Retraction

Retraction: Experimental analysis and characterization of Mechanical, Physical properties of Aluminium (Al6061) Metal Matrix composite reinforced with SiC and Al₂O₃ using Stir casting (IOP Conf. Ser.: Mater. Sci. Eng. 1145 012109)

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[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

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Experimental analysis and characterization of Mechanical, Physical properties of Aluminium (Al6061) Metal Matrix composite reinforced with SiC and Al₂O₃ using Stir casting

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Abstract. Metal matrix is defined as two or more material mixing with each other, In these constituents, one is mainly metal and the other is non-metals such as ceramics, glass and rubber etc. There is a wide scope for metal matrix composites nowadays. Among various metal matrix composites, Aluminium MMC yields good results, when compared with other MMC (metal matrix composite). These reinforcements have much higher strength and wear resistance than pure aluminium. Multiple reinforcements in an aluminium metal matrix composite have a lot of potential. The use of metal matrix composites with Al6061 as parent material and infusion of reinforcements like Carbides, Oxides and Borides have resulted in materials with improved mechanical strength and usability. This paper contains the investigation of Mechanical Properties of Aluminium 6061 and Aluminium 6061 reinforced with SiC, Al₂O₃ particles. In this, we are focusing Al MMC by undergoing various tests such as impact, hardness and tensile tests. In the present work, aluminium matrix hybrid composite of Al6061+ X wt% of Al₂O₃ + Y wt% of SiC (X=2.5,5 % and Y=5,2.5%) was successfully fabricated by stir casting method. The effect of Al₂O₃ and SiC reinforced in the matrix were investigated through tensile test, impact test, hardness values and SEM analysis (for Morphological characteristics) and the best composition of AMMC matrix was determined.

Keywords: Aluminium Metal Matrix, Aluminium Oxide, Silicon Carbide, Stir Casting

1. Introduction
In recent trends, the scope of aluminium was vastly available. In these grade Al6061 is widely used in aircraft designing structural applications, boats and furniture for its high priority characteristics. Liquid state, semisolid state, and powder metallurgy are the three types of Al MMC manufacturing techniques available [1]. Compare to all other Al grades, Al6061 as a parent metal mixed with reinforcement SiC enhances the mechanical strength. The properties are determined by the amount of reinforcement (wt%), grain size, chemical reaction, and manufacturing process. In engineering and automobile fields instead of using heavy metal, (Bronze, cast iron) Al reinforced SiC can be replaced. As a light metal it results in enhanced
mechanical strength. Silicon Carbide (SiC), Alumina (Al₂O₃), Graphite (Gr), Silica (SiO₂), Boron Carbide (B₄C), Tungsten Carbide (WC), Granite dust, and Fly ash have all been identified as reinforcement materials for Al6061-based MMCs. Aluminium-based metal matrix composites have recently increased in popularity due to their low weight. However, in industries, pure aluminium does not meet our desired requirements. To solve this, an aluminium metal matrix reinforced with SiC and Al₂O₃ provides a better solution [2].

2. Methodology
The progression of the work is initiated with the literature survey in which the discussion has been made for selecting the materials. We selected Al 6061 grade, SiC and Al₂O₃ for the research [3]-[6]. The formation of the composition is carried by stir casting process with different ratios of three materials composition, then testing of the materials has been carried out. The work flow diagram is mentioned in Figure 1.

3. Experimental details
3.1 Material Selection
In this paper, we have selected Aluminium as a metal matrix and the reinforcement materials are Silicone Carbide and Alumina [7].

3.2 Matrix Material
Type 6061 aluminium is one of the most widely used aluminium alloys. Its weld-ability and formability make it suitable for many general-purpose applications [8]. The key properties of Al6061 are Density = 2.7 gm/cm³, Tensile strength = 310 MPa, Elastic Modulus = 68.9 GPa and Thermal Expansion Coefficient = 23.2 x 10⁻⁶/°C.

3.3 Reinforcement Materials
3.3.1 Aluminium Oxide. Al₂O₃ possesses a high thermal conductivity with good electrical insulation. Some key properties of Aluminium Oxide are Density = 3.98 gm/cm³, Tensile Strength = 416 MPa, Coefficient of Thermal expansion = 7.4, Modulus of Elasticity = 380 GPa [9].

3.3.2 Silicon Carbide. Silicon Carbide is a type of ceramic material have oxidation has resistance and high hardness. It has its application in automotive brakes and clutches [10]. It has the nature of low coefficient...
thermal expansion as 4.6 x 10^{-6}/°C. Some of its other key features are Density = 3.3 g/cm³, Tensile strength = 588MPa, Modulus of Elasticity = 345 GPa.

3.4 Fabrication Technique

In this project, the aluminium composite material is fabricated by stir casting fabrication technique. This process involves stirring of melted proportions. These techniques consist of an induction furnace with three mild steel stirrer blades [11]. By using mechanical stirring the reinforcement is distributed on the Aluminium matrix. At the time of the pre-heating stage, the reinforcements are isolated heated to 400°C, whereas Aluminium 6061 melted in a separate furnace at a temperature of 830 °C. Table 1 shows the weight percentage of Matrix and Reinforcement for different samples. Machined components are shown in Figure 2.

![Fabricated and machined Metal matrix component](image)

**Table 1. Compositions of Matrix and Reinforcement in wt%**

| Sample | Al 6061 (in %) | SiC (in %) | Al₂O₃ (in %) |
|--------|----------------|------------|--------------|
| 1      | 100            | -          | -            |
| 2      | 92.5           | 5          | 2.5          |
| 3      | 92.5           | 2.5        | 5            |

Then the above-mentioned proportions are blended and allowed to solidify. The distribution of reinforcement into the aluminium molten matrix depends on the fill actions such as the geometry of the mechanical stirrer, stirring speed, placement of the stirrer, melting temperature, and Characteristic of the particle is added [12]-[18].

4. Testing

The following tests are performed on the Aluminium 6061 Metal Matrix with reinforcements of Aluminium Oxide and Silicon Carbide in order to find the mechanical properties [19]. The table 2 shows about the various test carried out in the research period, purpose of the testing and the machines used in the testing process.

**Table 2. Testing and its purpose**

| Test No | Testing | Purpose | Machine Used |
|---------|---------|---------|--------------|--------------|
|         |         |         |              |              |


Tensile Test
To determine the ability of the sample to withstand the load before elongation.

Universal Testing Machine (UTM)

Yield Stress
To find the Yield point of the sample. Below this point the sample returns to its original shape and above this point the fracture occurs.

Universal Testing Machine (UTM)

Elongation
It is a measure of deformation that occurs before the sample breaks.

Universal Testing Machine (UTM)

Impact Test
To find the amount of energy absorbed by the sample during fracture.

Charpy Impact Test

Hardness Test
To find the Hardness property of the samples which we used.

Vickers Hardness Test

SEM Analysis
To analyse the wettability and bonding of the matrix metal with reinforcement.

FESEM MAKE Resolution 1.5 Nm

5. Result and discussion

5.1 Tensile test, Yield stress, Elongation
The Tensile test, Yield Stress and Elongation are performed using UTM (Universal Testing Machine) [20]. The results for these tests are presented in table 3.

Table 3. Tensile test, Yield Stress and Elongation test results

| Samples | Tensile Strength in MPa | Yield Stress in MPa | Elongation in % |
|---------|-------------------------|---------------------|-----------------|
| 1       | 154.52                  | 133.08              | 5.28            |
| 2       | 194.46                  | 167.43              | 4.36            |
| 3       | 129.03                  | 110.26              | 4.48            |

5.1.1 Tensile Test (in MPa). From the above table we came to know that the sample 2 has the high Tensile strength than others and sample 3 has the lower Tensile strength than others.

5.1.2 Yield Stress (in MPa). From the above table the Yield Stress is also same as the Tensile Strength result (i.e.) Sample 2 > Sample 1 > Sample 3.

5.1.3 Elongation (in %). The above table clearly shows us that Sample 1 has the greater elongation compared with Sample 2 and Sample 3. Whereas Sample 2 and 3 has slight difference in their Elongation property.

The overall comparison of the Mechanical Properties of the Metal matrix composites is mentioned in the Figure 3.
5.2 Impact test
The impact test for three samples is done by Charpy Impact test. The Impact test results for the respective samples are given in Table 4.

| Samples | Impact Values (in J) |
|---------|---------------------|
| 1       | 4                   |
| 2       | 6                   |
| 3       | 6                   |

From Table 4 we came to know that sample 1 absorbs less amount of energy compared with Samples 2 and 3. In case of reinforced samples the absorbs equal amount of the energy. The overall comparison for the impact test is shown in the Figure 4.

5.3 Hardness test
The Hardness Test are performed by Vickers Hardness test at 1 Kg load applied. The obtained results are shown in Table 5.
Table 5. Hardness Test Results

| Samples | Hardness Value (in HV) | Average value (in HV) |
|---------|-----------------------|----------------------|
| 1       | 71,73,72              | 72                   |
| 2       | 76,78,79              | 77.6                 |
| 3       | 64,68,67              | 66.3                 |

Figure 5. Comparison of Hardness values of Metal matrix composites

From the above table we observed that sample 2 has the highest Hardness value compared with others. The Hardness value is in the order Sample 2 > Sample 1 > Sample 3. The comparison status of the Hardness values is given in Figure 5

5.4 SEM Analysis

SEM (Scanning Electron Microscopy) is a test method that uses an electron beam to scan a sample and create a magnified image for analysis. SEM analysis gives us high-resolution imaging about an object [21]. This method is very useful to examine various material for fracture, flaws, contaminants or corrosion. SEM process involves scanning of an object or sample with an electron beam to produce a magnified image for analysis [22]. This method is also known as SEM microscopy and it has its opportunity effectively on both microanalysis as well as in failure analysis of solid materials. SEM has its scope in the field such as life science, geology, medical and metallurgy. Analysis of microstructure and chemical composition of samples were conducted on SEM [23].

SEM analysis for the samples is taken after completing tensile test [24]. Results shows that the tensile stress is being increased with increasing the percentage of particulates Sample 1,2,3 are compared by using SEM images, the sample 1 has 100% of Al6061, so the atom are tightly bonded and binding nature also very high. So, these is less no. of blow holes [25]. When compare to other samples. Sample 2 has Al6061 with 5% of SiC and 2.5% of Al2O3 where the blow hole is little higher than pure Al6061 and sample 3 blow holes are higher among the three [26].

SEM image of specimen after tensile test is shown in the Figure 6.
Figure 6. SEM image comparison of the metal matrix composites after tensile test
a) SEM image of the 100% Al6061, b) SEM image of metal composition with Al6061(92.5%), SiC(5%), Al₂O₃(2.5%), c) SEM image of metal composition with Al6061(92.5%), SiC(2.5%), Al₂O₃(5%)

SEM image of specimen after impact test is shown in the Figure 7.

Figure 7. SEM image comparison of the metal matrix composites after impact test
a) SEM image of the 100% Al6061, b) SEM image of metal composition with Al6061(92.5%), SiC(5%), Al₂O₃(2.5%), c) SEM image of metal composition with Al6061(92.5%), SiC(2.5%), Al₂O₃(5%)

6. Conclusion

In this paper, the Aluminium Metal Matrix Composite is fabricated by using Stir Casting method with different compositions of reinforcements such as alumina and silicon carbide at a wt% of 2.5% and 5% respectively and vice versa. These are the following conclusions that arrived after completing the Mechanical tests.

- The Tensile strength of the composites increases with the increase in wt% of Silicon Carbide.
- The energy absorbed by the sample 1 (Al 6061) is less than the other samples because of the absence of the reinforcement materials.
- The Hardness value is higher in the sample 2 (Al6061 with 5% of Sic and 2.5% of Al₂O₃) compared with the other two samples.
- In Conclusion sample 2 (Al6061 with 5% of SiC and 2.5% of Al₂O₃) has the superior mechanical properties than the other two specimens.
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