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# Analysis on Wear Parameters of Heat Treated Aluminium 6061 Composites Reinforced with Graphene Hydroxyl

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***Abstract*---In recent years, aluminium-based metal matrix composites (MMC) have become trendy in many aerospace and automotive applications due to their light weight and high strength to weight ratio. Aluminium 6061 (Al6061) is used as a matrix material because of its excellent mechanical properties, good formability and a wide range of industrial applications. In this study, Al6061 alloy reinforced with graphene hydroxyl with various weight percentage of as-cast (0 wt%), 0.5 wt%, and 1 wt% and the specimen are synthesized by stir cast process and the test samples are prepared according to ASTM test standards. The prepared specimen are subjected to heat-treatment in a muffle furnace at 530 °C for 2 hours, then cooled with oil and then artificially aged at 170 °C for 4 hours, air-cooled to room temperature. Another set of specimen was heat treated (annealed) at a temperature of 350 °C for 2 hours. Then they allowed for dry cooling with sand and then artificially aged at 170 °C for 4 hours, air-cooled to room temperature. Wear characteristics are analyzed for dry run on a hard disc of EN-32 ground disc and the results are analyzed. The results of heat treated specimen are compared with an untreated sample results and the variations are compared. The results depicted that the wear properties of the composite material are improved in heat treated specimen.**

***Keywords*--- Aluminum Metal Matrix Composites, Quenching, Annealing, Artificial Ageing, Wear, Graphene Hydroxyl**

## I. INTRODUCTION

In the past few years, the call for lighter substances with enlarged exact power and energy to weight ratio for the automobile and aerospace industries has brought on the development and consumption of aluminum alloy based composites a significant. The metal matrix composites (MMCs) are becoming more significant because of their light weight and high strength to weight ratio. the application aluminum composites are trendy in applications like automobile, aerospace, naval, sports and construction area. Aluminum alloys are very attractive because of their low density, good corrosion resistance, and high thermal and electrical conductivity. The mechanical properties depend on the chemical composition of aluminum. The matrix metal-aluminum matrix composite material is usually reinforced with alumina, silicon carbide, silicon dioxide, graphite, graphene, boron nitride, boron carbide, etc.

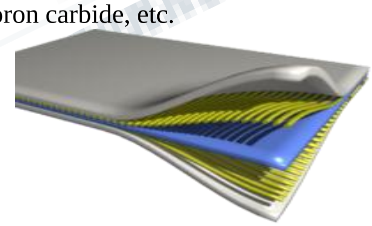

**Fig 1: Composite Material**

## II. SELECTION OF MATRIX MATERIAL

**Aluminum 6061:**

Aluminum 6061 material is a precipitation of aluminum alloy with magnesium and silicon as the main constituents. It is one of the most widely used aluminum alloys in the 6000 series. It is an extruded alloy that can be heat treated, forged and has medium and high strength properties and has good toughness, surface finish, resistant to atmospheric corrosion. Low wear resistance of aluminium is the main disadvantage of this material for its application where wear is a common phenomenon. So it is reinforced with graphene hydroxyl which has a noble wear resistance as it is an allotropic form of carbon. The chemical abd physical properties of Aluminum 6061 are tabulated in table1 and table2.

**Fig 2: 6061 Aluminum Material**

**Table -1: Mechanical Properties**

| Sl. No. | Property | Value |
|---|---|---|
| 1 | Density | 2700 Kg/m3 |
| 2 | Young's Modulus | 68.9G |
| 3 | Poisson's Ratio | 0.33 |
| 4 | Elongation | 12.25% |
| 5 | Tensile Yield Strength | 276Mpa |
| 6 | Ultimate Yield Strength | 310Mpa |
| 7 | Shear Strength | 207Mpa |
| 8 | Fracture Strength | 96.5Mpa |
| 9 | Brinell Hardness Number | 95 |
| 10 | Melting Temperature | 650 °C |

**Table -2: Chemical Properties of Graphene**

| Constituent | Mg | Si | Cu | Fe | Cr | Zn | Mn | Ti | Al |
|---|---|---|---|---|---|---|---|---|---|
| Wt. % | 1.49 | 0.68 | 0.60 | 0.49 | 0.36 | 0.30 | 0.27 | 0.25 | Balance |

**Graphene Hydroxyl:**

Graphene (Gr) is an allotropic form of carbon. It is composed of atomic layers, the atoms arranged layer by layer which form a two-dimensional honeycomb structure. Graphene layers are superimposed on each other to form graphite. It was developed by the professors Andre Heim and Konstantin Novosz lo at University of Manchester and awarded with Nobel Prize for their contribution n development of material in the year 2010.

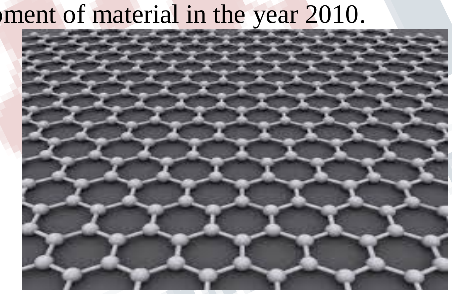

**Fig 3: Structure f Graphene Reinforcement**

**Table -3: Mechanical properties of Graphene Hydroxyl**

| Sl. No. | Property | Value |
|---|---|---|
| 1 | Density | 2700 Kg/m3 |
| 2 | Young's Modulus | 68.9G |
| 3 | Poisson's Ratio | 0.33 |
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| 9 | Brinell Hardness Number | 95 |
| 10 | Melting Temperature | 650 °C |

**Table -4: Chemical properties of Graphene Hydroxyl**

| Constituent | Mg | Si | Cu | Fe | Cr | Zn | Mn | Ti | Al |
|---|---|---|---|---|---|---|---|---|---|
| Wt. % | 1.49 | 0.68 | 0.60 | 0.49 | 0.36 | 0.30 | 0.27 | 0.25 | Balance |

## III. LITERATURE REVIEW

**Srinivasa M R et.al, [1]** have studied "Analysis on wear behavior of aluminum composites reinforced with graphene hydroxyl" Aluminum is a valuable material used in structural applications in the aerospace, locomotive and automotive industries. If wear is one of the characteristics of the part, the low wear resistance of aluminum limits its use. Carbon is combined with aluminum as an alternative to reinforcing materials, which can enhance the properties like hardness and wear resistance, because it acts as a self-lubricating material. This article focuses on the wear resistance of composite materials when aluminum is used as a matrix to enhance graphene, which increases the wear resistance of the composition. This will be discussed through parameters such as coefficient of friction, friction and material loss caused by wear.

**Anil Parmar et al., [2]** the "abrasion resistance of aluminum-based compounds during stirring casting" was studied. The document pointed out that the main purpose of aluminum is low density, electrical and thermal conductivity, ductility and other excellent properties. The first property required is the wear resistance of the composite material, which is obtained by mixing different types of reinforcing agents with aluminum. In addition, the document also shows the effect of filling parameters on the properties of aluminum compounds.

**Sachith T S et al. [3]** reviewed "Aluminum-based hybrid Nano composites: an overview of reinforcement, mechanical and tribological properties." The new Nano matrix Metal Manufacturing Alloy (HNMMC) meets the latest requirements in the field of advanced manufacturing. Pressure is achieved by improving performance, reducing assembly costs and high-quality weight loss factors. When these links are merged, the project parameters are linked.

## IV. MATERIAL SYNTHESIZATION:

**Stir Casting:**

Aluminum material with a definite quantity is weighed and heated in a graphite crucible. It is heated to a temperature of 650°C. The heating is continued about 100 minutes and stabilizes within 15 minutes after reaching 700°C.The graphene reinforcement particles with a size of about 5-10 microns is heated to a temperature of 300-400°C for about 60 minutes and wrapped in aluminium foil paper to make it as a billet. It is added to molten aluminum in the weight percentage of as-cast, 0.5% and 1.0%. The hexa-chloro ethane degassing tablet is added to molten metal to remove the gasses entrapped during melting.

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Immerse the stirrer in the molten metal and stirring action for about 6 minutes and billets of heated Graphene material is added slowly. The mixture is heated for 10 minutes and stirred for uniform mixing. After stirring, the molten composite mixture is poured into the pre-heated mould box. After the material cooled to room temperature, the cast composite is taken out of the mould. The casting process is shown in fig.4.

**Fig 4: Aluminum Being Stirred for Effective Mixing with Reinforcement**

**Heat Treatment:**

Two basic heat treatment process are performed; 1. Quenching 2. Annealing

The procedure followed is as follows;

**Quenching:** The Al6061 molding compound was dissolved and treated in a muffle furnace at 530°C for 2 hours, then oil-cooled and artificially aged at 170°C for 4 hours followed by air-cooling to room temperature.

**Annealing:** Strengthening is heat treatment technique which modifies the microstructure of a material to change its mechanical properties. The specimen is heated to a temperature of 350 °C and kept for 2 hours in furnace. After that it is allowed to cool slowly by a dry cooling material (sand) or furnace, which reduces the internal residual stress.

**Fig 5: Oil Quenching**

**Fig 6: Electric Furnace**

## V. TESTING:

**Wear Test**

The experiment was performed to check the dry friction and abrasion resistance of the composite material sample. A ground disc made of EN-32 material with a surface roughness of 0.394 µm and a hardness of 62 HRC was used as the rotating component, and then the sample was cleaned with acetone. An electronic balance is employed to weigh the samples to the nearest 0.1 mg. The wear of the specimen is measured by the displacement of the specimen, measured with a LVDT mounted on one end of the arm holding the specimen. The pin is fixed and disc is made to rotate. The specifications of the setup are shown in Table 5. The experiment is conducted to a fixed track length of 2000 meters with sliding velocity of 1256 m/s and normal loads of range 20 N, 30 N and 40 N. As mentioned above, experiments are performed with different load condition.

The specimens are characterized by scanning electron microscope (SEM) to observe the worn surface of the selected sample to analyze the debris and material removal path. The specimen used for testing of wear and the pin-on disc setup is shown in fig. 7 and fig.8 and the specification are tabulated in table5.

**Fig 7: Specimen for wear test**

**Fig 8: Pin on Disc Set-Up**

**Table 5: Equipment Specifications**

| EQUIPMENT SPECIFIACTION | |
|---|---|
| Rotating Speed | Up To 2000 Rpm |
| Normal Load Range | Up To 200N |
| Track Diameter | 40mm To 118mm |
| Wear or Displacement Range | ±2000 Microns |
| Pin Size | 25 to 30mm |
| Disc size | EN-32 Steel , Dia. of 120 mm and Thickness 8 mm |
| Frictional Force | Up to 200N |

## VI. RESULTS AND DISCUSSIONS:

The test is conducted for a normal weight of 20N, 30 N and 40 N. The material weight loss due to wear is taken as output parameter.

**Table 6: Loss of material due to Wear for 20N**

| Percentage of reinforcement | Material Weight Loss (gms) | | |
|---|---|---|---|
| | Untreated | Quenched | Annealed |
| As Cast | 0.1632 | 0.0394 | 0.0413 |
| 0.5% | 0.0185 | 0.0066 | 0.0132 |
| 1% | 0.0153 | 0.0054 | 0.0118 |

The amount of wear decreases from 0.1632 gms to 0.0153 gms (90.62%) as the graphene percentage increases from 0 to 1 wt. % for un-heat treated composites, found decreased from 0.0394 gms to 0.0054 gms (86.29%) as the graphene content increases from 0 to 1 wt. % for heat treated (quenching) composites 20N and 0.0413 gms to 0.0118 gms as the graphene content increases from 0 to 1 wt. % for heat treated (Annealing) composites, under a normal load of 20N (71.42%).When the graphene content is increased from 0 % to 1.0% under a given load, a decrease in wear is observed. Here, the loss of mass is very less for quenching heat treatment compared to annealing and untreated specimens.

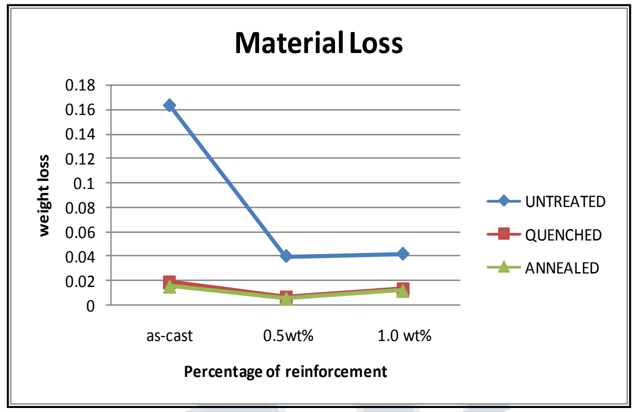


**Figure 9: Comparison of Un- Heat Treated and Heat Treated (quenching, annealing) Composites at 20N**

**Table 7: Loss of material due to Wear for 30N**

| Percentage of reinforcement | Material Weight Loss (gms) | | |
|---|---|---|---|
| | Untreated | Quenched | Annealed |
| As Cast | 0.2869 | 0.0617 | 0.0823 |
| 0.5% | 0.0399 | 0.0273 | 0.0234 |
| 1% | 0.0342 | 0.050 | 0.0151 |

The amount of wear decreases from 0.2869 gms to 0.0342 gms (88.70%) as the graphene percentage increases from 0 to 1 wt. % for un-heat treated composites, found decreased from 0.0617gms to 0.050 gms (18.90%) as the graphene content increases from 0 to 1 wt. % for heat treated (quenching) composites 30N and 0.0823 gms to 000511 gms as the graphene content increases from 0 to 1 wt. % for heat treated (Annealing) composites, under a normal load of 30N (81.65%).When the graphene content is increased from 0 % to 1.0% under a given load, a decrease in wear is observed. Here, the loss of mass is very less for quenching heat treatment compared to annealing and untreated specimens.

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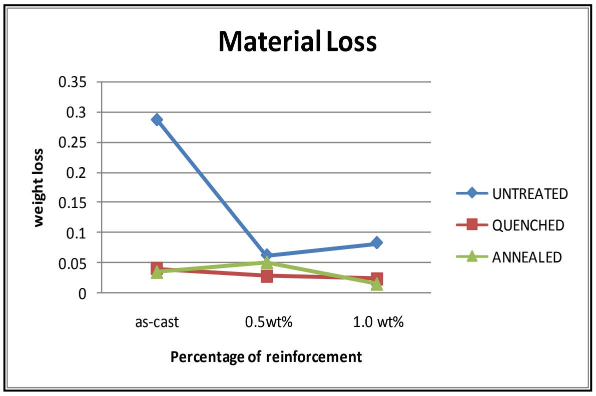


**Figure 10: Comparison of un-treated and Heat Treated (quenching, annealing) Composites at 30N**

**Table 8: Loss of material due to Wear for 40N**

| Percentage of reinforcement | Material Weight Loss (gms) | | |
|---|---|---|---|
| | **Untreated** | **Quenched** | **Annealed** |
| As Cast | 0.6762 | 0.6006 | 0.5443 |
| 0.5% | 0.6668 | 0.1616 | 0.3678 |
| 1% | 0.5187 | 0.30840 | 0.3796 |

The amount of wear decreases from 0.6762 gms to 0.5187 gms (14.31%) as the graphene percentage increases from 0 to 1 wt. % for un-heat treated composites, found decreased from 0.6006 gms to 0.30840 gms (30.28%) as the graphene content increases from 0 to 1 wt. % for heat treated (quenching) composites 40N and 0.5443 gms to 0.3796 gms as the graphene content increases from 0 to 1 wt. % for heat treated (Annealing) composites, under a normal load of 40N (48.65%).When the graphene content is increased from 0 % to 1.0% under a given load, a decrease in wear is observed. Here, the loss of mass is very less for quenching heat treatment compared to annealing and untreated specimens.

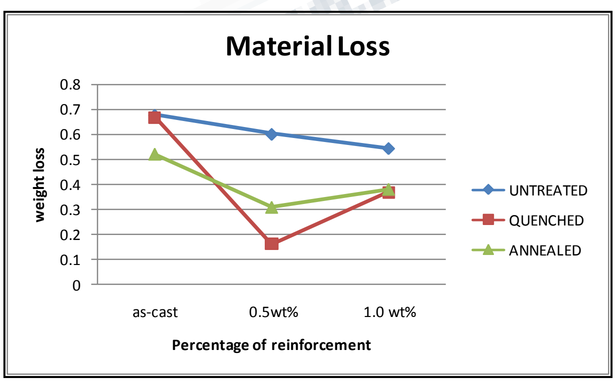


**Figure 11: Comparison graph between Un- Heat Treated and Heat Treated (quenching, annealing) Composites at 40N**

**SEM analysis of the worn surface:**

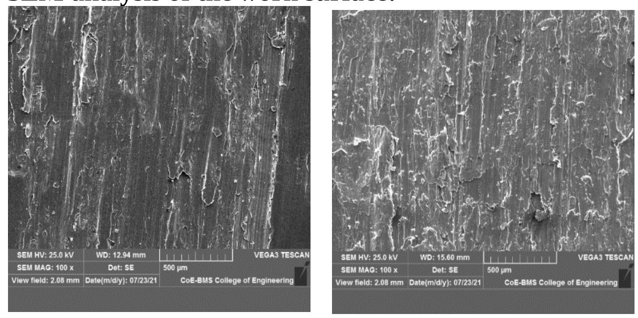

**Fig 12: SEM Representation of Un-Heat treated and Heat Treated (Quenching, Annealing) Wear Specimen For 0%.0.5% and 1% (wt. %) of graphene.**

In this study, a scanning electron microscope (SEM) was used to analyse the composite material, a microstructure analysis was performed to check the worm surface area, porosity, particle size and dispersion concentration of the reinforcement, and the sample was analysed by SEM. Scanning electron microscope (SEM) is used to analyse the distribution of graphene particles in the aluminum matrix material.

## VII. CONCLUSIONS

Referring to the above results and discussions, the conclusions can be drawn as below;

- The addition of graphene as a reinforcing element can improve the wear properties of aluminum.
- It can also be seen that the stirring casting process helps to obtain improved performance due to the better dispersion of the reinforcing particles.
- The wear properties of aluminum 6061 are improved by heat treatment process. Hence it can be concluded that the loss of material or wear loss is very less in heat-treated composites material when compared to the un-treated composites material.
- It is observed that the higher the graphene content in the composite material, the greater will be the wear resistance of the composite material.

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