Fabrication of Al6061-Al2O3 composite through liquid metallurgy technique

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Abstract. Aluminium Metal Matrix Composites (MMCs) are preferred to other conventional materials in the fields of aerospace, automotive and marine applications owing to their improved properties like high strength to weight ratio, good wear resistance etc. In the present work, an attempt has been made to synthesize Al6061-Al2O3 particulate metal matrix composites by liquid metallurgy route (stir casting technique). Aluminium metal matrix composite was fabricated with Al6061 alloy as a matrix and Al2O3 as a reinforcement material. Reinforcement was added in the range of 0, 3 and 6 percentage by weight into the molten alloy, hence the Al6061 metal matrix composite was produced and their properties were estimated. Micro-Vickers hardness of the composite was found to increase with increase in filler content in the composite. Along with the hardness, compressive strength and the corrosion resistance properties of composite material steadily increases with the increase in the reinforcement particles in the matrix. Besides that the impact strength of composite was found to decrease with the enhancement of the ceramic reinforcement particle Al2O3 into the Al6061 alloy matrix.

Keywords: Liquid metallurgy, Micro-Vickers hardness, Corrosion, Impact strength

1. Introduction

In recent years, researchers were focussing upon the metal matrix composites, in this many of the automobile components were fabricated by ferrous and its alloys. Their main drawbacks are their heavy weight and less corrosion resistance. From this, it is observed that there the need to discover alternative material arises. Many researchers have found that the metal matrix composites were the suitable replacement for the conventional ferrous alloys. They have chosen various methodologies to fabricate metal matrix composites [1-4]. G. B. Veeresh Kumar[5] et al. have fabricated Al6061-6%SiC and Al7075-6%Al2O3 through liquid metallurgy route and have found that the fabricated alloy composites of Al6061-SiC showed better micro-hardness, tensile strength and tribological properties than Al7075-6%Al2O3. Madeva nagaral[6] et al. and A. Baradeswaran[7] et al. had evaluated the mechanical and tribological properties of Al60161 and Al7075 as matrix and Al2O3 and graphite as reinforcements respectively by stir casting. It was observed that the hardness of the hybrid composite increases with the increase in reinforcement content into the matrix.

S. Boopathy [8] et al. has prepared the composite with the composition of Al6061 with reinforcement through stir casting process. It was observed that the increased content of alumina influences the hardness of the composites. Rajeshkumar Gangaram Bhandare [9 &10] et al. prepared
aluminium matrix composite by stir casting method with aluminium alloy (Al6061) is selected as matrix phase while SiC, Alumina and Graphite act as reinforcement phase. The composite shows improved mechanical and wear resistance properties than the parent alloy. G. Straffelini [11] et al. had prepared Al6061 with 20% Al2O3 as reinforcement. They had observed that the composite shows improved wear properties.

It was found that if the content of Al2O3 is larger in the matrix, then the ceramic particle does not distribute uniformly throughout the matrix and stagnate at certain regions and agglomeration effect occurs. In order to overcome that content of Al2O3 is restricted to maximum of 6% into the matrix. From the literatures, it was commonly found that most of the researchers have focussed upon improving the mechanical and tribological properties of Al6061 alloy. Only few of the researchers have concentrated on enhancing the corrosion resistance properties of Al6061 alloy. So this work encompasses with the preparation of Al alloy composite by stir casting process with Al6061 alloy as matrix phase and Al2O3 as reinforcement phase by different composition of 0%, 3% and 6% content into the matrix and evaluating the hardness, impact strength, compression strength and corrosion properties of the composite.

In the present work, an attempt has been made to synthesize Al6061-Al2O3 particulate metal matrix composites by liquid metallurgy route (stir casting technique). Aluminium metal matrix composite was fabricated with Al6061 alloy as a matrix and Al2O3 as a reinforcement material. Reinforcement was added in the range of 0, 3 and 6 percentage by weight into the molten alloy, hence the Al6061 metal matrix composite was produced and their properties were estimated.

2. Materials and Processing Techniques

Stir casting is a liquid state method of composite materials fabrication, in which a dispersed phase usually reinforcement, is mixed with a molten matrix metal by means of mechanical stirring.

![Stir Casting apparatus](image)

Figure 2.1 Stir Casting apparatus

The above figure 2.1 shows the stir casting processing apparatus setup. The matrix material is Al6061 aluminium alloy and the reinforcement material is Alumina (Al2O3). Three aluminium metal matrix composite samples of various compositions were prepared, manufactured and tested. Three composite specimens were generated with 0% Al2O3, 3% Al2O3 and 6% Al2O3. The stirring speed of the entire process is 600 rpm and it is stirred for a time interval of 15 minutes in closed environment. After stirring the molten metal is poured into the die and specimen of size 5cm x 5cm is produced.

3. Results and Discussion
3.1 Hardness testing

The prepared composite samples were subjected to hardness test and it is estimated through brinell hardness test apparatus. The term hardness refers to resistance to bending, scratching, abrasion or cutting.

The Brinell hardness number (BHN) was calculated using the formula,

\[ \text{BHN} = \frac{\text{Force on sample}}{\text{Area of indentation}} \]

\[ \text{Area of indentation} = \pi D(D-\sqrt{D^2-d^2}) \]

Force on sample = 500 kgf
D= Diameter of the indenter = 10mm
d= Diameter of indentation

| S.No | Specimen Composition       | Diameter of Indentation (mm) | BHN  |
|------|---------------------------|------------------------------|------|
| 1    | 100% Al6061 alloy         | 3.9                          | 19.02|
| 2    | 97% Al6061 alloy- 3% Al₂O₃| 3.9                          | 20.17|
| 3    | 94% Al6061 alloy - 6% Al₂O₃| 3.9                          | 21.28|

The prepared composite samples were subjected to hardness test and it is estimated through brinell hardness test apparatus. The above table 3.1 depicts the hardness number for both aluminium alloy and aluminium alumina composite samples. The hardness number of aluminium alloy at a load of 500kgf is 19.02 BHN. While at the same loading conditions,
the composite sample of 3% Al₂O₃ has a hardness of 20.17 BHN and the composite sample of 6% Al₂O₃ has a hardness of 21.28 BHN. From the results, it is clearly revealed that the hardness of the composite got increased when the content of Al₂O₃ in the Al6061 alloy matrix got increased. The composite samples have higher hardness number compared to alloy material. The reinforcement alumina particles hold the aluminium matrix material hold together strongly restricting the movement of matrix material.

3.2 Impact testing

![Impact testing apparatus](image)

The Izod Impact test consist of striking a suitable specimen with a hammer on a pendulum arm and the specimen is held securely as shown in the below figure 3.2. A notch is be made on the specimen to a depth of 2mm. The hammer strikes opposite to the notch. The energy absorbed by the specimen is determined by dial mounted inside the indicator. The dial gets displaced when decrease in motion of the pendulum arm occurs. The standard izod impact test specimen consist of a metal bar of 75x10x10mm having a notch machined across one of the larger dimensions as per ASTM standards.

| S.No | Specimen composition | Impact energy (joules) |
|------|----------------------|-----------------------|
| 1    | 100% Al6061 alloy    | 11.1                  |
| 2    | 97% Al6061 alloy-3% Al₂O₃ | 10.9              |
| 3    | 94% Al6061 alloy - 6% Al₂O₃ | 8.9               |

The above table 3.2 shows the results of aluminium alloy and its composite samples when subjected to izod impact test. Aluminium alloy without reinforcement samples had impact energy of 11.1 joules and composite samples of 3% and 6% reinforcement had impact energy of 10.9 and 8.9 joules respectively. From the table, it is inferred that the composite sample exhibits poor impact energy than the alloy samples. This is due to the reason that the reinforcement ceramic particulates impart lower toughness than the lighter matrix materials.

3.3 Compression test

Figure 3.3 shows the compression testing apparatus. This test is conducted to evaluate the compression strength.
Table 3.3 Compression testing results

| S.No | Specimen composition                  | Compressive Strength(N/mm²) |
|------|---------------------------------------|-----------------------------|
| 1    | 100% Al6061 alloy                     | 5.54                        |
| 2    | 97% Al6061 alloy- 3% Al₂O₃             | 6.44                        |
| 3    | 94% Al6061 alloy - 6% Al₂O₃            | 6.66                        |

The above table 3.3 shows the results of aluminium and its composite samples when they are subjected to compression test. Aluminium 6061 alloy sample had compressive strength of 5.54N/mm². While the composite sample of 3% reinforcement and 6% reinforcement have a compressive strength of 6.44 and 6.66 N/mm² respectively. The prepared composite sample shows an improvement in the compressive strength when compared to parent alloy. This shows that the ductile behaviour of aluminium have been gradually transforming to brittle nature. This transformation had occurred due to the reinforcement of hard ceramic alumina particulates into the soft ductile aluminium metal matrix.

3.4 Corrosion test

Corrosion is the gradual destruction of materials by chemical reaction with the environment. The below figure 3.4 shows how corrosion test was conducted.
The prepared samples should be weighed and submerged in concentrated hydrochloric acid for two days in a closed environment. After completion of two days, the dipped samples have to be taken out and weighed again and the difference in weight is noted and it is tabulated above in the table3.4. It is observed that the aluminium alloy sample have weight loss of 1.25gm and the composite sample of 3% Al₂O₃ and sample of 6% Al₂O₃ shows a weight loss 1.20 and 1.19gm respectively. It is revealed that comparatively more weight loss had occurred on the Al6061 alloy than the composite samples of various compositions. The alumina particulates improve the corrosion behaviour of composite samples and reduce the weight loss.

| Specimen composition | Initial weight (gm) | After 48 Hours (gm) | Difference on weight (gm) |
|----------------------|---------------------|---------------------|--------------------------|
| 100% Al6061 alloy    | 10.29               | 9.04                | 1.25                     |
| 97% Al6061 alloy- 3% Al₂O₃ | 11.67               | 10.47               | 1.20                     |
| 94% Al6061 alloy - 6% Al₂O₃ | 12.62               | 11.43               | 1.19                     |

4. Conclusion

Aluminium metal matrix composite was fabricated with Al6061 as matrix and Al₂O₃ as reinforcement through stir casting technique with by varying the ceramic content by three different compositions of 0%, 3% and 6% by weight. After preparation of specimens, the composite undergoes the following tests,

a. Micro-hardness of the composite increases with the increase in alumina content into the matrix
b. Compressive strength of the composite also increases with the increase in Al₂O₃ into the matrix
c. Along with these, the corrosion properties of the composite also steadily increases
d. With all these, the impact strength of the composite decreases with increase in the alumina weight

5. References

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