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

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***Abstract-* In this experiment, the micro-SiC particles are introduced to the A7075 alloy while it is still liquid, followed by permanent mold stir casting. The weight fractions used were 0, 5, 7.5, and 10 percent. The addition of micro-SiC particles was carried out at four different percentages. Composites were prepared via stir casting and a permanent mold. 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 (80 MPa) were found in the 0 wt% micro SiC aluminum matrix composites. The greatest average strength (309 MPa) and highest average yield strength (103 MPa) were found in the 10 wt% composites. Hardness tests were carried out to determine the maximum value. The hardness values for the cast specimens increased from 102 to 114 Vickers (10 kg), respectively, as the concentration of micro-SiC particles increased from 0 to 10 wt%.**

***Index Terms-* Strength, hardness, composite, and Micro SiC**

I. INTRODUCTION (HEADING 1)

In the majority of composites, reinforcement is frequently added to the matrix of the bulk material [1–8] to increase its strength and stiffness. By reducing material density while concurrently raising stiffness, yield strength, and ultimate tensile strength, structural weight can be reduced. This inspired the aerospace industry to develop and explore innovative materials featuring combinations of decreased density, higher stiffness, and high strength as enticing alternatives to the present high-strength aluminum alloys and titanium alloys.

The high-strength metal-matrix composites [6,7] combine the ductility and toughness of the light metals with the high strength and hardness of the reinforcing phase. Additionally, the need to dramatically improve structural dependability, efficiency, and overall performance by reducing absolute weight or raising the strength-to-weight ratio has created a demand for better design methodologies. Recent research results have made it possible to envisage integrating these effects through the development of reinforced lightweight alloys [8,9].

The advantages of metal-matrix composites are essential for their selection and use as structural materials. One of these advantages is the ability to combine high strength, high elastic modulus, high toughness, and high impact resistance; another is the low sensitivity to temperature changes or thermal shock; a third is the high surface durability and low sensitivity to surface flaws; a fourth is the high electrical and thermal conductivity; a fifth is the reduced exposure to the potential issue of moisture absorption leading to environmental degradation; and finally, the improved fabricability with conventional metal working equipment [10,11]. With the exception of wires, which are composed of metal, reinforcements are typically made of ceramic.

Because of their superior synergy of specific strength and stiffness at low and high temperatures, oxides, carbides, and nitrides are frequently used as these ceramics. Silicon carbide, boron carbide, and aluminum oxide have been used as the three principal particle reinforcements. These come in a range of purity and size dispersion levels. Particles of silicon carbide are also produced by the processes used to make the whiskers of these materials [10,12]. The use of particulate-reinforced metal-matrix composites in a range of industrial, governmental, and aerospace applications has shown promise [2,14].

The development of reinforcing elements that are either more cost-effective or offer better properties than the existing monolithic materials has helped revive interest in metal-matrix composites [9,10]. Due to the accessibility of numerous reinforcements, the development of manufacturing processes 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 produce these materials, particulate-reinforced metal matrices have attracted a lot of interest. Furthermore, the problems associated with creating continuous-reinforced metal-matrix composites, such as fiber deterioration, microstructural heterogeneity, mismatched fibers, and interfacial reactions, are diminished when discontinuous reinforcements are used. For applications subjected to heavy loads or extreme thermal fluctuations, such as in automotive components, the discontinuously reinforced metal-matrix composites have been shown to provide near isotropic properties with noticeably better strength and stiffness compared to those offered by the monolithic materials [12,13].

The most common kind of particle composite system is an aluminum alloy reinforced with silicon carbide. So far, the bulk of matrices have been chosen from the 2xxx and 6xxx series alloys. Despite having the greatest strength of any commercially available aluminum alloys and being commonly utilized in structural applications, far less study has been done on the 7xxx series alloys reinforced with silicon carbide particles [14–18]. Stronger matrix alloys frequently lead to stronger composites. Particle size, weight/volume ratio, and aging condition are among the factors that have an impact on these composite systems' mechanical properties [16–20]. This work seeks to investigate the mechanical behavior of silicon carbide- and AA7075-based permanent mold stir-cast composites.

II. EXPERIMENTAL PROCEDURE

The wrought alloy AA7075 was chosen as the matrix material. Significant alloying elements include zinc. The second is magnesium, which is used largely to enhance wetting between the matrix and the reinforcing phase. Table 1 lists the chemicals that make up the AA7075.

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

This experimental endeavor made use of a permanent mold die, an electric arc induction furnace, and stir casting. The induction furnace's graphite crucible generated a homogenous liquid phase. After reaching the alloy melt, nano silicon carbide powder was added, and the mixture was quickly stirred. The liquid metal was then poured into the permanent mold die, where it was kept until the mold properly formed. After that, the specimen was removed for machining and made ready for mechanical testing. The casting in a permanent mold may be seen in Figures 1 and 2. During the melting, mixing, and casting of the metal matrix composition, the melting temperature of the AA7075 was recorded as 980–1080°C. This technique has been carried out for each percentage reinforcement of 0 wt%, 0.5 wt%, 1 wt%, and 1.5 wt% micro SiC composites. Three specimens for each micro SiC composition were created throughout each casting procedure. The same procedure is used in the subsequent casting to accept the addition of wt% of micro SiC. Following machining, samples of all cast material were taken for tensile testing, hardness testing, and SEM, as shown in Table 2.

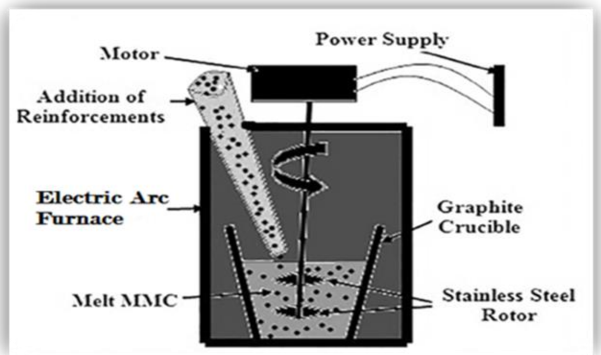


Figure- 1: Casting process

Figure- 2: Castings

Table- 2: Casting composition

Cast No.	Castings
1	AA7075 + 0 wt% micro SiC
2	AA7075 + 5 wt% micro SiC
3	AA7075 + 7.5 wt% micro SiC
4	AA7075 + 10 wt% micro SiC

Mechanical testing

Tensile strength tests and microhardness tests were conducted. Three samples of each composition were used for evaluation under as-cast conditions. The three cast tensile test specimens on all compositions were also put through testing. Data on load vs. elongation were collected during the tensile test. Values for the ultimate tensile strength were also evaluated. Maximum stress values (MPa) were converted into kilograms to represent the highest loads that were seen. Before and after breakage, the lengths of the tensile test samples were compared, and the cross-sectional areas of the samples were evaluated. All of the burrs were ground in order to avoid the notch effect. The percentage of elongation is also calculated.

Tensile test

The specimens for the tensile test consisted of four distinct composite alloys with compositions of 0%, 5%, 7.5%, and 10%, respectively. Wt% micro SiC was given a vertical permanent mold die-casting treatment to produce the test specimens for the tensile test. Create three unique samples for each composition. Following the machining on the lathe, only the burrs were removed from the tensile test specimens before the mechanical testing. The sizes and shapes of the test specimens used for tensile testing are shown in Figures 3 and 4. The stress-strain graphs, maximum tensile strengths, and average yield strengths are shown in Figures 5, 6, and 7.

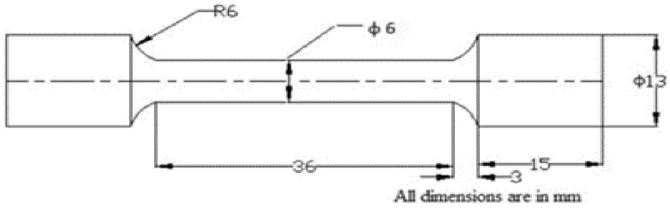


Figure- 3: Tensile test design

Figure- 4: Tensile test specimen

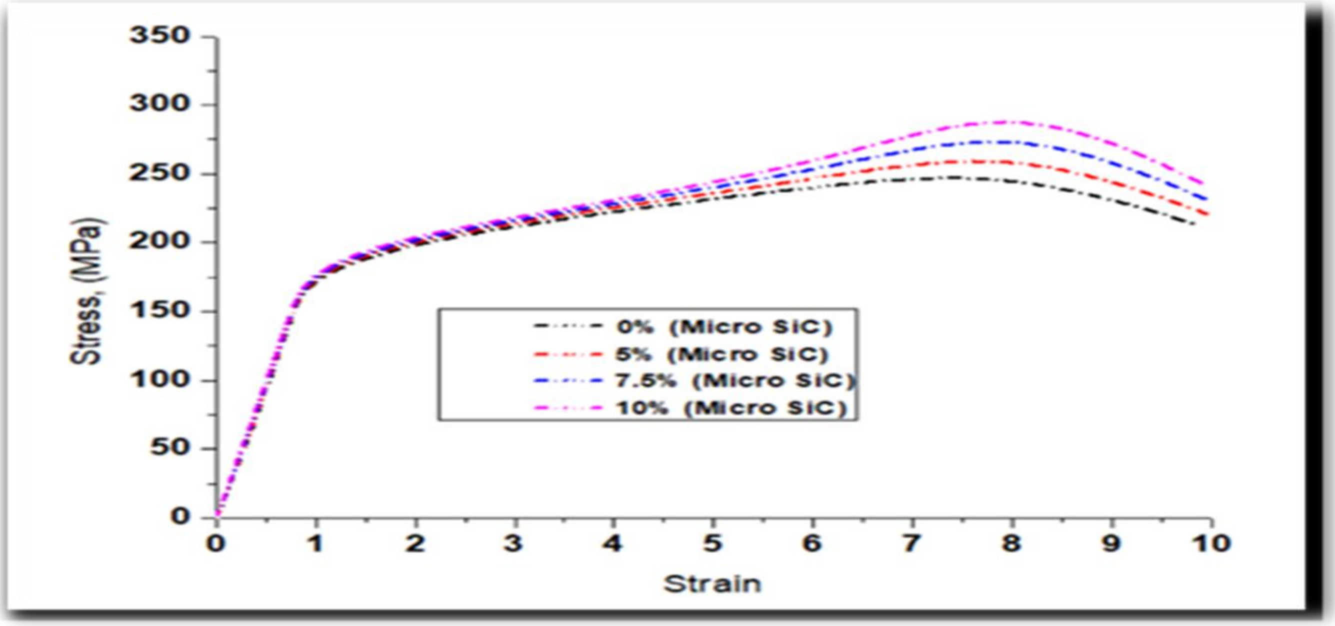
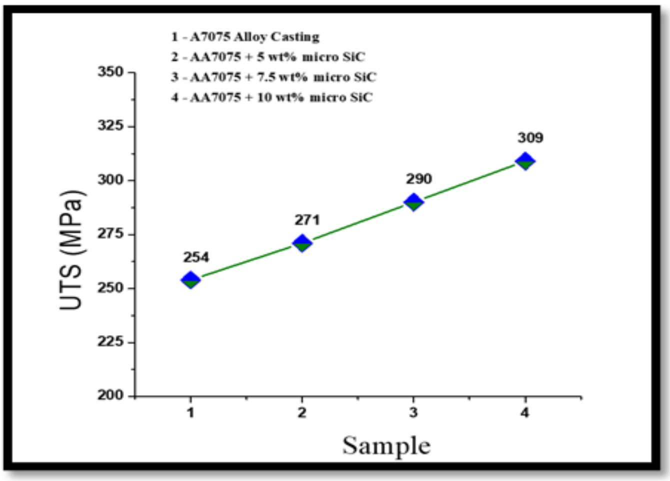


Figure- 5: Stress-strain graphs



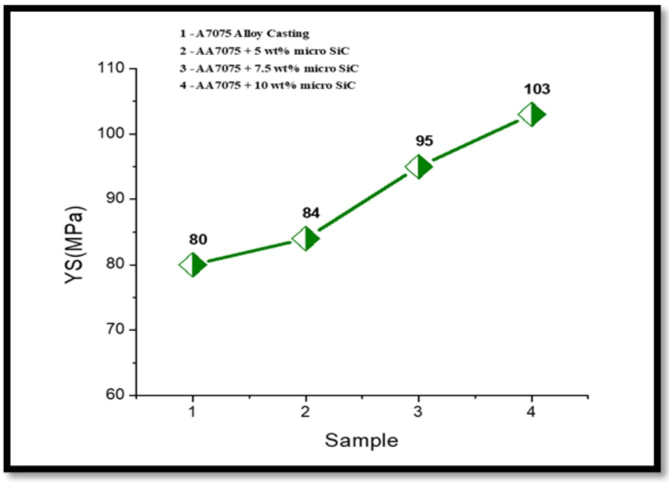


Figure- 6: Average ultimate tensile strengths graphs

Figure- 7: Average yield strength graphs

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 + 5 wt% micro SiC)	271	84	2.20
3	(AA7075 + 7.5 wt% micro SiC)	290	95	2.15
4	(AA7075 + 10 wt% micro SiC)	309	103	2.0

Hardness test

Hardness tests were carried out in order to investigate the effects of silicon carbide's weight-percent addition on the AA7075 matrix since hardness is a measure of a material's resistance to plastic deformation. For the hardness test, the cast material was separated into three pieces for each composition, and its surface was finely policed using emery paper. The Vickers hardness test (VHN) was used to evaluate three samples of each percent variation of nano-SiC. The average result is shown in Table 4 and is seen in Figures 8 and 9.

Figure- 8: Hardness test specimen

Figure- 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% micro SiC	101	103	102	102
AA7075 + 5 wt% micro SiC	106	104	105	105
AA7075 + 7.5wt% micro SiC	108	110	112	110
AA7075 + 10wt% micro SiC	112	114	116	114

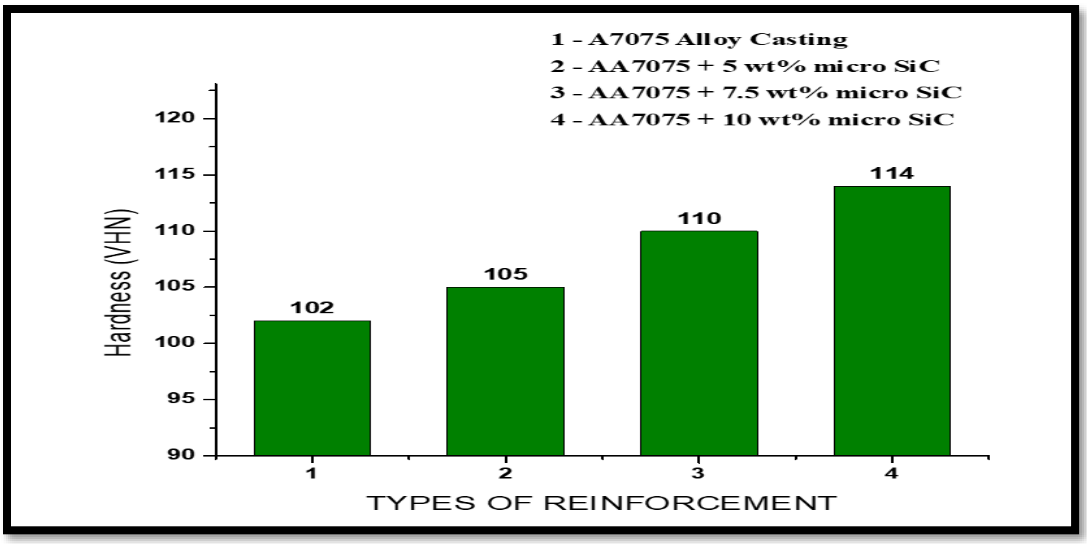


Figure- 9: Average hardness bars of four composition

III. RESULT AND DISCUSSION

The tiny SiC particles were evenly dispersed throughout the die stir-cast, permanently molded 7075 composites. Figures 10 and 11 show a scanning electron microscope sample specimen and micrographs of the 0 weight percent, 5 weight percent, 7.5 weight percent, and 10 weight percent micro SiC particles in an AA7075 matrix. There is some agglomeration when the micro SiC particles are close to one another, but no evidence of porosity has been discovered. This shows the higher hydrogen gas saturability of the matrix during solidification. Tensile testing was used to analyze the fracture behavior of the silicon carbide-added aluminum matrix composite and reveal different silicon carbide addition percentages. All of the specimens showed brittle fracture behavior upon surface observation. The die-cast AA7075 composites developed and discussed in this study have an aluminum matrix composite maximum strength of 10% micro SiC reinforced. When the ideal circumstances for 10 wt% micro SiC reinforcement were achieved, the strength increased by around 316 MPa over the aluminum alloy matrix. Flexural strength and strain hardening are increased as a result. Both the aluminum matrix composites and the as-die cast composites underwent tensile testing. The composition strength values for matching micro SiC concentrations of 5, 7.5, and 10% were typically increased by the tensile test results. Analysis of SEM micrographs revealed no Al_3C_4.

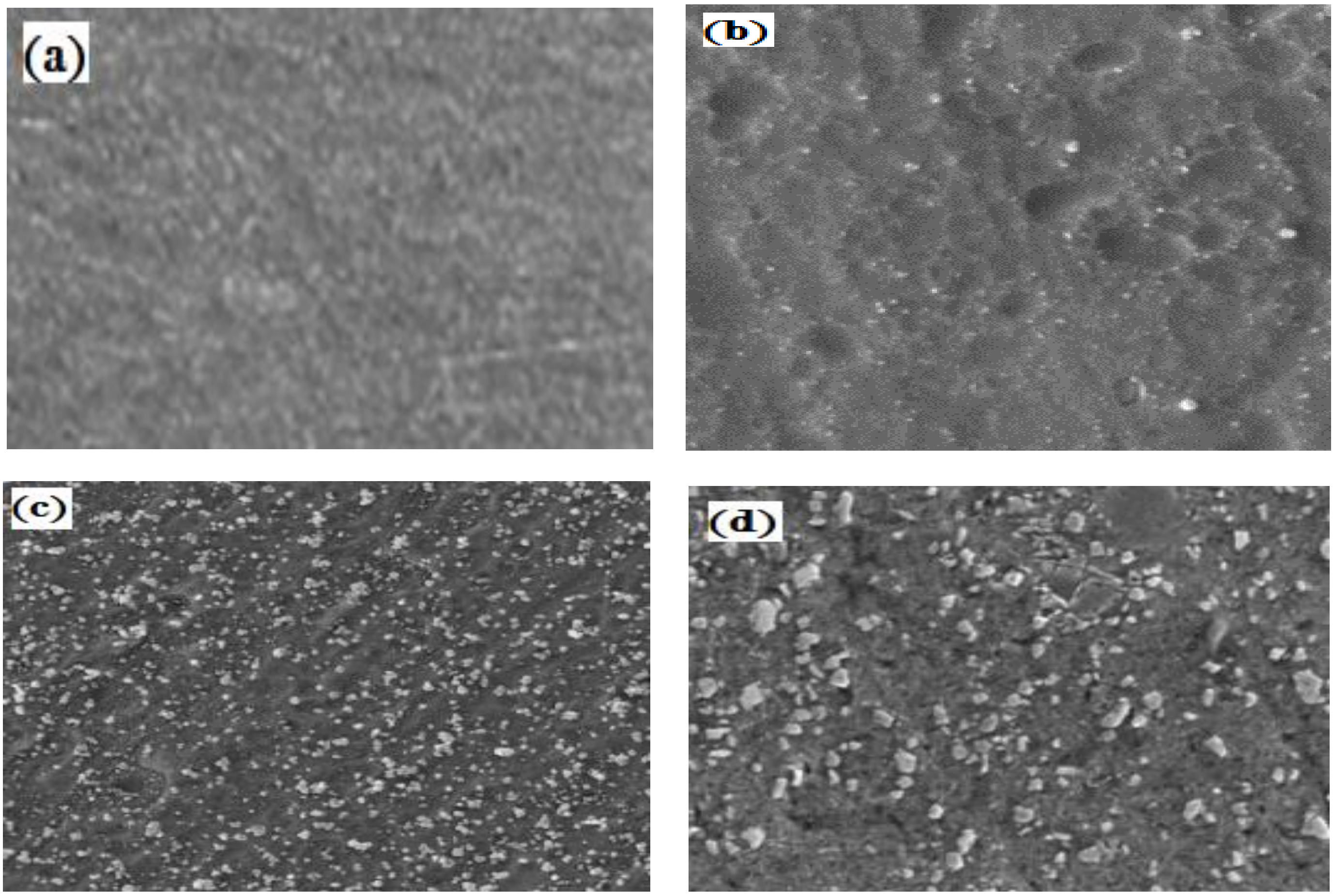


Figure- 11: SEM micrographs (a) AA7075 + 0 wt% micro SiC (b) AA7075 + 5 wt% micro SiC (c) AA7075 + 7.5 wt% micro SiC and (d) AA7075 + 10 wt% micro SiC

IV. CONCLUSION

1. The composites containing 10 weight percent of micro silicon carbide demonstrated the highest strength in tensile tests, whereas the composites containing 0 weight percent of micro SiC had the lowest tensile strength.
2. Tiny silicon carbide particles gathered in a few of the tensile test specimens.
3. The hardest samples were those containing 10 weight percent of micro silicon carbide, whereas the softest samples included 0 weight percent of micro silicon carbide.
4. The hardness of the composites was gradually increased. The maximum hardness values are 10.5% greater than the as-cast hardness data.

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