Enhancing the Tribological Properties of Talc and Boron Nitride based Composites by T6 - Heat Treatment

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Abstract. Aluminium matrix composites (AMC) strengthened with hard particles has given rise to a potential material particularly for wear resistant and weight basic applications. The effect of heat treatment of aluminium alloys sliding wear nature are observed under varying load and speed. Irrespective of materials heat treatment improves hardness of the material. The particulate reinforcements embedded with Al2218 Aluminium metallic element alloy with 4% constant weight proportion of Talc, Boron Nitride and a variable amount of hard reinforcement particulates. By introducing fly ash as reinforcement satisfies the structural and thermal properties. 5%, 10% & 15% of fly ash added to the composite by metal stir casting technique. The specimens are treated with ASTM T6 standard. Performance of heat-treated matrix composite was investigated with a pin on disc apparatus through a constant load 2 kg and with a desirable rpm. Hardness of the specimen at temperature were measured before and once the heat treatment. Heat treated metal exhibits high hardness and wear resistance. This investigation reveals that 2218 Aluminium matrix composites with high hardness and wear resistance will replace the material employed in Automobiles like brake drum, cylinder block, connecting rod, piston etc for higher performance and longer life.

Keywords- Aluminium (Al2218), ASTM T6, Boron Nitride, Hardness and Talc

1. Introduction

The two significant parameters that are Light weight and Eco-friendliness in automobile field are most common genuine natural issues these days. ¹Aluminium alloys are remarkable materials because of their high explicit strength and stiffness for the use in automobile fields as segments of internal combustion engines e.g. liner, bearing, cylinder and piston. But their applications are turned down due to poor wear resistance. It is well known that this aluminium matrix composite have predominant mechanical properties, particularly high wear resistance than other composites. Besides, some investigators have studied the friction and wear properties of the tailor made materials comprising a combination of soft and hard reinforcements. Particle-reinforced as compound element in metal matrix composites (MMCs) containing ash and Al₂O₃ have established nice consideration within the past few years. Because of their reduced coefficient of thermal expansion, enhanced wear resistance, high elastic modulus and improved strength related to unreinforced chemical element alloys. ²Though they have found possible applications in weight-critical components in automobile, aerospace region and defence systems, the applying base of those particulate MMCs is increased by their performance.

Recently, low-cost chemical element alloy MMCs embedded with ash, a waste by-product of coal combustion, has been considered to act an additionally for typical particulate MMCs in numerous applications to widen the applying basis of this class of MMCs. ³The addition of ash into tailor made
MMC's may well be one more imitativeness that lowers the disposal worth of ash, could increase energy savings by dropping the amount of chemical element created, and makes healthier surroundings. Aluminium ash composite is metal matrix dispersion strengthened composite inside that soft and ductile chemical element matrix is strengthened by heavy and brittle ash particles. It's being used in cast and formed chemical element alloys to form aluminium alloy and fly ash based composites. Hence, ash bolstered composites materials are widen their unfold applications in the result of improved mechanical properties. The stirring arrangement improves the distribution and wettability. The overall approach of this study is to develop and characterize by heat treatment of unique composites from the traditional metal or similar types of metal alloy. This composite squares the usage in advanced applications with low price.

2. Experimental Procedure

2.1 Matrix Material:

So far most of the alloys that are used as matrices in aluminium being targeted on the A356, 2xxx and 6xxx series alloys. Although only a few studies are based on the 2xxx series alloys strengthened with ash and solid lubricating particles, abundantly less attention has been paid to the 2xxx Al alloy matrix composites, within which it provides the best strength of all industrial Al alloys and used for structural application. the most important objective of this entire research is to analyse the friction, wear and fracture of ash and solid lubricant strengthened metal matrix composite. Here Al 2218 was used as matrix material. The main component is copper. The second is atomic number 12 which is magnesium that is preponderantly value-added to extend the moistening between matrix and reinforcement to improve interfacial effect. Composition of metal AA2218 tabulated in Table 1.

| Composition (wt %) of Aluminium 2218 |
|--------------------------------------|
| Copper | Nickel | Magnesium | Silicon | Iron | Titanium | Aluminum |
| 3.87   | 1.90   | 1.47       | 0.51    | 0.16 | 0.02      | Bal       |

2.2 Heat treatment:

The constituent alloy material and reinforcement embedded composites are heat treated through an electrically powered Muffle furnace. There are several stages of treatment are undergone during the heat treatment of the selected material (Al2218) are: (i) Solution treatment: the aluminium alloy or matrix composite are heated for 6 hrs with a temperature of 520° C till the solute elements are mostly been dissolved in Al solid solution, (ii) Quenching: the solution treated material is cooled rapidly in water to prevent the indefinite quantity of the solute elements and to get a saturated solid solution and (iii) Artificial aging: In this process hardening is done by reheating the solute alloy to a temperature of 200° C for 6 and 8 hours to achieve the desired properties.

2.3 Reinforcement Material:

Fly ash is incorporated as main particulates to strengthen the composites, Talc and Boron Nitride are the additional reinforcement materials used to reduce the friction and wear.

| Properties of Reinforcement Particles |
|--------------------------------------|
| Fly ash | Talc | BN |
| Density (g/cm³) | 1.6 | 2.7 | 2.1 |
| Melting Temperature (°k) | 1409.15 | 1773.15 | 3246.15 |
2.4 Processing of Composites using Stir Casting Method:

Stir casting is a liquid state method used for the fabrication of composite materials, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. Stir casting is the simplest and most cost-effective method of liquid state fabrication. Thermal power plant ash powder and selected lubricant particles are reinforced with Al2218 by stir casting methodology. Liquid metallurgy technique was used to manufacture the hybrid composite specimens. The matrix alloy Al2218 was primarily superheated over its melting temperature and thus the essential quantities are evaluated exactly and fed into the chamber. Stirring was carried at 650 rpm relating to fifty seconds till the interface among the particle and thus the matrix promotes moistening and thus the particles were consistently distributed. The metal is coagulated during a forged iron mould to induce flat plate samples. so, all three are in totally different compositions were solid as declared over by stir casting methodology. The stir casting setup used for study and board for dominant the stirrer speed and thus the temperature is delineating in Figure 1.

3. Investigation & Result Analysis

3.1 Brinell indentation test:

Hardness is that quantity of resistant force of solid matter. The hardness of specimens is evaluated through hardness tester with Brinell hardness number. Penetration of intender is depends on the resistivity force created by the substance embedded with base alloy. Weak bonding between the atoms is results with low hardness value. Results of hardness have also been used to evaluate the proper mixing and uniform distribution of particulates.

To improve the adhesiveness between the particulates and base alloy is the result of wettability. This effect has been improved by the addition of Mg. In the present investigational work specimen has to be tested for three times and the average value is taken for evaluation because indenter meets the soft reinforcement particulates, the impression is much larger than the hard particle approach.

This test experimentation has to be carried out on both base alloy and heat treated metals. Heat treatment of metals above re-crystallization temperature results with refinement of grain structure. Ultimately, hardness of the metal improves drastically with respect to the cooling rate. Faster cooling gives higher hardness. Figure number 2 shows the hardness tester, which is calibrated properly as per the ASTM standard and verified with master gauge.
3.2 Result of indentation:
Brinell indentation tests were executed on developed composite and base alloy specimens. The BHN of the test specimen were deliberated with Brinell hardness measuring scheme with 10 mm diameter ball intender by a compressive force of 500 kg. The confinement time of indentation is 30 seconds. Three tests were taken on all samples to eradicate opportunity of isolation and average assessment has to be considered. Table number 3 shows the experimental results of Boron Nitride bases specimens.

Table 3. Hardness of AL-2218 with 5% Boron Nitride

| Brinell Hardness of Al-2218 with 5% BN | Air | Water | Brine solution |
|---------------------------------------|-----|-------|----------------|
|                                       | 6   | 8     | 6              |
|                                       | 77  | 79    | 78             |

Figure 3 shows the variation of hardness value of specimen results with heat treatment process. Quenching with brain solution exhibits high hardness value because of salt contamination in the solution improves the heat transfer capacity.

Table No. 4 Hardness of Al-2218 with 5% Talc

| Brinell Hardness of Al-2218 with 5% Talc | Air | Water | Brine solution |
|-----------------------------------------|-----|-------|----------------|
|                                         | 6   | 8     | 6              |
|                                         | 49  | 51    | 54             |
Al 2218 embedded with 5% Talc and 15% Fly ash particulate based composite specimens exhibits same results as that of BN. The results are tabulated in Table number 4 and the correlation between the aging and quenching medium is significantly explains in figure number 4.

It is evident from figure number 3 & 4 that the quenching reaches the highest hardness value than base alloy and untreated metals. In heat treatment process quenching is the fastest cooling method than annealing, tempering and normalizing. Quenching of specimen with different medium leads to the improved hardness, as to be expected. This has to be possible by the development of massive quantity of Martensite in the composite structure, commencing from austenite structure.
3.3 Friction and Wear test

The pin on disc is an equipment to test the tribological properties of circular specimens these properties comprised resistance to the sliding wear rate and coefficient of friction. Arrangement of wear tester is shown in figure number 5. Developed specimen is placed on a rotating disc in radial direction to the rotation. Rotation of disc is controlled by drive system and control unit. Radial load is applied on the pin and the opposing frictional force opposite to the direction of rotation is measured as frictional force by LVDT. The tangential force and resistance force are measured and therefore the volume of removed materials is often measured by weighing the specimen.

![Wear Apparatus – Pin on Disc](image)

**Figure 5.** Wear Apparatus – Pin on Disc

| Wear rate ($10^6$ mm$^3$/m) |
|-----------------------------|
| Air | Water | Brine solution |
|-----|-------|----------------|
| 6   | 8     | 6 8 6 8       |
| 575 | 530   | 436 411 430 375 |

Progressive loss of metal due to rubbing together with other metal is known as wear. The relative motion is caused by rotating the disc and radial load on pin. Life and performance of the engineering components is limiting by its wear resistance, whether the machine or mechanism is as large as heavy apparatus, or as tiny as a small mechanical, electrical and electronic device.

![Wear of Al 2218 with 5% Boron Nitride](image)
Figure 6. Wear loss of Al 2218 with 5% Boron Nitride

The figure number 6 and 7 shows the correlation between harness and effect of aging hours in terms of mass loss of metal. It was clearly identified that the improved hardness ruined to reduce the mass loss of metal with dry sliding wear.

Table number 6 and figure number 7 be evidence of volume loss of the heat treated specimens with three different quenching medium. Mass loss of every composite specimen is improved with rising aging times. The dry sliding wear of specimens shows that the volume loss has been low while quench with brain solution. At the same time increase in aging time also have significant effect on hardness and wear loss of metal.

Table 6. Wear loss of Al 2218 with 5% Talc

| Wear rate (10^{-6} \text{ mm}^3/\text{m}) | Air | Water | Brine solution |
|------------------------------------------|-----|-------|----------------|
| 6 | 8  | 6  | 8  | 6  | 8  |
| 426 | 486 | 305 | 289 | 241 | 276 |

Figure 7. Wear of Al 2218 with 5% Talc

4. Conclusions

In this research, the effects of heat treatment of composite specimens are experimented. Based on the experimental results,
This analysis work is to explore the helpful properties of a heat-treated Stir casting processed Al-based composite materials bolstered with particles reinforcement.

Stir casting methodology is employed to synthesize the composites might produce the uniform spreading of the reinforcement.

Primarily physical, mechanical properties of Al2218 matrix composite have also been analysed.

With the evident of experimental results, increase in aging time has improves the hardness of metal.

Quenching with brain solution results with lesser mass loss. Eight hours aging with brain solution quenching exhibits improved performance.

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