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Macrostructure and Mechanical Properties of AA6082/SiC Composite Produced By Mechanical Stir Casting Process

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Abstract

In the present study, AA6082/SiC metal matrix composite with different size of reinforcements (75µm, 50µm and 25 µm) were fabricated by mechanical stir casting route. Macrostructural analysis, tensile test, hardness test, impact test were performed to find out microstructure and mechanical properties of the metal matrix composites. Minimum porosity was observed for the 25 µm of silicon carbide. The mechanical properties showed that the reduction of the size of SiC particles led to the improvement in tensile strength, hardness and toughness. It indicates that size of reinforcement is the effective factor influencing the mechanical properties.

1. Introduction

Aluminium alloys have important advantages in relation with other structural alloys, because of their higher specific mechanical strengths and corrosion resistance. When an aluminium alloy is reinforced with ceramic particles, an increase in specific strength and stiffness can be obtained, controlling other interested properties [1]. Mechanical properties are one of the most relevant current fields of research. The events that occur on the surface, such as wear, corrosion or stress concentration create regions prone to crack nucleation, which under static or dynamic loading will eventually lead to most components and structures failures. These result in important losses in repairs or unscheduled maintenance operations [2]. Aluminum alloy (AA) 6082 is a precipitation-hardenable medium-strength alloy with excellent corrosion resistance. In addition, it has the highest strength in the 6xxx series. As a result of its high strength-to-weight ratio and specific stiffness, AA6082 (Al–Mg–Si alloy) is being extensively used in automotive and shipbuilding industries and recently is being used for aerospace applications in the form of forged products and in dissimilar joints with high strength aluminum alloys of the 2xxx. In solid solution alloys, alloying elements dissolve in the matrix to form solid solutions but in heat treatable alloys, some part of the solute elements interact with each other to form intermetallic phases. AA6082 contains magnesium and silicon as major alloying elements [3]. The demand for improved light weight structural designs has drawn increasing focus to the development of Metal Matrix Composites (MMC). One strategy to improve the strength to density ratio of the existent light weight alloys consists on adding reinforcements to their composition, such as, fibbers or particles. If these reinforcements are coherent with the metallic matrix, they will induce local strain fields upon loading, which can impair the movement of dislocations and, as such, contribute to enhance hardness and toughness. MMC are attractive as they present improved stiffness, creep and wear resistance in comparison with the base material properties [4].

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2. Selection of the Material

2.1 Matrix material

In the present work, AA 6082 has been selected as a matrix material. Aluminium alloy 6082 is a medium strength alloy with excellent corrosion resistance. It has the highest strength of the 6000

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series alloys. Alloy 6082 is known as a structural alloy. In plate form, Aluminium alloy 6082 is the alloy most commonly used for machining. As a relatively new alloy, the higher strength of Aluminium alloy 6082 has seen it replace 6061 in many applications. The addition of a large amount of manganese controls the grain structure which in turn results in a stronger alloy [5].

Table: 1. Typical chemical composition for aluminium alloy AA6082

Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
0.7-1.3	0.5	0.1	0.4-1.0	0.6-1.2	0.2	0.25	0.1	Balance

Table: 2. Typical mechanical properties for aluminium alloy AA6082

Property	Value
Proof Stress 0.2% (MPa)	60
Tensile Strength (MPa)	130
Shear Strength (MPa)	85
Elongation A5 (%)	27
Hardness (BHN)	40
Density (kg/m^3)	2700
Melting Point (^{0}C)	555

2.2 Reinforcement

The additions of reinforcements in metal matrix considerably obtain better the wear, thermal and mechanical properties. Silicon Carbide (SiC) is collected of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice [6].

Table: 3. Properties of Silicon Carbide [15]

Melting point temperature	2200-2700^{0}C
Hardness (Vickers)	2800-3300
Density (g/cm^3)	3.2
Crystal structure	Hexagonal

3. Experimental Procedure

The mechanical stir casting set-up is shown in Figure 1. Three different size of reinforcement (25 μm, 50 μm and 75μm of SiC) are fabricated with AA6082 aluminum alloy. Silicon carbides are preheated at 500 K for 1 h prior to introduction into

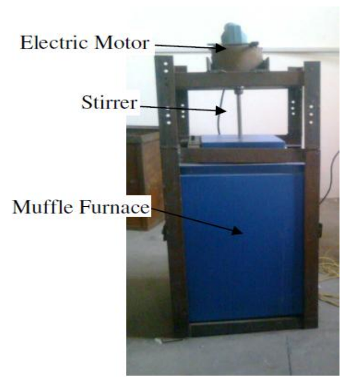

Fig: 1. Experimental Set-up of Mechanical Stir Casting Process

the melt AA6082 alloy. The temperature inside the furnace is controlled about to 750^{0}C. The stirring is continued before the composite is not reached in mushy zone. The cooling is done in the furnace.

4. Results and Discussions

4.1 Macrostructure analysis

The macrostructures of the AA6082/SiC composites used to observe the quality of the composites. Figures 2(a), 2(b) and 2(c) show three representatives macrostructure for the AA6082/SiC metal matrix composites. The macrostructure of the AA6082/SiC composites showed that SiC particles were distributed uniformly, and very low porosity for 25 μm silicon carbide reinforcement (Figure 2 (c)).

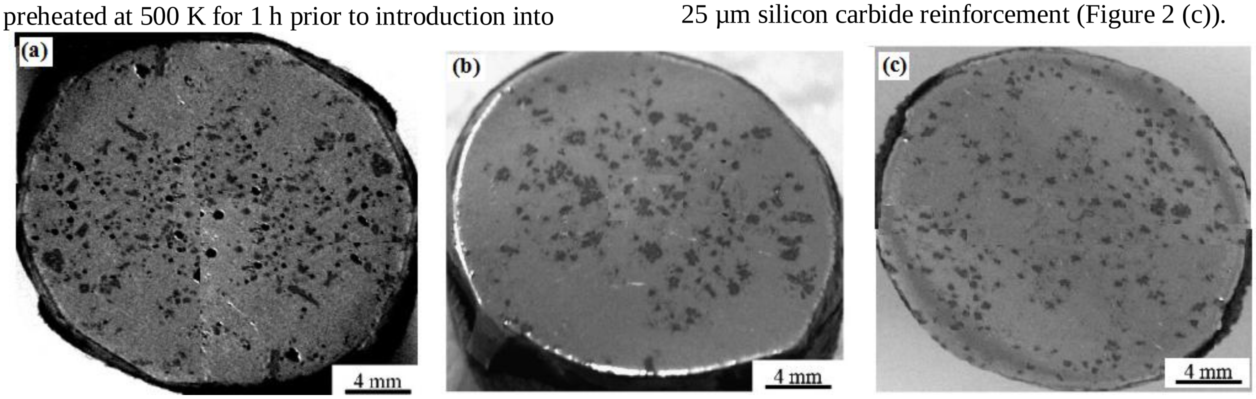

Fig: 2. Macrostructure of AA6082/SiC MMC: (a) 75 μm of SiC, (b) 50μm of SiC, (c) 25 μm of SiC

4.2 Percent Porosity Analysis

It can be observed from Table 4 and Figure 3 that porosity of samples for sizes 25 µm, 50 µm, 75 µm of reinforcements are 2.44 %, 3.49 % and 6.29 % respectively. On the basis of porosity measurement [7], it can be winded up that percent porosity increases with the size of reinforced silicon carbide particles.

Table: 4. Percentage Porosity of AA6082/SiC metal matrix composite

Metal Matrix Composite ($AA6082/SiC_p$)	Theoretical density (g/cm^3)	Percentage porosity	
		Experimental Density (g/cm^3)	Percentage Porosity
$AA6082/SiC_p$ (25 µm)	2.86	2.79	2.44 %
$AA6082/SiC_p$ (50 µm)	2.86	2.76	3.49 %
$AA6082/SiC_p$ (75 µm)	2.86	2.68	6.29 %

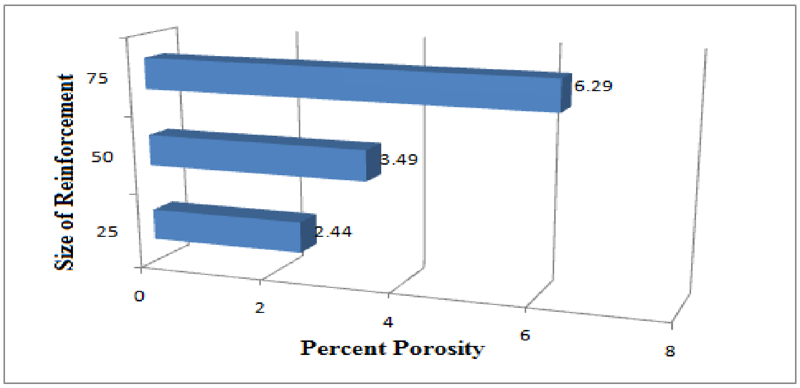

Fig: 3. Percentage Porosity of AA6082/SiC metal matrix composite

4.3 Tensile Strength Analysis

For tensile testing of AA6082/SiC metal matrix composite fabricated by mechanical stir casting process, three samples for each size of reinforcement have been prepared. Table 5 and Figure 4 presented tensile strength of AA6082/SiC metal matrix composite for 25 µm, 50 µm, 75 µm of reinforcements are 149.33, 138.66 and 137.33 respectively. From here, it can be concluded that reduction the size of silicon carbide particle results in an increase in the tensile strength.

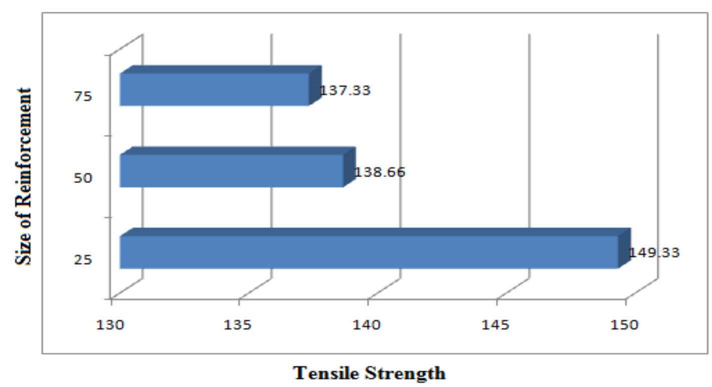

Fig: 4. Tensile strength of AA6082/SiC metal matrix composite

Table: 5. Tensile strength of AA6082/SiC metal matrix composite

Metal Matrix Composite ($AA6082/SiC_p$)	Sample Number	Tensile strength (MPa)	Average Tensile strength (MPa)
$AA6082/SiC_p$ (25 µm)	1	145	149.33
	2	148	
	3	155	
$AA6082/SiC_p$ (50 µm)	1	139	138.66
	2	145	
	3	132	
$AA6082/SiC_p$ (75µm)	1	145	137.33
	2	131	
	3	136	

4.4 Hardness Analysis

For hardness testing, three samples of AA6082/SiC metal matrix composite from each size of reinforcement have been prepared as per dimension (10 mm x 10 mm x 25 mm). Brinell hardness of AA6082/SiC composite is associated with the allocation of SiC particles in the AA6082 alloy. If distributions of the SiC particles are good then hardness of AA6082/SiC composites is high. It can be seen from Table 6 and Figure 4 that average hardness for 25 µm, 50 µm, 75 µm of reinforcements are 52.33 BHN, 48.33 BHN and 47.33 BHN respectively.

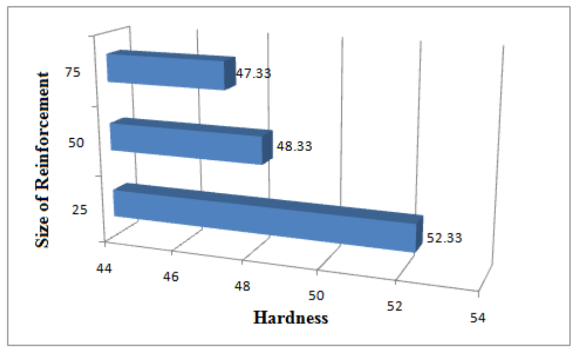

Fig: 5. Hardness of AA6082/SiC metal matrix composite

Table: 6. Hardness of AA6082/SiC metal matrix composite

Metal Matrix Composite ($AA6082/SiC_p$)	Sample Number	Hardness (BHN)	Average Hardness (BHN)
$AA6082/SiC_p$ (25 µm)	1	49	52.33
	2	55	
	3	53	
$AA6082/SiC_p$ (50 µm)	1	57	48.33
	2	43	
	3	45	
$AA6082/SiC_p$ (75µm)	1	41	47.33
	2	58	
	3	43	

4.5 Toughness Analysis

According to EN 10045 standard, three specimens from each size of reinforcement (10 mm x 10 mm x 55 mm) have been prepared. The toughness of AA6082/ SiC composites is shown in Table 7 and Figure 5. It was found, average toughness of samples for 25 µm, 50 µm, 75 µm of reinforcements are 10.33 joule, 6.66 joule and 6.16 joule respectively.

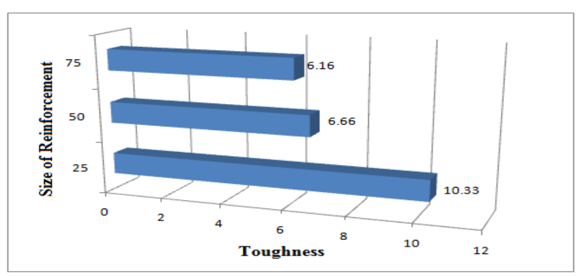

Fig: 5. Hardness of AA6082/SiC metal matrix composite

Table: 7. Toughness of AA6082/SiC metal matrix composite

Metal Matrix Composite ($AA6082/SiC_p$)	Sample Number	Toughness (Joule)	Average Toughness (Joule)
$AA6082/SiC_p$ (25 µm)	1	9	10.33
	2	10.5	
	3	11.5	
$AA6082/SiC_p$ (50 µm)	1	7.5	6.66
	2	6.5	
	3	6	
$AA6082/SiC_p$ (75µm)	1	6	6.16
	2	6	
	3	6.5	

5. Conclusions

AA6082/SiC composites [8] for different size of reinforcement (25 µm, 50 µm, 75 µm) were fabricated by mechanical stirring. By studying the properties of AA6082/SiC metal matrix composite, following conclusions can be drawn:

1. Very low percentage porosity was observed for 25 µm silicon carbide particle.
2. The tensile strength for 25 µm, 50 µm, and 75 µm is 149.33 MPa, 138.66 MPa and 137.33 MPa respectively.
3. From the results, hardness of samples for 25 µm, 50 µm, and 75 µm is 52.33 BHN, 48.33 BHN and 47.33 BHN respectively.
4. The value of toughness of AA6082/SiC composites for 25 µm, 50 µm, and 75 µm is 10.33 joule, 6.66 joule and 6.16 joule respectively.

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