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Investigation on Tensile and Impact Behavior of Aluminum Base Silicon Carbide Metal Matrix Composites

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Abstract

Objectives: The scope of this work was to: 1. to fabricate Silicon Carbide (SiC) particle Metal Matrix Composites (MMC) by vortex method; 2. to investigate the effect of SiC particles on the tensile and impact behavior of SiC particle reinforced 6061 aluminum alloy composites. Recently, the material technology has seen many contemporary developments in the field of fabricating new materials which reinstates the current materials for different applications. Amidst these, the composite materials have an important aspect which is a combination of different materials possessing various physical and chemical properties. **Methods:** This Aluminum base metal Matrix Composite (AMC) has been manufactured by wrought aluminum alloy by varying the weight fractions of silicon carbide to compose five distinct forms of composites. Stir – casting has been chosen as the manufacturing technique, in this study. **Findings:** The manufactured composites were tested to determine their tensile and impact properties and the result proves that the sample with higher percentage of silicon carbide has better mechanical properties, comparably. **Applications:** This study essentially focuses on establishing AMC as they find applications on aerospace and automotive industries because of their admirable properties compared with the unreinforced alloys.

Keywords: Aluminum 6061, Mechanical Properties, Metal Matrix Composite, Silicon Carbide, Stir Casting

1. Introduction

The need for Metal Matrix Composites (MMCs) has been expanding tremendously in recent days. Like all other composites, the MMCs too consist of distinct physical and chemical properties, where the matrix and the reinforcements were evenly distributed to maintain the property that cannot be obtained by individual phases or monolithic alloys. Because of its good mechanical properties like enhanced hardness, high specific strength and specific modulus, aluminum base metal matrix are used in aerospace and automobile industries for manufacturing cylinder liners, pistons, connecting rods, turbochargers, bearings etc. In[1] investigated the impact behavior of Aluminum metal Matrix Composites (AMC) by reinforcing distinct sizes of Silicon Carbide (SiC) particles and tested using Charpy test under different temperatures ranging from -176°C to 300°C and have concluded that the impact strength of AMC increases with the increase in SiC particle size. In[2] have investigated two aluminum (Al) alloys AA5083 and AA1100 in sea water for its corrosion resistance and proved that AA1100 has better corrosion resistance than the other alloy. In[3] have fabricated AMCs by varying the compositions of alumina and boron carbide (B_4C) and concluded that the Al with 2 % by wt Alumina and 3 % by wt B_4C have maximum tensile strength. In[4] have employed stir casting technique to fabricate Al MMC using Al 6061 and Al_2O_3 particles and have evaluated the mechanical and tribological properties and proved that the tensile strength and hardness increases

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with the increase in the volume of reinforcements. In[5] have employed electro-magnetic stir casting method for preparing A359 – Alumina MMC and concluded that the hardness and tensile strength increases with the increase in the amount of alumina particles. In[6] have fabricated AMCs with varying the alumina (Al_2O_3) particles (up to 30% of weight fraction) and studied the effects of Al_2O_3 particle content as well as its size on hardness and tensile strength. He has concluded that porosity increases with increase in weight fraction but decrease in size of the particles and has also proved that hardness and tensile strength increases with decrease in size and increase in weight fraction of the Al_2O_3 particles. Apart from MMC, particle reinforced Al alloys (PMCs) are also widely accepted for its myriad applications and are fabricated using liquid phase processing (stir casting) and solid phase processing (powder metallurgy). Comparably, stir casting has more advantages over powder metallurgy as they have better matrix-particle bonding called wettability, simple and inexpensive method[7,8]. In[9] have investigated the influence of B_4C particles in mechanical behavior of Al 7075 composites. They have concluded that the wear resistance of the composite increases with increase in the content of the B_4C particles and wear rate was less for the composite, when compared with the Al alloy and have also described that the co-efficient of friction decreases with increase in B_4C particles. In[10] have fabricated Al MMC by reinforcing TiB_2 particles using vacuum stir casting method and have optimized the input parameters using L_9 Taguchi techniques to obtain best surface roughness. The scope of this work was to: (a) to fabricate SiC particle MMC by vortex method; (b) to investigate the effect of SiC particles on the tensile and impact behavior of SiC particle reinforced 6061 aluminum alloy composites.

2. Experimental Procedure

2.1 Materials

A commercial grade of Al 6061 with theoretical density of 2.7 g/cm^3 is used as a metal matrix material and its used for aerospace, transportation and marine applications, as it has excellent mechanical properties like weld ability, weld strength, highly corrosion resistance. The constituents of Al 6061 have been given in Table 1. SiC is taken as the reinforcing material as it is one of the hardest known ceramic materials. The density of SiC is 3.21 g/cm^3 and its melting point is 2730°C.

2.2 Fabrication Procedure

Stir casting method has been selected for fabricating Al MMC and the coding by which the MMCs were prepared has been given in Table 2.

The Al alloy has been accommodated into the crucible furnace and temperature has been raised to 750°C in the furnace (i.e.) above the liquids temperature of the Al alloy. Pre-heated SiC particles were added in 5%, 10% and 15% by wt into the molten Al alloy in steps, and it has to be mixed thoroughly to get the uniform distribution of the SiC particles in MMCs, as it has been done by mixed stirring at a speed of 500 rpm for about 5 minutes. Then the slurry has been poured into the pre-heated mould, to get the shape according to the ASTM standards for testing tensile and impact strengths.

3. Results and Discussions

3.1 Density and Hardness Test

The experimental densities for the composites have been shown in Figure 1. The density of the base alloy (Al 6061) is less when compared with its reinforced composites, as

Table 1. Constituents of Al 6061

Mg	Si	Cu	Zn	Fe	Ti	Mn	Cr	Al
1.0	0.6	0.25	0.25	0.7	0.15	0.15	0.3	Bal

Table 2. Coding of MMCs

No	Composition	Coding
1	Al base (alloy)	Al
2	Al + 5% by wt SiC	Al 5SiC
3	Al + 10% by wt SiC	Al 10SiC
4	Al + 15% by wt SiC	Al 15SiC

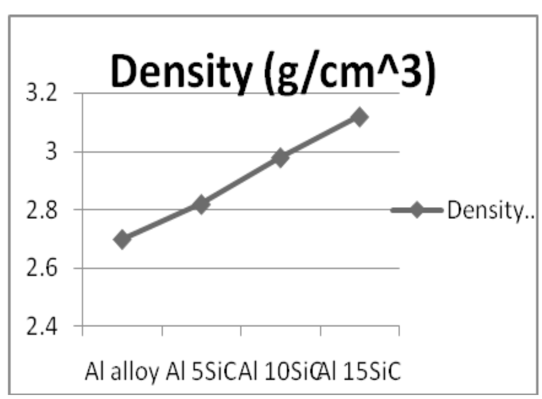

Figure 1. Experimental densities of Al MMC

the density of the MMC increases with the addition of the reinforced particles. Brinell hardness testing machine has been employed for testing the hardness of the MMCs and the samples were prepared as per the American Standards for Testing and Materials (ASTM) E10-00 standards. The test has been conducted at ambient temperature with a 10mm ball indenter and 500 kgf load. The tests were conducted at different places in samples and the average of the values has been.

Figure 2 shows the hardness values of the composite materials, as this conceals that the addition of SiC particles increases the hardness of the composites, comparable to the base alloy. This is because, the SiC particle acts as a barrier for crack propagation and also reveals that there is a good bonding between the Al matrix alloy and the SiC reinforcing material.

3.2 Tensile Strength Observations

The tensile tests were done using Universal Tensile testing Machine (UTM), for investigating the mechanical behavior of the MMCs as per the ASTM E8 standards. From Table 3, it is evident that the tensile strength of the composites are greater, when they are compared with the as cast Al alloy. When the content of the particles in MMC increases, the tensile strength increases because, the addition of the reinforcement particles hinders the plastic deformation in the matrix. Figure 3 represents the tensile strength of the Al MMC.

3.3 Impact Strength Observations

The impact tests were done on the samples using Charpy test as per IS 1757 standards. The values for the impact tests have been given in Table 4 and it's been clear that the sample with 15% SiC absorbs more energy than other samples. Figure 4 represents the amount of energy absorbed by the Al MMC.

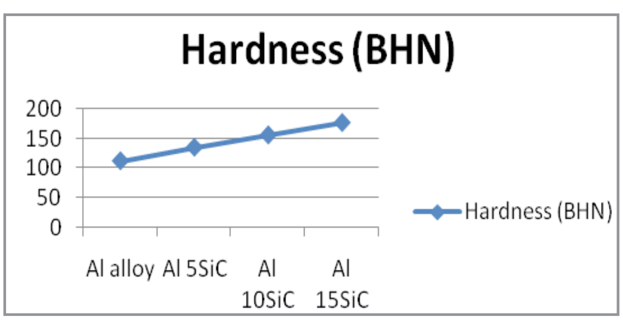

Figure 2. Hardness of Al MMC

Table 3. Tensile test results of Al MMC

No	Composition	Tensile Strength (MPa)
1	Al base (alloy)	90.12
2	Al + 5% by wt SiC	98.44
3	Al + 10% by wt SiC	119.34
4	Al + 15% by wt SiC	141.91

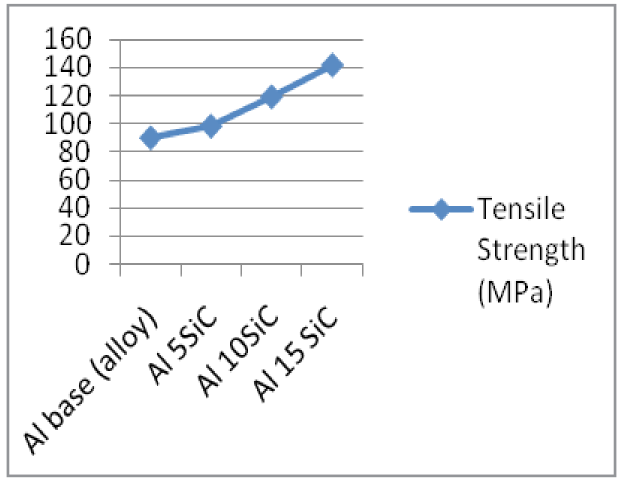

Figure 3. Tensile strength of Al MMC

Table 4. Impact test results of Al MMC

No	Composition	Energy Absorbed (J)
1	Al base (alloy)	1.41
2	Al + 5% by wt SiC	2.62
3	Al + 10% by wt SiC	3.53
4	Al + 15% by wt SiC	3.97

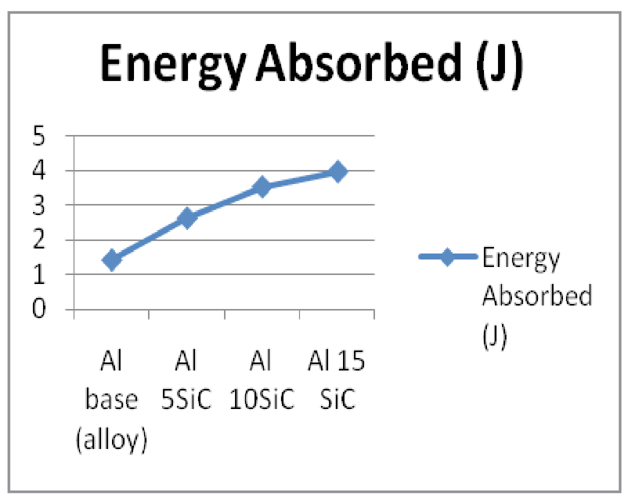

Figure 4. Impact strength of Al MMC

4. Conclusion

The mechanical properties of Al 6061 – SiC MMC have been studied in detail. The stir casting technique has been employed for fabricating the Al MMC. The uniform distribution of SiC particles has improved the mechanical properties of the MMC like hardness, tensile strength and impact strength.

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