# Investigation of Performance Characteristics in Al-SiC-$Al_2O_3$ Hybrid Metal Matrix Composites

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**ABSTRACT**:

*Aluminium based composites have superior strength, lightweight, high tensile strength, creep resistance and high-temperature resistance. Owing to these virtues they have found applications in aerospace and automobile industries. In this study, a modest attempt has been made to develop Aluminium-based Silicon Carbide and Aluminium oxide hybrid metal matrix composites. Usually, the reinforcements are strong with low densities while the matrix is usually a tough material. Aluminium has been chosen as matrix and Silicon Carbide and Aluminium Oxide are selected as reinforcement material. Different weight fractions such as 5%, 7.5% and 10% of Silicon Carbide and Aluminium oxide each were considered for making HMMC specimen. The processing temperatures selected are 700, 800 and 900 degrees Celsius.*

**Keywords**: **Composites, Matrix, Reinforcement, HMMC**.

## I. INTRODUCTION

Composite materials are expanding the limits of designers in all engineering branches. In composites, matrix and reinforcements are combined in such a way that enables us to make use of their advantages and at the same time minimizing to some extent their deficiencies. Composites present a lot more freedom for a designer with the selection and manufacture of superior materials. By combining materials of different properties as matrix and reinforcement, a designer can tailor composites to suit particular design requirements. And because of the ease with which it can be manufactured, composites can often lead to both cheaper and better solutions.

There are different methods available for manufacturing composites. Among them, stir casting method is most widely used for the manufacturing of MMC. The matrix material is to be melted in the furnace of the casting machine and then preheated reinforcement material is added to it which will solidify to provide the required composites. It is one of the simplest and cost-effective method adopted for the production of Metal Matrix Composites. The matrix material chosen is Aluminium. The Silicon Carbide and Aluminium Oxide particles are chosen as reinforcement for making MMC (The particle size is 320 meshes).

## II. SAMPLE PREPARATION

The method that has been employed in the manufacturing of the Al-SiC-Al2O3 hybrid metal matrix composites for the purpose of our study is Stir Casting. Nine sets of composite plates, each of size 100 mm x 100 mm were fabricated using this method. For this Aluminium, silicon carbide, Aluminium oxide and magnesium strip were required and purchased.

For each casting, the crucible should be filled with 1Kg of Aluminium. Crucible then placed in the main furnace and the heating starts to the required temperature range. At the same time, the required amount of Silicon Carbide and Aluminium Oxide are weighed and put it into another crucible. This crucible is placed in the preheater furnace and heated.

**Fig. 2.1 STIR CASTING MACHINE**

After the Aluminium gets melted, the preheated Silicon Carbide and Aluminium Oxide is added to the molten Aluminium along with magnesium foils. The stirring unit helps to get a uniform mixing of reinforcements. After proper stirring, the molten composite is taken out of the main furnace and poured into the mould. Mould is then opened and takes the composite plate out. This procedure is repeated for other compositions also.

The manufactured nine different sets of Al-SiC-$Al_2O_3$ hybrid metal matrix composites were needed to be cut into thin rectangle bars for the purpose of testing their individual values for Hardness and Toughness respectively. Intensive care should be taken while cutting the composites plates. Cutting was done using power hacksaw. Proper cooling was provided for heat dissipation.

The workpieces cut from plates were mainly of two dimensions. One is of 55mm for Izod Test and another one of 70 for Charpy Test. The workpieces for SEM analysis were cut in 10mm×10mm square sections with thickness 7mm. The cut workpieces were properly marked and stored in plastic covers so that mixing of workpieces and other confusions could be avoided. The workpieces were then ground and filed for proper surface finish. The V groves were also cut using a hacksaw and they are at a distance of 27.5mm from one side for both workpieces.

## III. TESTING PROCESSES

The tests were carried out with atmost care and precision. Accuracy of the testing machines wer important for precise results hence all the machines were caliberated before carrying out the actual testing. Proper lighting was also provided for better results.

### 3.1 HARDNESS TESTING

Testing of the composites samples remained a mandatory part of my work, as the essence of the study lies in the variation of strength-wise properties of the Al-SiC-Al2O3 hybrid metal matrix composites with respect to temperature and composition.

Brinnel Hardness Testing Machine is a materials testing machine or materials test frame, is used to test the hardness of materials. The hardness testing machine types HPO 250 was used. The specimen is set on an adjustable supporting table and subjected to load by an indentor of 2.5 mm diameter. The impression produced on the specimen is projected on a screen by an illuminating device and its dimension is found out from a scale fitted with the screen and hardness is calculated. Three workpieces were tested from each sample and diameter of impression was noted down and respective hardness was also calculated.

### 3.2 TOUGNESS TESTING

To test the toughness property of Al-SiC-$Al_2O_3$ hybrid metal matrix composites with respect to temperature and composition, the Izod test and Charpy test were conducted using impact testing machine. The testing machine consists of two controlling levers, one for raising the pendulum and others for fixing the specimen. The impact value of the test specimen is read on the dial which has a live pointer and recording pointer. The impact values for each sample were noted down in Charpy as well as Izod test and toughness was calculated.

### 3.3 SCANNING ELECTRON MICROSCOPY ANALYSIS

For analysing the microstructure of the composites sample SEM analysis was done. It was conducted at Sophisticated Testing and Instrumentation Centre (STIC), CUSAT, Cochin.

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## IV. EXPERIMENTAL RESULTS

### 4.1 HARDNESS TEST

The hardness of the prepared specimen is estimated using Brinnel Hardness Testing Machine where the specimen is loaded with 187.5 Kg of load using an intender. From the diameter of the impression, the hardness of the composites was calculated. Calculated values for different composites samples were tabulated and graphs were also plotted.

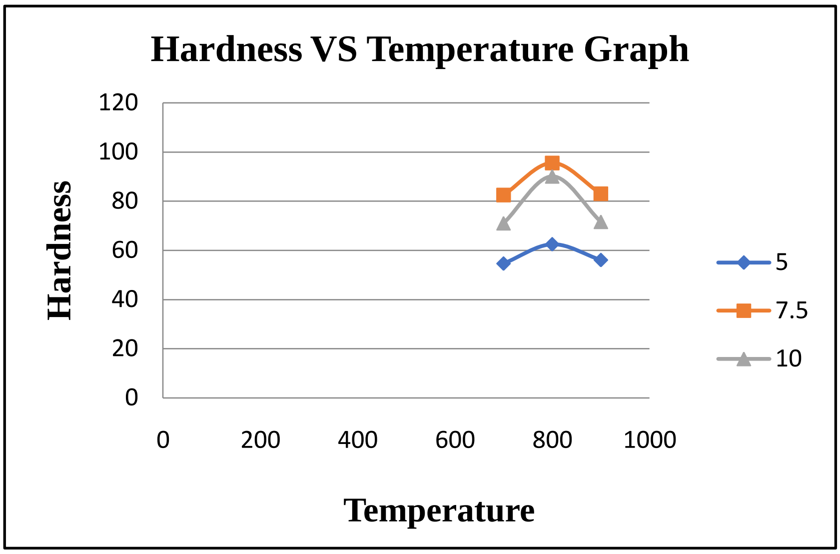


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**Fig. 4.1 Hardness vs Temperature Graph**

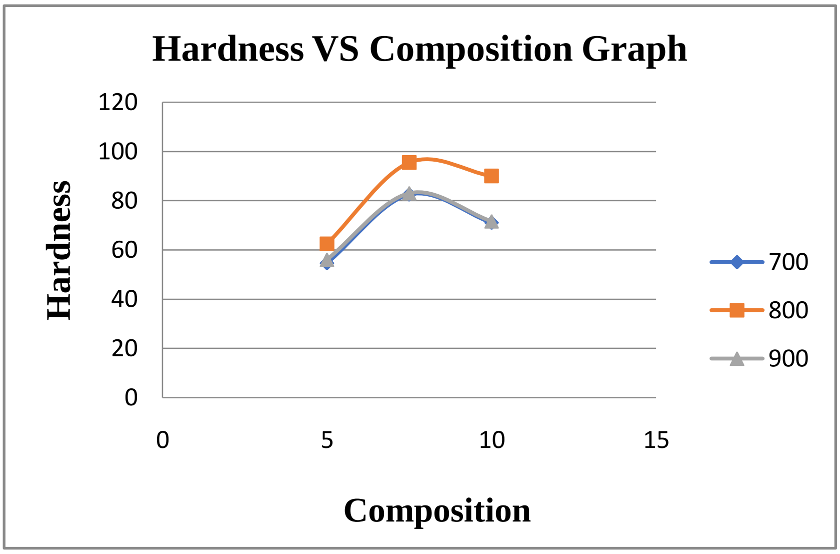


**Fig. 4.2 Hardness vs Composition Graph**

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### 4.1.1RESULTS OF HARDNESS TEST

After testing of samples, it was observed that the hardness of Al-SiC-$Al_2O_3$ is high for sample 5 which is having a composition of Al+7.5%SiC+7.5% $Al_2O_3$ processed at $800^0$C. The hardness of the samples increases as the temperature increases from $700^0$C to $800^0$C and then decreases as the temperature increased from $800^0$C to $900^0$C. The hardness of the samples increases as the composition increases from 5% to 7.5% and then decreases as the composition increased from 7.5% to 10%.

### 4.2 TOUGHNESS TEST

Charpy test and Izod test were conducted to measure the toughness of the prepared specimen is estimated using. From the angle of the rise of the dial, the toughness of the composites was calculated.

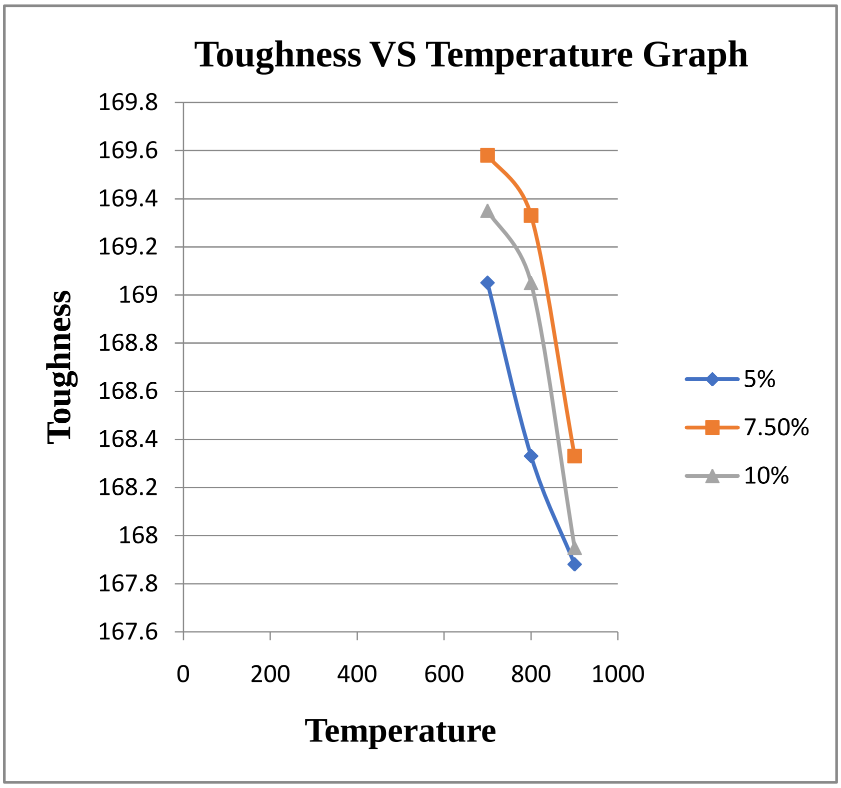


**Fig. 4.3 Toughness vs Temperature graph**

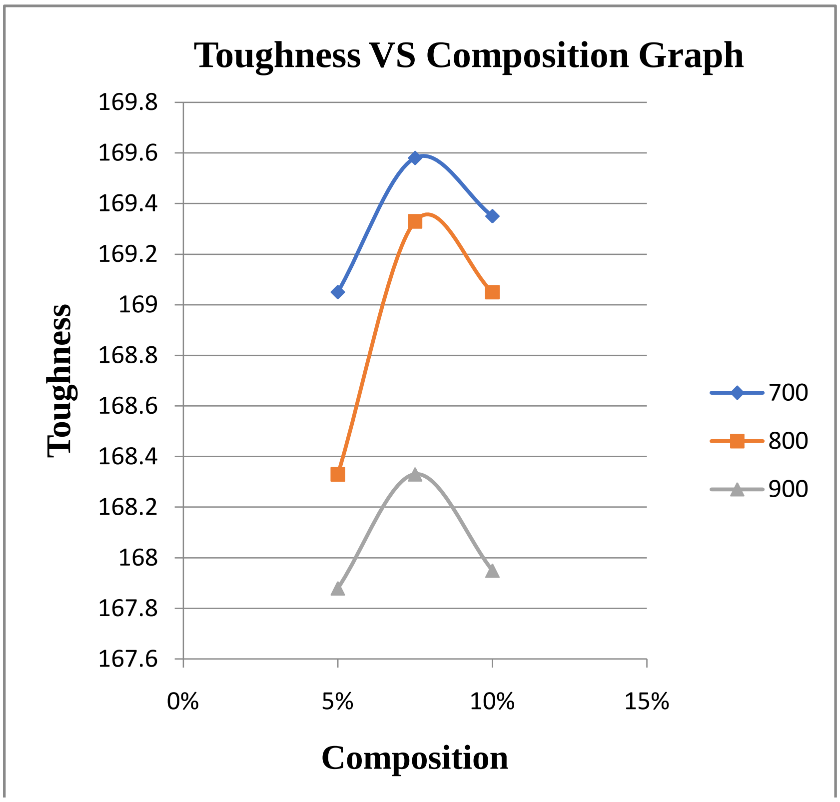


**Fig. 4.3 Toughness vs Composition graph**

### 4.2.1 RESULTS FOR TOUGHNESS TEST

After testing of samples, it was observed that the toughness of Al-SiC-$Al_2O_3$ is high for Sample 4 which is having a composition of Al+7.5%SiC+7.5% $Al_2O_3$ processed at $700^0$C. The toughness of the samples decreases as the temperature increases from $700^0$C to $900^0$C. The toughness of the samples increases as the composition increases from 5% to 7.5% and then decreases as the composition increased from 7.5% to 10%.

### 4.3 SEM ANALYSIS

Analysis of microstructure and chemical composition of samples were conducted on SEM. The following are their results. Each combination consists of three images of different zoom levels, i.e. 500X, 1500X& 3000X. This SEM image shows the presence of silicon carbide and aluminium oxide particles. The presence of SiC and $Al_2O_3$particle in the images has increased with the increase in the percentage of the addition of SiC and Al2O3 in different combinations. These microstructure analyses were conducted at CUSAT, Cochin.

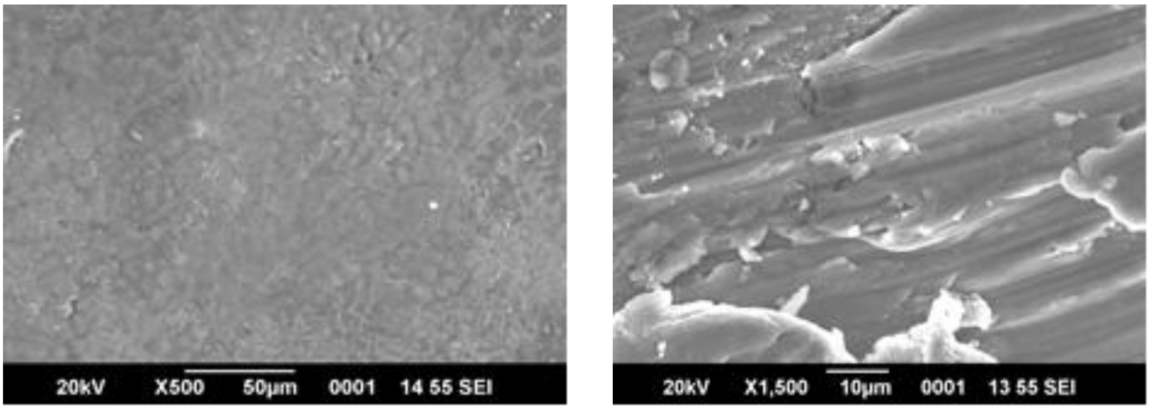


**FIG. 4.4 SEM IMAGES**

## V. CONCLUSION

Each workpiece was subjected to Charpy Test and Izod Test using Toughness Testing Machine and Hardness test using Brinnel Hardness Machine. The obtained readings were carefully analyzed and represented graphically. The hardness of the samples increases as the temperature increases from $700^0$C to $800^0$C and decreases when temperature increased from $800^0$C to $900^0$C.The hardness of the samples increases as the composition increases from 5% to 7.5% and then decreases as the composition increased from 7.5% to 10%. The toughness of the samples decreases as the temperature increases from $700^0$C to $900^0$C. The toughness of the samples increases as the composition increases from 5% to 7.5% and then decreases as the composition increased from 7.5% to 10%. SEM image shows the presence of Silicon Carbide and Aluminium oxide.

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