Fabrication and Characterization of hybrid aluminium-fly ash-graphite composite

Mayank Saxena¹, Md. Tarique¹, Md. Rafi¹, Mukul Anand¹, Sumit Joshi¹, Vipin Kumar Sharma¹*, R. C. Singh², Rajiv Chaudhary²

¹Department of Mechanical and Automation Engineering, Maharaja Agrasen Institute of Technology, Rohini Sector-22, Delhi-110086
²Department of Mechanical Engineering, Delhi Technological University, Bawana Road, Delhi-110042.

*Corresponding Author email Id- vipin.dtu@gmail.com

Abstract

In the present paper, an aluminium metal composite with fly ash and graphite as the reinforcement were prepared using the stir casting route. The effects of reinforcements on the hardness of the Al 6061 were evaluated using a Brinell hardness tester and optical micrographs and XRD analysis was done to inspect the distribution of the reinforcements in the Al 6061 matrix. It was observed that the introduction of reinforcements in the Al matrix greatly influenced the surface hardness. There was about 32 % improvement in the hardness value. Optical micrographs also indicated the homogeneous distribution of reinforcements in the aluminium matrix.

Keywords: Aluminium, graphite, fly ash, composite

Introduction

In this modern world Aluminium metal is widely used in many industries, like automobile industry, aerospace industry etc. mainly due to its low Density and lighter in weight as compare to another metals. Some aluminium alloys (7XXX series) have high tensile strength and lower density than steel. The use of Aluminium reduces the weight of the automobile and also increases its strength. Due to weight reduction of automobile fuel efficiency as well as power to weight ratio increases. Automotive industry is helping to reducing some other metals like steel & brass with aluminium in the manufacture components like engine block, alloys, bolts, master cylinder. Aluminium alloy 6XXX series is use due to its low cost than other grade. But also 6XXX series has low hardness and tensile strength as compare to other Aluminium grade. So for the improvement of its mechanical and chemicals properties reinforcement is use nowadays. Reinforcement is majorly Natural and Synthetic. Natural reinforcement are consisting of some natural waste like rice husk, sugarcane baggage, coconut shell ash. Where Synthetic reinforcement are composed from factory waste like flyash, B₄C, Al₂O₃ etc.
Govindharajan et al. (2015) [1] fabricated the composite Aluminium 6061 with FA, glass fibre with the help of stir casting method. The author studied the effect on mechanical properties and compared the results with the base material. The comparison was made between 4 samples of different composition of fly ash and glass fibre. The results show that the U.T.S, Y.S, compressive strength, % elongation and hardness of specimen increase as the content of fly ash increases. Bharathi et al. (2017) [2] studied the effect on hardness, M.S, and density of reinforced pure aluminium with fly ash by stir-squeeze cast method. By this experiment, the author saw that as wt% of FA increases with load and speed lead to an increase in wear rate. As reinforcement increases hardness increases and density decreases. Chaithanyasai et al. (2014) [3] studied the effect on the density and hardness of Aluminium 6061 matrix when reinforced with eggshell through powder metallurgy route. It was observed that the eggshell was successfully reinforced with the Al matrix resulting in strong bonding. Further, it was observed that hardness of composite increases with the increase in wt% of eggshell. Gladstone et al. (2017) [4] fabricated AA6061 with rice husk ash by composting to see the results on Wear rate, M.S. The author compared the outcomes and as grain refinement rises with enhanced RHA particle content. RHA particles enhanced composite wear property and increased hardness but as the load increased the wear rate also increases compared to the base metal. Patel et al. (2017) [5] utilised the stir casting route for fabricating the aluminium metal matrix composite having Al6061 as matrix with Fly ash and E-glass fibre as reinforcement. The prepared composite was further investigated for mechanical behaviour. It was concluded that properties such as tensile and compressive strength, yield strength, ductility and hardness enhanced on addition of Fly Ash with continuous E-glass fibre except 6 % fly ash sample which exhibited reduction in the hardness. Further, toughness was found to be reduced in case of fly ash reinforced sample. Sharma et al. (2019) [6] used the graphite particles in the SAE 15W-40 multigrade lubricating oil. A magnetic stirrer along with an ultrasonicator was used to mix the graphite with oil. The tribological properties of the graphite mixed oil were evaluated with the help of a pin on disc setup. The formulated lubricating oil was introduced between the pin and disc specimens at various loading conditions and coefficient of friction was recorded. Authors reported that, graphite particles acts as a rolling body between the specimens and reduced the coefficient of friction.

Based on the literature review, Flyash and graphite were selected as the reinforcement for the 6061 aluminium matrix. Stir casting technique was utilised to fabricate the aluminium metal matrix composite. The Microstructural and mechanical characterization of the prepared composite sample was investigated through optical micrographs, XRD technique and Brinell hardness tester.

**Materials and Method**

**Material Selection**

Aluminium has a very wide classification of its alloys; these were the base of the aeronautical industry. It also utilized to help with cooking and packing. It helps in the production of high-grade steels and it was additionally used for the base of flexible paint. Pure aluminium was delicate, malleable, and corrosion resistant in nature and has a high electrical conductivity. In the present study, 6061 aluminium alloy was selected as the parent material. The aluminum was procured in the form of ingots from Aluminium Trading Co., Delhi, India. Al6061 consists of Mg and Si as the major alloying elements. The elemental composition of Al 6061
characterized through spectroscopy test is shown in Table 1. The mechanical properties of Al 6061 are presented in table 2.

Table 1: Chemical Composition of Al-6061 alloy.

| Elements | Si  | Fe   | Mg   | Mn   | Ti   | Zn   | Ni   | Cr   | Al  |
|----------|-----|------|------|------|------|------|------|------|-----|
| wt %     | 0.6 | 0.273| 0.6941| 0.1074| 0.0736| 0.0693| 0.039| 0.0345| 98.01|

Table 2: Mechanical Properties of Al6061

| Property                | Value    |
|-------------------------|----------|
| Young’s Modulus         | 68.3 GPa |
| Tensile Strength        | 165 MPa  |
| Elongation              | 18-33%   |
| Melting Temperature (Tm) | 615°C    |
| Thermal Conductivity(k) | 201-218 W/m*K |

Fabrication

Preparation of Materials

There are number of methods to fabricate the composite materials. The proper distribution of the reinforcements into the matrix materials is the prime requirement for a good composite material. Stir casting method is one of the famous methods used by the researchers for the fabrication [7-10]. In this method, the mixtures of matrix and reinforcement are continuously stirred with the help of a stirrer. The continuous stirring resulted in the uniform mixing of the reinforcing particles in the metal matrix . In this work, Al 6061 was first heated to about 800°C temperature and preheated fly ash and graphite particles were added in the molten Al 6061. The complete mixture was continuously mixed by rotating the stirrer at a rotational speed of 100 rpm. After the mixing the molten mixture was poured in the preformed metal mould and later samples were machines for characterization and hardness testing.

Characterization and Hardness Testing

Microstructure

The Microstructural observation assists in studying the effect of reinforcement particles on the performance of metal matrix composite. The characterization consists of polishing the sample surface with 100, 120, 220, 320, 400, 600, 1200, 2000 grits emery paper. The dry polishing was followed by wet polishing through sliding of samples against the rotating disc having fine emery. Finally, wet polishing was performed with aluminium powder of three grades: I, II and III on velvet cloth. Finally, the samples were cleaned using ethanol as cleaning with water was not sufficient to reduce surface impurities. The samples were etched in Keller’s reagent solution for few seconds to reveal the grain boundary.

X-ray diffraction (XRD)
The XRD technique is based on the constructive interference phenomena of monochromatic X-ray. The samples were focussed and aimed under the high intensity X-rays. When the rays interfere with the sample, constructive interference occurs as per the Bragg law. The XRD analysis was done for the identification of intermetallics in the samples. The samples were polished before XRD analysis to remove the roughness and providing evenness in the surface.

**Hardness**

The hardness measurement was performed according to ASTM E10-18 standard. Before the hardness test, samples were polished with fine grit emery for removing oxides and unwanted scales present in the sample surfaces. The polished workpiece was placed on the table of machine. The polished specimen surface was brought in contact with indenter. Machine was loaded weight with 500Kgf force and the diameter of steel ball (indenter) was 10 mm. Then lever is pulled due to which load was acting on it and holding time of the weight was 30 second. After that lever was pushed and indentation on the workpiece was cleaned by acetone and diameter was measured with microscope. Using the BHN formula BHN no. was calculated for each test. Ten readings were taken for each specimen and average of them was considered for further analysis.

**Results and Discussion**

*Microstructure characterization*

The microstructure micrographs obtained from optical microscope are presented in Figure 1 (a-c). The fly ash and graphite particles were observed in the samples of prepared composites. Figure 1 (a) shows the microstructure for sample 1. The flyash particles were spread throughout the aluminium matrix. The flyash particles were larger in shape. Figure 1 (b) presents the microstructure for the 10% w/w graphite particle mixed aluminium composites. The graphite particles were small in shape. Similarly, Figure 1 (c) shows the 5% w/w flyash and 5%w/w graphite mixed aluminium composite.
Figure 1: Optical micrographs for (a) 10% w/w flyash particles (b) 10% w/w graphite particles (c) 5% w/w flyash and 5% w/w graphite particles.

X-Ray Diffraction analysis

The XRD results exhibits the presence of reinforcement peaks in the sample of the Al6061 and in the processed samples. The major elements of Al 6061 were Al and Al-Fe-Si as depicted by XRD peaks. The fly ash presence in the composite was confirmed by the elemental peaks of Ca, Si, O, Al, and Mg as depicted in Figure 2 (a-d). The bonding between the fly ash and the Al was observed in the microstructure. The presence of oxide layer on the
samples was confirmed by the XRD results since aluminium have tendency to react with the atmospheric oxygen.
Figure 2: XRD spectrum for (a) Al 6061, (b) 10% w/w flyash particles (c) 10% w/w graphite particles (d) 5% w/w flyash and 5% w/w graphite particles.

**Hardness**

The improvement in hardness value for the Al 6061 with the use of reinforcements is presented in figure. The pure Al 6061 material has a Brinell hardness number as 36 BHN. With the addition of flyash and graphite the Brinell hardness number gets improved. With
addition of fly ash the hardness number improved with 6-7%. With graphite there was an improvement of about 24 % (Figure 3).

![BRINELL HARDNESS](image)

Figure 3: hardness for prepared samples

**Conclusion**

Stir casting method was successfully used to fabricate the aluminium-flyash-graphite composites. Three aluminium metal composites, Al-10 %w/w flyash, Al-10% w/w graphite and Al-5%w/w flyash-5%w/w graphite were fabricated. The reinforcement particles were found to have uniform distribution in the aluminium matrix. The presence of reinforcements also improved the Brinell hardness by 32% for the 10% w/w graphite mixed aluminium composite.

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