CHAPTER 4

STUDY OF MECHANICAL PROPERTIES OF Al-HMMC

4.1 INTRODUCTION

In engineering applications, the new generation of Al HMMC having excellent mechanical properties such as low density, lightweight with higher strength, a higher rate of hardness and stiffness to fulfil the current requirements. From the literature, it is evident that the existing work on aluminium reinforced composite makes more advantages in the industrial applications. To increase the industrial applications the present study finds such applications. The composites save material and energy. The specific requirement makes these materials more popular in a variety of applications such as aerospace, automotive (pistons, cylinder liners, bearings), and structural components.

In the present study, Al7075 alloy-based metal matrix composite reinforced with mixtures of silicon carbide (SiC) and graphite particles were fabricated by stir casting method. The mechanical properties such as Hardness, Tensile and Compressive strength were studied on developed samples according to ASTM standards. The hardness of the specimen was measured at room temperature. The magnitude of hardness increases naturally as the function of the volume fraction of the particle. The influences of SiCp and graphite reinforcement on tensile strength have been evaluated. The microstructure was also evaluated using SEM image. The results show that the reinforcement has been increased the mechanical properties.
4.2 EXPERIMENTAL PROCEDURE AND MATERIALS

This chapter describes the materials used for the fabrication of the metal matrix composites and the test methods employed to carry out this investigation. It presents the details of the tests related to the physical, mechanical and microstructure characterization of the prepared Al HMMC specimens. The methodology based on Taguchi experimental design and the prediction model is described in this part of the thesis.

The Aluminium 7075 metal matrix composite material used in the present study. Due to its advantages of weldability, formability and resistance to corrosion the alloy were chosen for this study. The size of the reinforcement particle was 8 – 12 µm approximately. Liquid metallurgy technique fabricated the composite. The parent metal was heated about 800-900°C for one hour. The reinforced alloy of SiC and graphite was introduced into the molten metal. The constant rotation of stirrer at 600 RPM was maintained about 8 minutes. The mixture of aluminium alloy with SiC and Gr composite poured into the preheated metallic moulds, and it was allowed for solidification.

Silicon carbide is composed of tetrahedra of carbon and silicon atoms with strong bonds in the crystal lattice. It gives a solid and hard material. Acids, alkalis or molten salts do not attack silicon carbide up to the temperature of 800°C. The higher thermal conductivity with low thermal expansion and high strength produces these material exceptional thermal shock resistant qualities. Some typical uses of silicon carbide are found in fixed and moving turbine components, seals, bearings, heat exchangers etc.

Key Properties of Silicon carbide

- Low density
- High strength
- Low thermal expansion
- High hardness
- High elastic modulus
- Excellent thermal shock resistance

![Silicon carbide particles](image)

**Figure 4.1 Silicon carbide particles**

**Table 4.1 Properties of Silicon Carbide**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>3.1 g/cc</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>550 MPa</td>
</tr>
<tr>
<td>Elastic Modulus</td>
<td>410 GPa</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.14</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>3900 MPa</td>
</tr>
<tr>
<td>Hardness</td>
<td>2800 Kg/mm²</td>
</tr>
<tr>
<td>Maximum Use Temperature</td>
<td>1650 °C</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>120 W/m°K</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>4.0 10−6/°C</td>
</tr>
</tbody>
</table>

**Properties of graphite**
It is the Anisotropic, Easy to shear between carbon layers and High electrical and thermal conductivity and high modulus in the plane of the carbon layers. Graphite is also used reinforcement for the prepared specimen.

Table 4.2 shows the weight percentage of reinforcement for preparing the Al HMMC specimen.

**Table 4.2 weight percentage of reinforcement of Al7075**

<table>
<thead>
<tr>
<th></th>
<th>Al7075</th>
<th>SiC</th>
<th>Graphite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80%</td>
<td>17%</td>
<td>3%</td>
</tr>
</tbody>
</table>

The following figure shows the prepared Al HMMC specimen samples. That material is used for the tests conducted in the present study.

**Figure 4.2 Al HMMC fabricated specimen using stir casting**

The following figure gives the experimental setup of the stir casting manufacturing method in the lab. Using the setup, the moulded specimen was prepared.
4.3 MECHANICAL PROPERTIES OBSERVATION

4.3.1 Micro-Hardness Measurement

Micro-hardness testing means for measuring the hardness of the material in the form of microscopic scale. Microhardness was calculated by using the digital micro-hardness tester. The applied load is used to calculate a hardness value using the procedure mention in the introduction part. The impression length measured microscopically, and the applied load are used to calculate a hardness value. The indentations are typically made using either a square-based pyramid indenter (Vickers hardness scale) or an elongated, rhombohedral- shaped indenter. The tester applies the selected test load using dead weights. The length of the hardness impressions was accurately measured with a light microscope using either eyepiece or a video image and using the software in the computer. The test load is used for calculating the hardness number. The impression length and a shape factor for the indenter type are used for the test.

Micro-hardness measurement is done by using a Hardness Tester. A diamond indenter, right pyramid form with a square base and an angle 136degree between opposite faces, is forced into the material under a load F.
The two diagonals, i.e. X and Y of the notch placed on the material’s surface following the ejection of load are evaluated. Then, the mean (arithmetic), L is computed. In this investigation, the load measured is F=50N while the Vickers hardness number is computed by employing the following equation.

\[ Hv = 0.1889 \frac{(F)}{(L/2)} \text{ and} \]
\[ L = \frac{(X + Y)}{2} \]

Where F represents the load applied (N), and L implies the diagonal of the square impression (mm). Furthermore, X represents the horizontal length (mm) while Y shows the vertical length (mm). The specimens were prepared from cylindrical casting bar as per ASTM E8-82 standards.

4.3.2 Hardness Testing

Hardness is the material property by good value of which the material resists to plastic deformation. The hardness test was performed on the developed cast material to find the effect of reinforcement of SiC and Gr. The well-cleaned and polished specimen was tested using Rockwell hardness. It is the most common method for determining the hardness of ferrous and nonferrous metals. The depth of indentation determined the hardness. ASTM -E-18 specifications is used to calibrate the Rockwell hardness tester. A 20mmx20mm size specimen was used for the test. A load of 750Kgf was applied on the test specimen for 8-10 secs. The test was repeated for a better understanding. The hardness value was taken directly from the machine.

The following specimen shows the impact on the specimen at the, time of hardness testing. (Figure 4.4)
Figure 4.4  Vicker's hardness test 7075 Al HMMC

Figure 4.5 shows Vickers testing machine which is used for conducting the Vickers hardness test.

Figure 4.5 Vicker's hardness test setup

![Vicker's hardness test setup]

Figure 4.6 Vicker's Hardness test value comparison chart

![Vicker's Hardness test value comparison chart]
Figure 4.6 shows the comparison of Vickers hardness value between the 7075 Aluminium and the 7075 Al HMMC. It shows that the hardness value of the prepared Al HMMC specimen is slightly increased from the base material.

4.3.3 Brinell Hardness Test Method

Figure 4.7 shows the Brinell testing machine which is used for conducting the Brinell hardness test. The carbide ball indenter is pressed into the sample by an actual test force. The force is maintained for 10 - 15 secs. After that, the indenter is removed leaving a round indent in the prepared specimen sample. The size of the indent is determined optically using a portable microscope or load application device.

Figure 4.7 Brinell hardness measuring setup

Figure 4.8 shows the comparison Brinell hardness value of 7075 and 7075Al HMMC.
From the figure 4.8, it is easily noticeable that the composite’s hardness is above that of its cast matrix alloy. The composites having superior filter matters display superior hardness. Further, it can be noted that the Al 7075-SiC-gr composite’s hardness is beyond that of the Al 7075 composite.

### 4.4 TENSILE TESTING

The tensile strength of material could be defined as the entire quantity of tensile stress that it can take before failure. According to ASTM E8 standard, the test specimen was prepared, having 8mm diameter and 60 mm gauge length as revealed in Figure 4.9. The specimen was loaded into the TUN400 Universal Testing Machine (UTM) until the failure occurred in the specimens. The tensile strength and yield strength were measured from the different specimen. Figure 4.9 shows the tensile test specimen before and after testing in UTM.
Figure 4.9 Tensile test specimens before and after testing

The experimental setup for tensile testing is as shown in the following Figure 4.10

Figure 4.10 Tensile Test-UTM machine Sample loaded condition for testing

Further, it can be noted that the tensile strength of the Al7075-SiC-gr composite is above that of the composite of Al7075. The prepared Al HMMC specimen tensile strength result taken from the test was compared with the parent matrix, and the graph was drawn (Figure 4.11).
Figure 4.11 Tensile strength value comparison chart

4.5 COMPRESSION TESTING

Measuring the compressive strength of any material is to find the capacity of the material when the axial force occurred on the material. The test results provide the details of force versus deformation. When the limit of compressive strength exceeds, the materials are crushed. In this research, the test was conducted by using Universal Testing Machine (TUN400). The size of the specimen was prepared as per the ASTM E8 standards. The specimen having the size of 20 mm in diameter and 20 mm of length was utilized in this current research. The specimen surfaces were polished with 1μm diamond paste before testing. The load is given by an equal interval, and the corresponding changes in length are noted until its breaking. The Figure 4.13 shows the compression test specimen after testing.

Figure 4.12 Compression test - Load, apply during the axial compression test
From the Figure 4.13, it can be noted that the new composite material accepts the compressive force and changes shown by the applied force. The behaviour of the compressive force of the test specimen can be seen from the curve and the compressive strength calculations.

4.6 MICROSCOPIC ANALYSIS

4.6.1 Optical Microscopy

To carry out the microstructural analysis of the formed composites, an examination was made via the optical microscope.

A part of the prepared castings was taken that was initially belt-grinded tracked by polishing using various grades of emery papers. Next, they were cleaned and once more polishing of the sample using cloth was completed. After etching using Keller’s reagent, they were analyzed regarding microstructure in the optimal microscope at various enlargements.

The specimens’ microstructure, sliced from the plate casting at various positions, was noted, to understand the distribution of the powders(Figure 4.14). For the current situation, powders were not constantly spreading during the casting. The powders were separated out at the top, bottom as well as sides of plates. The casting’s internal part enclose extremely little powders, while in the situation, reinforced particles are present all over the casting. The
powder delivery robustly impacts on the composites density. Therefore, the density spreading can be utilized as a gauge for powder spreading. Figure 4.14 reveals diagrammatically the powder spreading in the cast plates.

![Particle distribution in casting specimen](image)

**Figure 4.14 Particle distribution in casting specimen**

Figure 4.14 reveals the micrograph of the Al-HMMC sample. It contains two chief parts. The darker gray powders are particles of Silicon carbide(SiC), and the black particles are graphite. They are scattered by a matrix of aluminium.

### 4.6.2 Scanning Electron Microscopy

Microstructural characterization investigations were carried out on the non-fortified and fortified specimens. This is achieved through the employment of the scanning electron microscope. The composite specimens were polished in a metallographic manner before analysis. Characterization is achieved in the etched situation. Etching was achieved using Keller’s reagent. The SEM micrographs of composites were achieved by employing the scanning electron microscope. The images were obtained in both the Secondary Electron(SE) as well as backscattered Electron (BSE) form in line with the need. Microscopic investigations to analyze the microstructure, powder size as well as morphology were carried out through the Scanning Electron Microscope(SME) prepared by means of an energy dispersive X-ray(EDX) sensor of Oxford data reference scheme micrographs are obtained at
appropriate stepped up voltages for the most favorable resolution, employing the secondary electron imaging.

4.7 SEM ANALYSIS

The microstructure of the Al7075 with SiC and Gr composites were studied using Scanning Electron Microscope (SEM). A small sample was cut from the cylindrical specimen fabricated by stir casting process. The specimen was first ground using belt grinder and then polished using polishing papers of gradually increasing fineness. The polished sample was then lapped on the polishing machine using diamond-lapping paste and velvet cloth for about 30 minutes to achieve a mirror finish. The sample was etched with 5 % NaOH solution for about 45 seconds and washed with distilled water before the microstructural analysis. Then the SEM of Al-HMMC composite specimen used to study for microstructural analysis. From the microstructural analysis, it can be seen that the developed composite has a little amount of porosity and uniform dispersion of Sic and Gr. The reinforcement has good plasticity with parent material.

The SEM micrographs of Al-HMMC composites are shown in fig 4.15. The density, size, type of reinforcing particles, and its the distribution have a marked effect on the properties of particulate composites. The variables affecting the distribution of particles are solidification rate, fluidity, type of reinforcement, and the method of incorporation. Particles are uniformly throughout the casting during particulate composite production is essential. The first task is to get a uniform distribution of particles in the liquid melt and then to prevent segregation/agglomeration of particles during pouring and progress of solidification. One of the significant requirements for uniform distribution of particles in the melt is its wettability. The composite prepared samples are mounted on stubs with silver paste. To enhance the conductivity of the samples, a platinum thin film is vacuum-evaporated on the
samples before taken the photomicrographs. The following SEM images are taken for study the specimen.

![SEM images](image)

**Figure 4.15 Scanning electron microscope image of Al-HMMC surface**

It is evidence that there is no significant difference in grain size and appearance of the Al powder and the reinforcement. The SEM images exposed the presence of porosity in all the composites, and the extent of porosity present is more in case of the composites reinforced with SiC and Graphite. The reinforcement particles are homogeneously distributed in the matrix. The clustering of the reinforcing particles is negligible in all the composites engaged. The interfacial integrity was assessed regarding interfacial debonding and the presence of microvoids at the interface. The specimen SEM photographs of the composites show good interfacial integrity between the matrix and the reinforcements. The deficiency of debonding or discontinuity at the interface indicated better sintering.