EXPERIMENTAL INVESTIGATION OF HARDNESS OF AL6061 WITH GRAPHINE AND MOLYBDENUM METAL MATRIX COMPOSITE

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Abstract - Aluminium metal matrix composites have gained importance in various industries because of their good mechanical properties such as wear resistance, low density, high strength and good structural rigidity. Aluminium metal matrix composites are preferred in the field of aerospace, military, automotive, marine and in many other domestic applications. In this study, it is intended to develop and study the hardness behavior of AL6061/graphite and molybdenum disulfide reinforced hybrid aluminium metal matrix composites. The composites are prepared by using liquid metallurgy route (stir casting technique), liquid state has some important advantages such as better matrix particle bonding, easier control of matrix structure, simplicity, low cost of processing, nearer to net shape and wide selection of material. AL6061 alloy is taken as the base matrix to which graphite and molybdenum particulates are used as reinforcements. 0.5, 1, 2, 3, and 4% of graphite is added to the base matrix, and molybdenum disulfide is varied from 0.5, 1.2, 3 and 4 wt% into the base matrix. For each composite, reinforcement particles are pre-heated to a temperature 240 degree centigrade. The hardness properties of prepared composites were examined using Rockwell hardness tester. The mechanical behavior of composite material were increased. Also, this composite material is having a good hardness behavior.

Keywords—Aluminium 6061, graphite and molybdenum disulfide, Stir casting process, hardness test

1. INTRODUCTION

Aluminium has many benefits over other materials including high strength to weight ratio, corrosion resistance. This material is sometimes referred to the group of aerospace alloys for their practical application in various industries. These alloys are engineered to be light weight and strong. The 6061 is commonly used for the following are Yacht construction, including small utility boats, Automotive parts, such as the chassis of the audi A8, Some tactical flash lights, Aluminium cans for the packaging of food and beverages, Bicycle frames and components, Many fly fishing reels, This materials used in some ultra high vacuum chamfers, Many parts of remote controlled model aircraft, notably helicopter rotor components. Graphite and molybdenum disulfide is having a more wear resistance and lowest cutting force. The two additives materials is mostly used in aluminium 6061, that material is graphite and molybdenum disulfide. Its containing good wear resistance and creates the lowest cutting force.

This composites were fabricates separately by introducing 0.5, 1, 2, 3, and 4 wt% by using stir casting process. Then the hardness of the each composite materials is find by using Rockwell hardness testing It’s obtaining the good lubricating process. Stir casting process is using this casting methods. There are five sample of casting products is produced. This composites were fabricated separately by introducing 0.5, 1, 2, 3, and 4 wt% by using stir casting process. In this paper, the hardness behavior of metal matrix composites reinforced with graphite particles has been reviewed. More specifically, aluminium 6061, graphite and molybdenum disulfide composites have been studied by using Rockwell hardness testing machine.

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II. LITERATURE REVIEW

M. Sayuti et al. [1] proposed to reduce the hardness, tool wear and surface roughness of steel AISI 4140 by using silicon oxide nano lubrication. Silicon oxide is using this methods in lubricating purpose also it can reduced the hardness and surface roughness.

Rahmathi et al. [2] studied to increasing the morphology of surface generated by using the molybdenum disulfide (MoS₂) nano lubrication in end milling machine. Aluminium 6061–t6 using this methods. In this research, the molybdenum disulfide is having a create good morphology of surface generation.

M. Nagaral and V. Auradi [3] studied to mechanical behavior of aluminium 6061 alloy reinforced with al2o3 & graphite particulate hybrid metal matrix composites. The graphite matrix is reducing the hardness of al6061 and aluminium oxide is increasing hardness of aluminium 6061. Also aluminium oxide is having a more hardness capacity.

R Balachandar and R Balasundaram et al. [4] have studied to dry sliding wear characteristics of aluminium 6061-t6, magnesium az31 and rock dust composite. In this work, the reinforcing materials, magnesium AZ31 and rock dust are used within al6061–t6 to find the wear characteristics. The mg rock dust are varied from 1% to 3% and with al6061–t6 during stir casting process. The adition of magnesium AZ31 will increase the ultimate tensil strength. The reinforcement of of rock dust will decrease the density. The rock dust is produced less wear by using L9 orthogonal array.

D Valavan and R Balasundaram et al. [5] studied to experimental design and analysis of carbon fiber reinforced composite drive shaft. This work examines mechanical properties like torsional strength, tensile strength, flexural strength, impact strength and hardness strength of carbon fibers composite materials. In this work the drive shaft is replaced by our proposed composite materials. Various mechanical tests are carried out as per the ASTM standard to evaluate the suitability of carbon fiber reinforced polymer composites.

III. MATERIAL PROPERTIES

1) ALUMINIUM 6061

These alloy are engineered to be light weight and strong, and their ease of formability allows complex shapes, which can then be further enhanced with heat treating aluminium AL6061 is an alloy which contains magnesium and silicon as major alloying elements. It has been a common alloy which is used for many purpose since it has been a common alloy which is used for many purpose since it has the superior mechanical properties such as hardness and good weldability. This is due to solutionize and tempered grade that belong to this type of aluminium. The common application for this kind of material is in aircraft industry, automotive industry and packaging food industry.
Fig 1. Material of aluminium 6061

Table 1. Thermal properties of aluminium 6061

| Property                                         | Value          |
|--------------------------------------------------|----------------|
| Melting temperature (Tm)                         | 585 °C (1,085 °F) |
| Thermal conductivity (k)                         | 151–202 W/(m·K) |
| Linear thermal expansion coefficient (α)          | 2.32×10⁻⁵ K⁻¹ |
| Specific heat capacity (c)                       | 897 J/(kg·K)   |

Table 2. Mechanical properties of aluminium 6061

| Property             | Value          |
|----------------------|----------------|
| Young’s modulus (E)  | 68.9 GPa (9,990 ksi) |
| Tensile strength (σt) | 124–290 MPa    |
| Elongation (ε) at break | 12–25%       |
| Poisson’s ratio (ν)  | 0.33           |

Table 3. Chemical composition of aluminium 6061

| Sl.No | MATERIALS | VALUES |
|-------|-----------|--------|
| 1     | Magnesium | 0.8    |
| 2     | Silicon   | 0.6    |
| 3     | Iron      | 0.6    |
| 4     | Copper    | 0.3    |
| 5     | Zinc      | 0.25   |
| 6     | Manganese | 0.13   |
| 7     | Chromium  | 0.3    |

2) MOLYBDENUM DISULPHIDE(MoS₂)

Molybdenum disulfide is an organic compound composed of molybdenum and sulfur. Its chemical formula is MoS₂. It is relatively unreactive. It is unaffected by dilute acids and oxygen. In appearance and feel, molybdenum disulfide is similar to graphite. It is widely used as a dry lubricant because of its low friction and robustness.
Fig 2. Material of molybdenum disulphide (MoS$_2$)

Table 4. Chemical composition of molybdenum disulfide (MoS$_2$)

| Sl.No | ELEMENT   | CONTENT % |
|-------|-----------|-----------|
| 1     | Molybdenum| 59.94     |
| 2     | Sulfur    | 40.05     |

Table 5. Properties of molybdenum disulfide (MoS$_2$)

| Sl.No | ELEMENT      | CONTENT                   |
|-------|--------------|---------------------------|
| 1     | Molar mass   | 160.07 g/mol              |
| 2     | Density      | 5.06 g/cm$^3$             |
| 3     | Melting point| 1185°C                    |

3) GRAPHITE

Fig 3. Graphite material

It is a native element mineral found in metamorphic and igneous rocks. Graphite is a mineral of extremes. It is extremely soft, cleaves with very light pressure, and has a very low specific gravity.
In contrast, it is extremely resistant to heat and nearly inert in contact with almost any other material. These extreme properties give it a wide range of uses in metallurgy and manufacturing.

These composite materials have the ability to achieve low friction and wear at the contact surfaces without any external supply of lubrication during sliding. The metal matrix composites reinforced with various self-lubricating particles such as graphite, molybdenum disulfide are being used as self-lubricating materials for various engineering applications.

IV. STIR CASTING PROCESS

![Fig 4 Assembly of stir casting process](image)

Stir casting is one of the prominent and economical route for development and processing of metal matrix composites materials. There are five sample of casting materials is produced in these methods. This method is fabricated the AL6061 reinforced with graphite and molybdenum disulphide stirred through manual mixing existed mechanism of stir casting and modified mechanism.

The following parameter is using this stir casting machine.

- Stirrer speed = 160 rpm
- Stirring time = 3 min
- Stirring blade angle = 30 degree
- Voltage = 650 V
- Melting temperature = 730 degree
- Pouring temperature = 800 degree
Table 6. Specimen preparation

| Sl.No | PERCENTAGE OF GRAPHITE | % OF MOLYBDENUM DISULPHIDE |
|-------|------------------------|---------------------------|
| 1     | 0.5                    | 0.5                       |
| 2     | 1                      | 1                         |
| 3     | 2                      | 2                         |
| 4     | 3                      | 3                         |
| 5     | 4                      | 4                         |

V. HARDNESS TEST

Hardness has variety of meaning to the metal industry, it may be thought of as resistance to permanent deformation. To the metallurgist, it means resistance to scratching penetration. To the lubrication engineer, it is a measure of flow stress. Hardness may also be referred to mean contact pressure. All of these characteristics are related to the plastic flow stress of materials. Rockwell hardness testing machine is using to calculate in this methods.

Table 6. Hardness testing values

| Sl.No | % OF SAMPLES | HARDNESS VALUES |
|-------|--------------|-----------------|
| 1     | 0.5          | 76.75           |
| 2     | 1            | 84.60           |
| 3     | 2            | 86.75           |
| 4     | 3            | 93.50           |
| 5     | 4            | 86.50           |

VI. CONCLUSION

Aluminium based hybrid metal matrix composites have been successfully fabricated by melt stir method by five step addition of reinforcement combined with preheating of particulates. hardness strength of prepared composites is higher in case of composites, when compared to cast Al6061. Addition of wt% molybdynem disulphide and graphite increases the hardness strength considerably with respect to base matrix Al6061. Rockwell Hardness testing machine is used the hardness measurements.also this composites is having a more hardness behavior..

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