Air               |
| 8            | 15% of fly ash + 5% MoS₂  | 6           | Brain Solution    |
| 9            | 15% of fly ash + 5% MoS₂  | 6           | Water             |
| 10           | 15% of fly ash + 5% MoS₂  | 8           | Air               |
| 11           | 15% of fly ash + 5% MoS₂  | 8           | Brain Solution    |
| 12           | 15% of fly ash + 5% MoS₂  | 8           | Water             |
| 13           | AA2218                 | 8           | -                 |

Prepared specimens are displayed in figure number 2.

**Figure 2.** Specimens
4. Test & Result Analysis

4.1 Hardness test:

Hardness is the quantities of how resistant solid matter is to numerous kinds of permanent shape variation when a compressive load is applied or deformation. The hardness tester is shown in figure 3.

Figure 3. Hardness Tester

The Brinell hardness of different composite material has a great impression on its mechanical properties\(^\text{10}\). In our experimental work specimen, it has been observed that the hardness of different work pieces is improved due to an effect of heat treatment.

Table 4.1. Brinell Hardness of AA2218 with 5% MoS\(_2\)

| Air  | Brine solution | Water |
|------|----------------|-------|
| 6    | 8              | 6     |
| 42   | 43             | 46    |
| 52   | 53             | 57    |

Table 4.2. Brinell Hardness of AA2218 with 5% Graphite

| Air  | Brine solution | Water |
|------|----------------|-------|
| 6    | 8              | 6     |
| 45   | 47             | 55    |
| 50   | 53             | 57    |

There is no much effect on heat treatment of base alloy moreover the hardness values are lesser than embedded materials. For this reason matrix alloy result is not included for comparison. Brinell hardness of the heat treated specimens is list in the above table 4.1 and 4.2. The results are plotted as graph in figure number 4 and 5.
From the test results, it was observed that the graphite specimen aging to 8 hours and quenched with brain solution gives higher hardness value than other specimen. Because of salt present in the brain solution enhance the heat transfer capacity. This has been effect on rapid cooling of specimens resulted with higher hardness.

4.2 Friction and Wear test:

The pin on disc is a device used to govern tribological properties of coating these properties comprised frictional coefficient and wear rate the coated specimen is placed on a rotating disc spring at an adaptable angular speed. A ball held by vertically reciprocating pin is constrained against the sample for a stable amount of full rotations of the disc. The tangential force and frictional coefficient are measured and the volume of removed materials can be measured by other Techniques.
Figure 6. Pin on Disc wear test apparatus

Table 4.3. Wear of Al-2218 with 5% MoS$_2$

|                  | Air    | Brine solution | Water  |
|------------------|--------|----------------|--------|
| Time in (hours)  | 6      | 8              | 6      |
| Wear value (10^{-6} mm$^3$/m) | 391    | 343            | 290    |

Figure 7. Wear of Al-2218 with 5% MoS$_2$
Table 4.4. Wear of Al-2218 with 5% Graphite

|                | Air  | Brine solution | Water |
|----------------|------|----------------|-------|
| Wear rate (10^-6 mm^3/m) | 6    | 6              | 6     |
|                | 8    | 8              | 8     |
|                | 328  | 253            | 354   |
|                | 359  | 243            | 309   |

Figure 8. Wear of Al-2218 with 5% Graphite

Volume loss of metal is evaluated through dry sliding wear test. The figure number 7 & 8 shows the wear test results of the developed specimens\(^ {11}\). Wear analysis gives inverse result with hardness value. Increase in hardness correspondingly reduces the wear loss of metal.

Conclusion

This research work is to explore the useful properties of a Stir casting processed Al-based composite materials reinforced with particles reinforcement. Stir casting method is used to make the composites could yield a uniform distribution of the reinforcement. Mainly physical, mechanical properties of Al matrix composite improved. Graphite reinforced composite specimen aging to 8 hours and quenched with brain solution exhibits higher hardness and improved wear loss. Thus, the fabricated reinforcement composites are used in manufacturing sectors where further strength is needed.

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