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Study on Mechanical Properties and Microstructure of Aluminum Alloy 63401 Metal Matrix Composite Reinforced with Silicon Carbide Powder

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Abstract

Objectives: The present research examine the mechanical properties and microstructure of aluminum alloy 63401 metal matrix composite reinforced with silicon carbide powder of different wt% i.e. 3%, 6% and 9% and different grain size. Different weight percent of SiC i.e. 3%, 6% and 9% with different grain size of 177 μm, 149 μm and 74 μm. **Methods:** The mechanical properties i.e. hardness, tensile strength and impact strength were studied by preparing the required samples by stir casting method. **Findings:** From the obtained results we found that more the weight percentage of SiC powder, impact strength, tensile strength and hardness increases but the percentage elongation decreases with increase in weight percentage of SiC and increases with decrease in grain size of SiC. Also microstructure shows the nearly distribution of reinforcement material. **Applications:** They can be used in making body parts of vehicles having great impact strength. Making different parts of aeroplanes and also used in producing bus bars of higher strength.

Keywords: Aluminum Alloys 63401, Silicon Carbide, Stir Casting

1. Introduction

Aluminum alloy because of its low density are used as a matrix element in composite material. MMCs are produced by mixing a reinforcing material with a metal matrix. For eg. silicon carbide powder reinforced with aluminum matrix in order to study its different mechanical properties or wear behaviour, corrosive nature etc.

SiC is composed of both silicon and carbon. It can maintain its strength up to 1600°C with no loss in its strength whether little or no impurities present. Some of its properties are like low density, high strength, high hardness etc. Used in suction box cover, heat exchangers, etc. It develops a protective silicon oxide coating at 1200°C.

In the paper wrought Al alloy 63401 is taken reinforcing with different weight percent of silicon carbide powder. In the past effect on mechanical properties were studied by addition of different reinforcement materials on different Al alloys like Al alloy 7075, Al alloy 6061 etc. but in our study first time wrought Al alloy 63401is used reinforced with SiC powder. Our main aim is to examine the different mechanical properties i.e. hardness, impact strength and tensile strength and if the mechanical properties increases then we can clearly say that Al alloy 63401 reinforced with SiC powder will be very helpful in different applications like bus bars etc. Before preparation of samples, we studied few papers which deals with the preparation of aluminum metal matrix reinforced with different materials and thereafter studied their mechanical properties. Some of them are as follows:

In[1] investigated the effect on mechanical properties of Al alloy (LM25) reinforcing with SiC, E-glass and red mud. They found that by using stir casting method, it is easier to produce aluminum composites. In order to properly mixing of reinforcing material, they varied the

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reinforcement material in smaller quantity. They found that by adding the reinforcing material mentioned above, the tensile strength, impact strength increases but % elongation gets reduced. And hardness gets minimized by addition of E-glass.

In[2] investigated the mechanical properties of Al alloy 7075 reinforcing with fly ash, SiC and red mud. They found that by maintaining constant weight percentage of SiC and fly ash the tensile strength is increased in Al7075. By taking Al7075 reinforced with SiC and red mud, they found that by increasing the content of red mud, the tensile strength gets increased and found that among Al7075 reinforced with SiC and red mud has higher tensile strength than Al7075 reinforced with SiC and fly ash. Also the energy absorbed is more by reinforcing Al alloy 7075 with SiC and red mud.

In[3] examined the mechanical properties of Al alloy (Lm6) by reinforcing with red mud, fly ashand SiC. They varied the wt. % of red mud and fly ash up to 6% which resulted increase in tensile strength with increase in weight % of red mud but elongation got decreased. The impact strength got improved by increasing wt. % of fly ash but got reduced by increasing wt % of red mud. They found that by taking Lm6 with 6% Sic and 6% fly ash, it gives a better resistive wear by comparing with other samples and by taking Lm6 with 6% Sic and 3% red mud gives better wear resistance. Overall observed that SiC + fly ash gave better result than SiC + fly ash.

In[4] studied the mechanical properties of Al alloy 6063 by reinforcing with alumina. They have taken different volume percent like 6%, 9%, 15%, 18% of Al_2O_3 and found that the tensile strength, yield strength and hardness increased by increasing weight percentage of Al_2O_3.

In[5] investigated the mechanical properties of Al alloy Al356.2 matrix reinforcing with ZrO_2 particles. They used the vortex method. They took 10%, 15% and 20% wt. of zirconium particles and found that the hardness and tensile strength got increased by increasing reinforcement up to 15% and thereafter decreases.

In[6] examined the characterization of 356-SiCp composites by compo casting and stir casting methods. The results exhibits that by adding SiC particles in the as (Al-SiC)cp composite powder and casting in semisolid state decreases the SiC particle size, strengthen the wet ability between the molten matrix alloy and their reinforcements and raises the spreading of the strengthening particles in the solidified matrix.

In[7] examined the properties of Al-5083 by reinforcing with SiC and found that the tensile strength along with compressive strength increases with increase wt% of SiC from 0% to 10% mixed along with modulus of elasticity. Also by introducing ultrasonic probe to stir casting route the compressive strength, tensile strength and modulus of elasticity got increased with wt % of SiC.

In[8] examined the different mechanical properties of Al alloy 7075 with addition of varying weight percentage composition such as SiC 8%, 6%, 4%, 2% and red mud 2%, 4%, 6%, 8% and silicon carbide particles by stir casting. Found that the mechanical properties i.e. tensile strength, hardness, compressive and yield strength got increased by addition of SiC and red mud.

In[9] produced the Al-TiB2 metal matrix composite having wt % of 12% TiB2p through in-situ process and compared the mechanical properties and microscopic study of Al 6061 alloy with Al–TiB2 metal matrix composite and found that the composite Al-6061/TiB2/12p successfully produced by the in-situ reaction procedure. The developed Al-TiB2 tensile strength, hardness and Young's modulus is more than the base alloy.

In[10] investigated the mechanical properties of Al alloy 6061 matrix reinforcing with different wt % of SiC i.e.2.5%, 5%, 7.5%, 10%) with all other parameters constant and found that by increasing wt % of SiC, hardness, tensile strength and toughness gets increased.

In[11] examined the mechanical properties and microstructure of pure commercial Cu of fine grain. The samples were fabricated by frictional stir technique. The parameters i.e. speed from 40-315, dimension of the shoulder of tool and no. of passes each of them having its own effect were varied. Having dimension around 100 x 60, the rolled sheets of Cu of thickness 6 mm were produced. They found that the frictional stir technique might reduce size of the grains of the samples produced. Speed of rotation is more benefit in case of frictional stir technique. The inner temperature and the size of the grain got decreased by decreasing the dimension of the shoulder of the tool. The hardness got increased but the size of the grain got decreased by increasing the no. of passes.

In[12] examined the cryogenic mechanical properties of polypropylene by reinforcing with different wt. % of Na+ and montmorillonite at a room temperature and temperature of liquid nitrogen both at 77 Kelvin. The samples were produced by twin screw extruder. Followed transmission electron microscope and XRD in order to study microscopic characteristic. They found from the microscopic study that montmorillonite can be shredded at wt. % of 5% of its content. The modulus of elasticity got increased by increasing the wt. % of the reinforcing material. The tensile strength and modulus of elasticity at 55 wt volume fraction of reinforcement got increased almost 3.1% and 13.2% more than the base polypropylene. The impact strength got increased having a value of 36.53 J/m as compared to the base polypropylene whose impact strength is 22.33 J/m. But at 77 Kelvin temperature obtained lower impact strength. At 3% wt. volume fraction of the reinforcement, the modulus of storage got increased up to maximum and the modulus of loss became minimum at 5% wt. volume fraction of the reinforcement material.

2. Experimental Methodology

The materials which were used in the present investigation are Aluminum alloy 63401, SiC of weight percentage like 3%, 6% and 9% with grain size of 177 μm, 149 μm and 74 μm. Table 1 represents the chemical composition of Al alloy 63401.

Stir casting method used for the preparation of the samples. For stir casting we have used induction furnace. Firstly, the Al alloy 63401 is placed in the furnace and melted at a temperature of 800°C. The reinforcing material SiC preheated at 400°C. After melting of Al alloy reinforcing material and magnesium 1% for better wet ability were added and mixing was done. After that once again it was kept in the furnace for sometime in order to proper mixing of reinforcing material and at last poured into the die. After solidification, composites were taken out and machining was done to obtain the required samples for hardness, tensile strength and impact strength testing. The whole process was repeated for different wt. % of SiC like 3%, 6% and 9% with different grain size like 177 μm, 149 μm and 74 μm.

Table 1. Chemical composition of wrought aluminum alloy 63401 (percent composition)

Cu	0.05
Mg	0.4-0.9
SiC	0.3-0.7
Fe	0.50
Mn	0.03
Zn	0.10
Ti	0.10
Cr	0.03
Al	Remainder

Result and Discussion

3.1 Microscopic Study

We have used optical microscope to conduct the microscopic study. And from the result obtained we have found that the reinforcement particles are approximately uniformly distributed. Figure 1 to Figure 3 shows the different microstructure of Al alloy 63401 reinforced with different percentage of SiC.

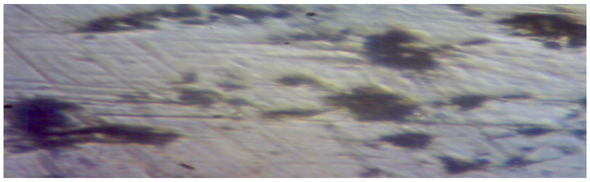

Figure 1. Microstructure of Al alloy 63401 with 6% SiC and grain size of 74 μm.

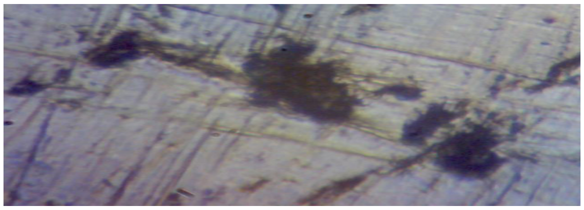

Figure 2. Microstructure of Al alloy 63401 with 3% of SiC and grain size of 74 μm.

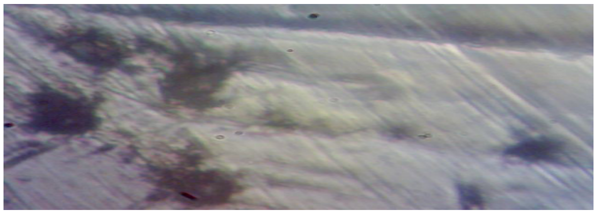

Figure 3. Microstructure of Al alloy 63401 with 9% SiC and grain size of 177 μm.

3.2 Hardness Test

We have used vicker hardness testing method in our study at a room temperature of 25±3°C. It is also known as micro hardness test method basically used for small parts. Table 2 represents the result of hardness test with varying weight percentage of SiC.

From the Figure 4 obtained results we found that as we increase the weight percent of SiC at constant grain size of 149 μm, the hardness of the Al alloy 63401 increases. By adding SiC, the hardness also increases.

Table 3 represents the result of hardness test with varying grain size of SiC.

From the Figure 5 we found that with the decrease in mess size of SiC at constant weight percent of SiC 6%, the hardness of the Al alloy 63401 increases.

Table 2. Result of hardness test with varying weight percent of SiC 3%, 6%, 9% keeping constant grain size of 149 μm

SiC weight (%)	SiC grain size (in μm)	HV
3	149	54
6	149	57
9	149	58

Table 3. Result of hardness test with varying grain size of SiC 177 μm, 149 μm, 74 μm keeping constant weight percent of SiC at 6%

SiC weight (%)	SiC grain size (μm)	HV
6	177	46
6	149	54
6	74	58

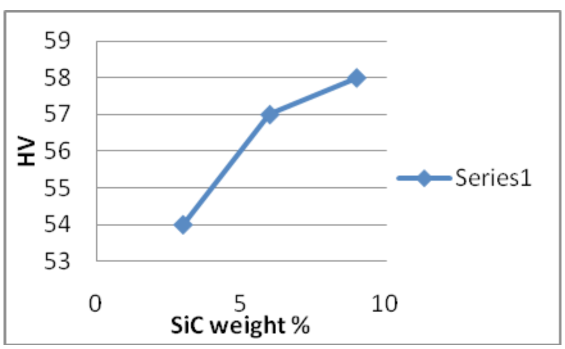

Figure 4. Variation of hardness value with increase in SiC weight percentage.

3.3 Impact Test

Izod V-notch test method used in order to calculate the impact strength. Table 4 represents the result of impact test with varying weight percentage of SiC.

From the obtained Figure 6 we found that with the increase in wt % of SiC at constant grain size of 149 μm, the energy absorbed by the Al alloy 63401 increases. Thus addition of SiC improves impact strength.

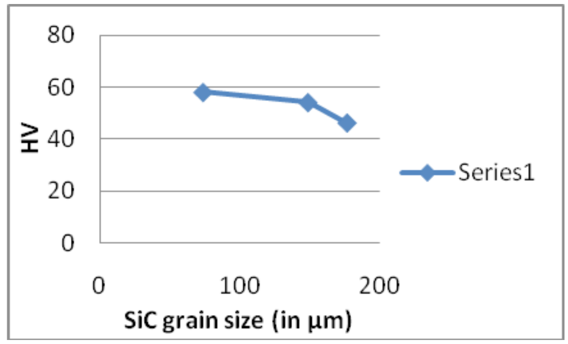

Figure 5. Variation of HV with decrease in grain size.

Table 5 represents the result of impact test with varying grain size of SiC.

From the above Figure 7 obtained results we found that with decrease in grain size of SiC at constant wt % of SiC at 6%, the energy absorbed by the Al alloy 63401 increases.

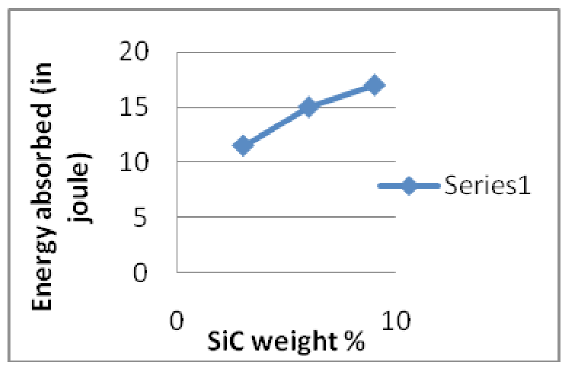

Figure 6. Variation energy absorbed with increase in weight percentage of SiC.

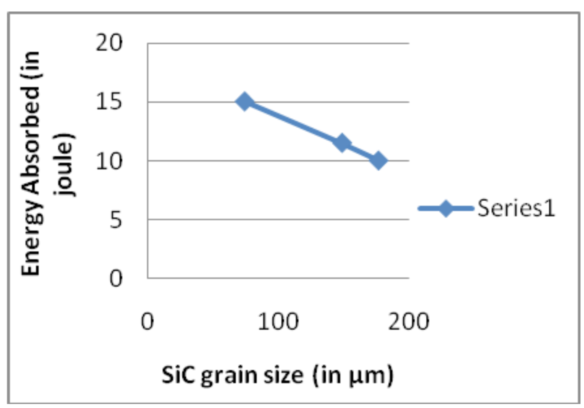

Figure 7. Variation of energy absorbed with decrease in grain size of SiC.

Table 4. Result of impact strength with varying weight percent of 3%, 6%, 9% keeping constant grain size of 149 μm

SiC weight (%)	SiC grain size (μm)	Energy absorbed (in joule)
3	149	11.5
6	149	15
9	149	17

Table 5. Result of impact strength with varying grain size of SiC 177 μm, 149 μm, 74 μm keeping constant weight percent of SiC at 6%

SiC weight (%)	SiC grain size (μm)	Energy absorbed (in joule)
6	177	10.5
6	149	11.5
6	74	15

3.4 Tensile Test

The instrument used for tensile testing is UTE100 of capacity 1000 KN, resolution 0.05 KN. Table 6 represents the value of tensile strength with varying weight percentage of SiC.

From the above obtained result from Figure 8 and Figure 9 we found that by increasing wt % SiC at constant grain size 149 μm, the tensile strength increases but % elongation decreases.

Table 7 represents the value of tensile strength with varying grain size of SiC.

From the above obtained result from Figure 10 and Figure 11 we found that with the decrease in grain size of SiC the tensile strength increases and also the % elongation increases.

Table 6. The values of tensile strength with varying weight percent of SiC 3%, 6%, 9% keeping constant grain size of 149 μm

SiC weight (%)	SiC grain size (μm)	T.S (KN/mm2)	% E.L
3	149	0.125	5.7
6	149	0.129	5.6
9	149	0.132	5.1

Table 7. The values of tensile strength with varying grain size of SiC 177 μm, 149 μm, 74 μm keeping constant weight percent of SiC at 6%

SiC weight (%)	SiC grain size (μm)	T.S (KN/mm2)	% E.L
6	177	0.128	5.6
6	149	0.129	5.6
6	74	0.163	6.8

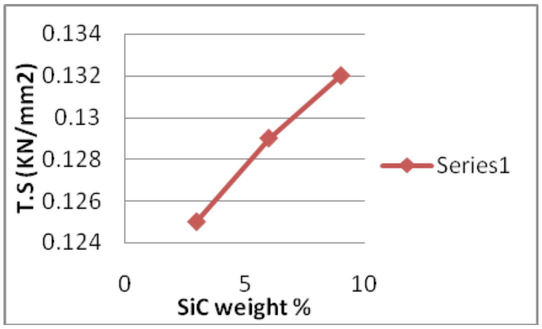

Figure 8. Variation of tensile strength with increase in weight percentage of SiC.

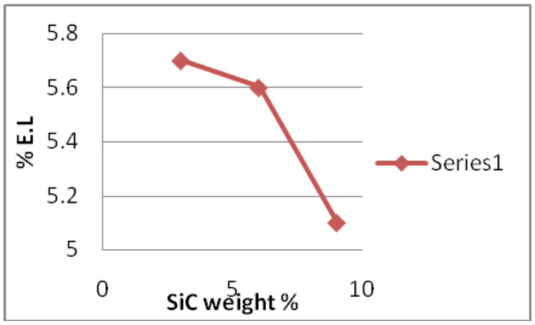

Figure 9. Variation of percentage elongation with increase in weight percentage of SiC.

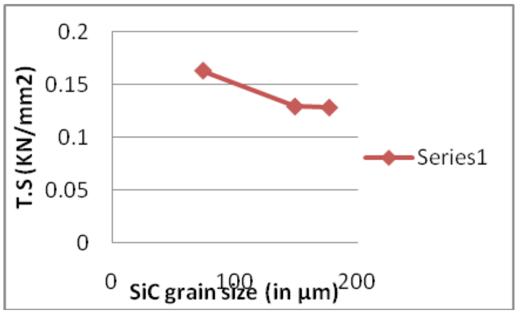

Figure 10. Variation of tensile strength with decrease in grain size of SiC.

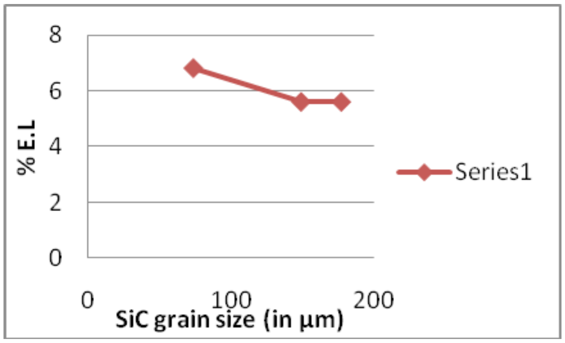

Figure 11. Variation of percentage elongation with decrease in grain size of SiC.

4. Conclusion

From the above experiment conducted, we can conclude from the obtained result that stir casting method is one of the easiest method which can be used to produce aluminum composites. The hardness and impact strength of the Al alloy increases with the increase in different percent of SiC 3%, 6%, 9% and with the decrease in grain size of SiC 177 µm, 149 µm, 74 µm. The tensile strength got increased by increasing wt % of SiC whereas % elongation decreases with the increase in weight percent of SiC and increases by decreasing grain size of SiC. Less the grain size of SiC more will be the hardness, tensile and impact strength.

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