Development of AA7075/ nano SiC composite through permanent mold stir casting technique and testing of its mechanical properties

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***Abstract*- In this experiment, the nano-SiC particles are introduced to the A7075 alloy while it is still liquid, followed by permanent mold stir casting. There were four different weight fractions used: 0 wt%, 0.5 wt%, 1 wt%, and 1.5 wt%. The addition of nano-SiC particles was done at three different percentages. Composites were treated using stir casting and a permanent mold die. A specialized mold can be used to create test specimens for tensile and microhardness. Tensile testing was used to measure the aluminum composites' fracture strength. The lowest average strength (254 MPa) and lowest average yield strength (106 MPa) were found in the 0 wt% nano SiC aluminum matrix composites. The greatest average strength (316 MPa) and highest average yield strength (106 MPa) were found in the 1.5 wt% composites. Hardness tests were carried out to determine the maximum value. The hardness values for the cast specimens increased from 102 to 115 Vickers (10 kg), respectively, as the concentration of nano-SiC particles increased from 0 to 1.5 wt%.**

***Index Terms*- Nano SiC, AA7075, Strength, Hardness, and Composite.**

I. INTRODUCTION

To boost the strength and stiffness of the matrix in the majority of composites, reinforcing is often applied to the matrix of the bulk material [1-8]. Reduced structural weight can be achieved by decreasing material density while simultaneously increasing stiffness, yield strength, and ultimate tensile strength. As appealing alternatives to the current high-strength aluminum alloys and titanium alloys, this prompted the aerospace industry to develop and study novel materials possessing combinations of reduced density, enhanced stiffness, and high strength. The high-strength metal-matrix composites [6,7] combine the high strength and hardness of the reinforcing phase with the ductility and toughness of the light metals. Additionally, the aim to significantly enhance structural efficiency, dependability, and overall performance through a decrease in absolute weight or an increase in strength-to-weight ratio has given birth to the need for improved design techniques. Through the creation of reinforced lightweight alloys, recent research findings have made it conceivable to foresee combining these effects [8,9]. The metal-matrix composites' benefits are crucial for their selection and application as structural materials. Some of these benefits include the ability to combine high strength, high elastic modulus, high toughness, and high impact resistance; low sensitivity to temperature changes or thermal shock; high surface durability; low sensitivity to surface flaws; high electrical and thermal conductivity; minimal exposure to the potential issue of moisture absorption leading to environmental degradation; and improved fabricability with conventional metal working equipment [10,11].

Reinforcements are usually made of ceramic, with the exception of wires, which are made of metal. These ceramics are often oxides, carbides, and nitrides, chosen for their superior synergy of specific strength and stiffness at low and high temperatures. The three main particle reinforcements that have been employed are silicon carbide, boron carbide, and aluminum oxide. These are available with various degrees of purity and size dispersion. The techniques utilized to create these materials' whiskers also yield silicon carbide particles [10,12]. The particulate-reinforced metal-matrix composites have shown promise for usage in a variety of commercial, military, and aerospace applications [2,14]. The creation of reinforcing material, which offers either enhanced qualities or lower cost when compared to the current monolithic materials, has contributed to the resurgence of interest in metal-matrix composites [9,10]. Particulate-reinforced metal matrices have drawn a lot of interest due to the affordability of a variety of reinforcements, the development of manufacturing techniques that successfully produce metal matrix composites with repeatable microstructures and properties, and the availability of standard and nearly standard metalworking techniques that can be used to create these materials.

Additionally, using discontinuous reinforcements reduces issues like fiber degradation, microstructural heterogeneity, mismatched fibers, and interfacial reactions that can arise when fabricating continuous-reinforced metal-matrix composites. The discontinuously-reinforced metal-matrix composites have been demonstrated to provide near isotropic properties with significant improvements in strength and stiffness compared to those offered by the monolithic materials for applications subjected to heavy loads or extreme thermal fluctuations, such as in automotive components [12,13]. An aluminum alloy reinforced with silicon carbide is the most popular type of particle composite system. The 2xxx and 6xxx series alloys have been selected as matrices the majority of the time thus far. A lot less research has been done on the 7xxx series alloys reinforced with silicon carbide particulates, despite the fact that these alloys have the highest strength of all commercially available aluminum alloys and are frequently used in structural applications [14–18].

Stronger composites often result from stronger matrix alloys. However, these composite systems have elements that affect the mechanical characteristics, such as particle size, weight/volume fraction, and aging state [16–20]. This study aims to examine the mechanical behavior of permanent mold stir-cast composites made from AA7075 matrix and strengthened with silicon carbide.

II. EXPERIMENTAL PROCEDURE

The matrix material, AA7075, a wrought alloy, was selected. Zinc is a significant alloying component. Magnesium is the second, and it is primarily included to improve wetting between the matrix and the reinforcing phase. In Table 1, the AA7075's chemical makeup is listed.

Table 1 Chemical composition (wt%) of AA7075

Cu	Mg	Zn	Cr	Fe	Si	Ti	Mn	Al
1.6	2.7	5.8	0.26	0.4	0.40	0.2	0.3	Balance

Casting procedure

For this experimental work, an electric arc induction furnace, a permanent mold die, and stir casting were employed. From the induction furnace's graphite crucible, a homogenous liquid phase was created. After obtaining the alloy melt, nano silicon carbide powder was added to the molten metal and stirred for a few seconds. The liquid metal was then poured into the permanent mold die and left there until the proper solidification occurred in the mold. The specimen was then ready for mechanical testing and was taken out for machining. The casting in a permanent mold is seen in Fig. 1 and 2.

The melting point of the AA7075 was reported at 980–1080^{o}C during the melting, mixing, and casting of the metal matrix composition. For every single percentage reinforcement of 0 wt%, 0.5 wt%, 1 wt%, and 1.5 wt% nano SiC composites, this procedure has been repeated. For each nano SiC composition, three specimens were produced at each casting process. The following casting accepts the addition of wt% of nano SiC by continuing the same process. All cast material was sampled following machining for tensile testing, hardness testing, and SEM as listed in Table 2.

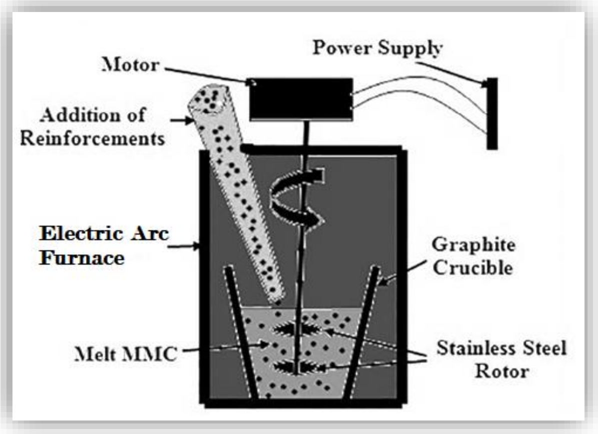


Fig 1 Casting process

Fig 2 Castings

Table 2 Casting composition

Cast No.	Castings
1	AA7075 + 0 wt% nano SiC
2	AA7075 + 0.5 wt% nano SiC
3	AA7075 + 1 wt% nano SiC
4	AA7075 + 1.5 wt% nano SiC

Mechanical testing

Tests for microhardness and tensile strength were performed. All compositions were evaluated using three specimens in as-cast circumstances. Additionally, the three cast tensile test specimens on all compositions underwent testing. During the tensile test, load versus elongation data were obtained. Additionally, the ultimate tensile strength values were assessed. The greatest loads that were observed were translated from kilograms to maximum stress values (MPa). The lengths of the tensile test samples were compared before and after breakage, and the cross-sectional areas of the samples were assessed. For the purpose of preventing the notch effect, all of the burrs were ground. The elongation percentage is also computed.

Tensile test

Four different composite alloys with contents of 0 wt%, 0.5 wt%, 1 wt%, and 1.5 wt% were used as the specimens for the tensile test. To create the test specimens for the tensile test, Wt% nano SiC was treated using a vertical permanent mold die-casting procedure. Make three distinct samples for each and every composition. Then, only the burrs were removed from the tensile test specimens before the mechanical testing after the machining on the lathe. Figures 3 and 4 provide the sizes and forms of the test specimens used for tensile testing. Figure 5, 6, and 7 shows the stress-strain diagrams, ultimate tensile strengths, and average yield strength.

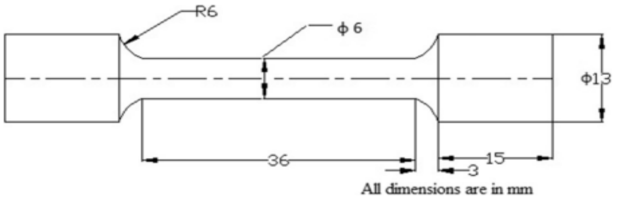


Fig 3 Tensile test design

Fig 4 Tensile test specimen

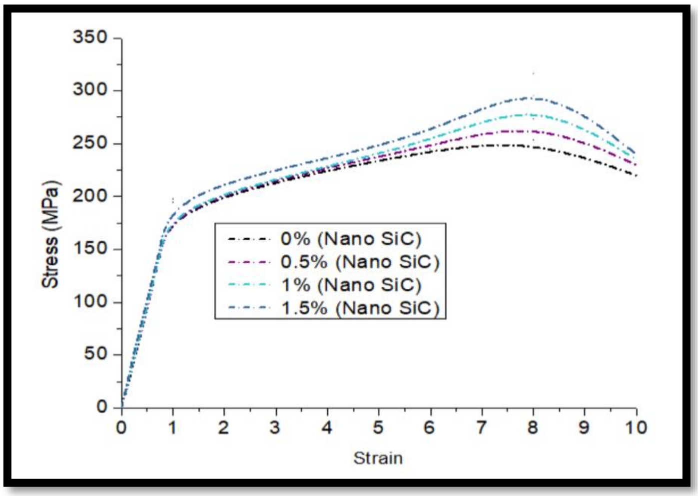


Fig 5 Stress-strain graphs

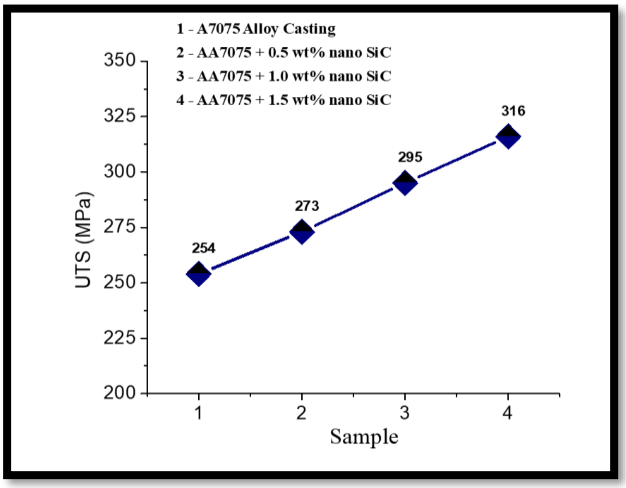


Fig 6 Average ultimate tensile strengths graphs

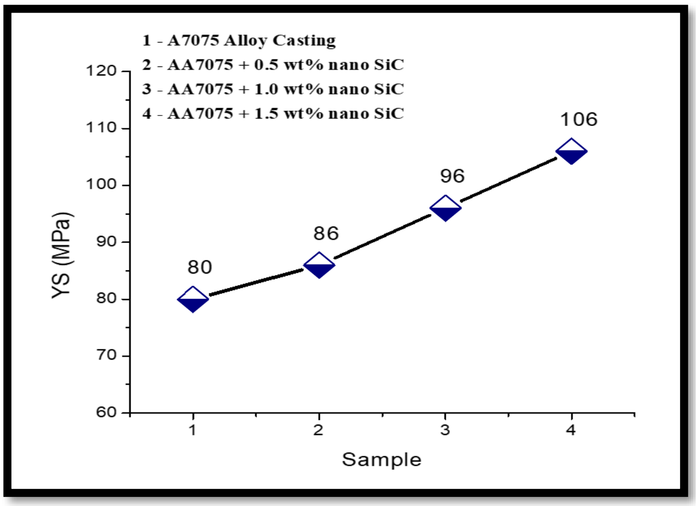


Fig 7 Average yield strength graphs

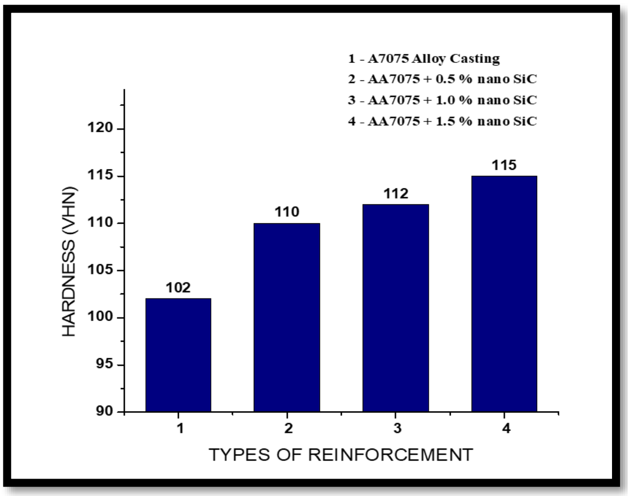


Fig 9 Average hardness bars of four composition

Table 3 Tensile strength observation

Sample No.	Sample Identification	Avg. UTS (MPa)	Avg. YS (MPa)	Percentage of elongation
1	(A7075 Alloy Casting)	254	80	3.40
2	(AA7075 + 0.5 wt% nano SiC)	273	86	2.45
3	(AA7075 + 1.0 wt% nano SiC)	295	96	2.30
4	(AA7075 + 1.5 wt% nano SiC)	316	106	2.10

Hardness test

Since hardness is a measure of a material's resistance to plastic deformation, hardness tests were performed to examine the impacts of silicon carbide's weight-percent addition on the AA7075 matrix. The cast material was divided into three pieces for each composition in order to prepare for the hardness test, and its surface was finely policed using emery paper. Now, three samples of each % variation of nano-SiC were manufactured, assessed by the Vickers hardness test (VHN), and the average result is given in table 4 as illustrated in figures 8 and 9.

Fig 8 Hardness test specimen

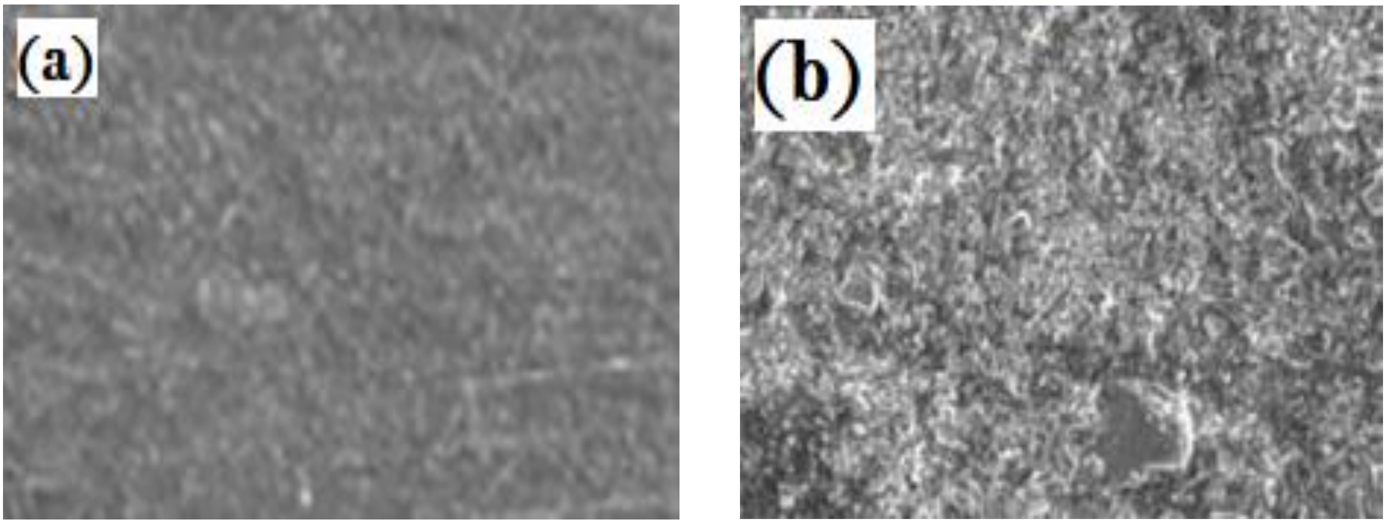
Fig 10 Scanning electron microscope specimen

Table 4 Hardness test results of the cast specimens measured by Vickers (VHN) test applied load (9.8 N) with the diamond indenter.

Measurement no.	1	2	3	Average
AA7075 + 0wt% nano SiC	101	103	102	102
AA7075 + 0.5 wt% nano SiC	108	111	111	110
AA7075 + 1wt% nano SiC	110	112	114	112
AA7075 + 1.5wt% nano SiC	116	114	115	115

III. RESULT AND DISCUSSION

The 7075 composites were permanently molded, die stir cast, and the micro SiC particles were distributed uniformly throughout. The 0 wt%, 0.5 wt%, 1 wt%, and 1.5% nano SiC particles in an AA7075 matrix are depicted in Fig. 10 and 11 by scanning electron microscope sample specimens and micrographs. When the nano SiC particles are near to one another, some agglomeration has been seen, but no sign of porosity has been found. The matrix's greater ability to saturate with hydrogen gas during solidification is demonstrated by this. The fracture behavior of the silicon carbide-added aluminum matrix composite underwent tensile testing to disclose varied silicon carbide addition percentages. Upon surface inspection, all of the specimens displayed brittle fracture behavior. The die-cast AA7075 composites created and described in this work have a maximum strength of 1.5 wt% nano SiC reinforced aluminum matrix composites. The strength improved by around 316 MPa above the aluminum alloy matrix when the optimal conditions for 1.5 wt% nano SiC reinforcement were reached. This increases flexural strength and strain hardening. Tensile testing was performed on both the aluminum matrix composites and the as-die cast composites. The tensile test findings for matching nano SiC concentrations of 0.5, 1, and 1.5% usually enhanced composition strength values. By SEM micrograph analysis, no Al_3C_4 was found.



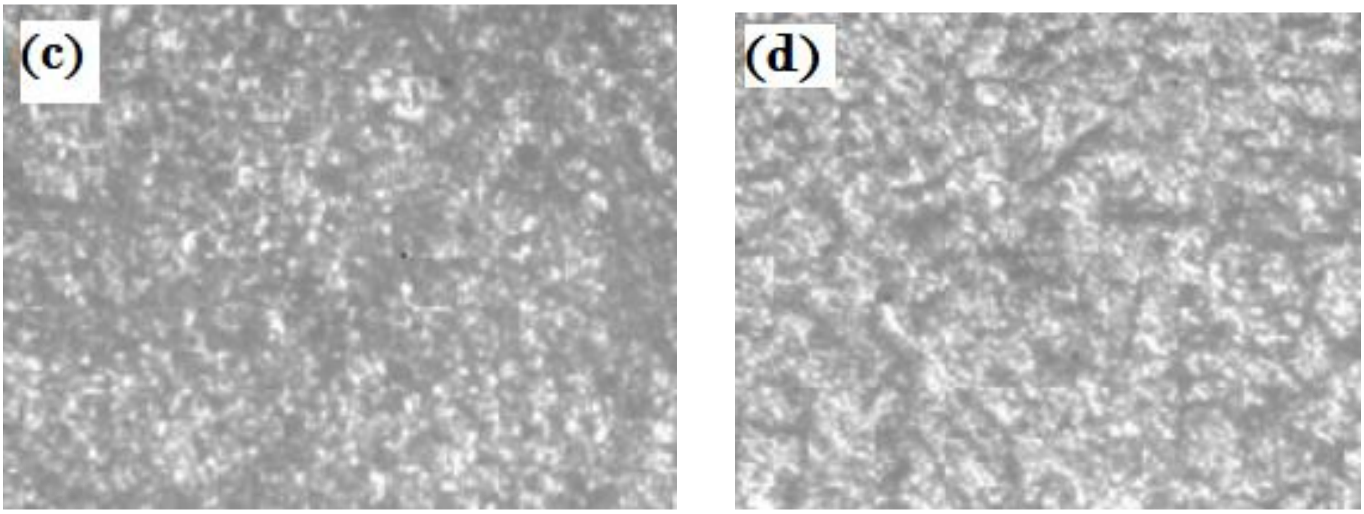


Fig 11 SEM micrographs (a) AA7075 + 0 wt% nano SiC, (b) AA7075 + 0.5 wt% nano SiC, (c) AA7075 + 1wt% nano SiC and (d) AA7075 + 1.5 wt% nano SiC

IV. CONCLUSION

1. In tensile testing, the composites containing 1.5 wt% nano silicon carbide showed the greatest strength, whereas the composites containing 0 wt% nano SiC had the lowest tensile strength.
2. In several of the tensile test specimens, tiny silicon carbide particles clumped together.
3. The 1.5 wt% nano silicon carbide showed the highest hardness values, while the 0 wt% nano silicon carbide showed the lowest hardness values.
4. The composites' hardness was steadily raised. In comparison to the as-cast hardness measurements, the maximum hardness values are 11.4% higher.

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