Evaluating the Influence of Heat Treatment and Reinforcement on the Mechanical Properties of Al-Mg-Si Alloy

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Abstract—*The aluminium matrix composites are highly in demand in automotive, aircraft and transport industry, as well as in structural work because of their superior properties over conventional materials. Aluminium matrix composite exhibits high strength, excellent wear and corrosion resistance, light in weight and low density. The present work investigate the effect of addition of different wt %age of reinforcement (SiC and Mg) and heat treatment on the composite based on aluminium alloy 6063,produced by liquid state fabrication method(stir casting). The tensile strength test, hardness and abrasive wear test were performed to investigate the mechanical properties of composite material. The results show that the properties of composite improved with the heat treatment and addition of reinforcement.*

Keywords: *Metal Matrix Composite, Aluminium alloy 6063, Heat Treatment, Stir Casting*

Introduction

Composite material based on the aluminium alloys are most widely used in engineering application such as automotive, aerospace, transport industries, as well as structural work [1].Composite material consist of two phases one is matrix phase and other is a reinforcement phase. Matrix and reinforcement phase work together to produce combination of material properties that cannot be met by the conventional materials [2].Aluminium matrix Composites are light in weight, having high strength and excellent wear and corrosion resistance [3].

Commonly used reinforcement particles in developing MMCs include carbides, nitrides, borides and oxides. Sic and Al_2O_3 are most commonly used reinforcements for aluminium matrix composite [4]. The addition of Mg in aluminium alloy improve the wettability and strength, as well as wear resistance of the composite [5].The heat treatment process enhances the mechanical properties of the composite. The artificial aging improves wear resistance of heat treatable aluminium alloy [6]. In present study, Al 6063 has been used as base material of aluminium matrix composite. SiC and Mg is used as reinforcement material. The study investigates the effect of heat treatment and different wt % of reinforcements added in the alloy on the mechanical properties of composite.

Experimental Procedure

Composite Preparation

The composite materials were prepared from 6063 alloy, by melting it in a graphite crucible in a muffle furnace at 800°C for four hours. Before addition of reinforcement the silicon carbide particles were preheated at 1000°C for one hour to make their surfaces oxidized. The furnace temperature was first raised above the liquidus temperature of Aluminium up to 750°C to melt the Al alloy completely. Simultaneously stirring was carried out for about 10 minutes at stirring rate of 290 r.p.m.

At this stage, the preheated SiC particles and Mg particles were added manually. Then again whole mixture was stirred so that uniform composition may be achieved. After stirring process the mixture was poured in the other mould to get desired shape of specimen. The Table 1 shows the chemical composition of aluminium alloy 6063 and Table 2 shows the composites produced with different %age of reinforcements.

Table 1: Chemical Composition of the Aluminium 6063 Alloy

Element	Si	Mg	Mn	Fe	Bi	Ni	Al
Wt%	0.53	.39	.009	.07	.082	.032	98.9

Table 2 Composites with Different %age of Reinforcements

Sample No.	Composite
Sample 1	Al 6063
Sample 2	Al 6063+11% SiC
Sample 3	Al 6063+11% SiC+0.7 %Mg
Sample 4	Al 6063+11% SiC+1.2 %Mg
Sample 5	Al 6063+14% SiC
Sample 6	Al 6063+14% SiC+0.7 %Mg
Sample 7	Al 6063+14% SiC+1.2 %Mg

From the prepared composites samples, specimens were prepared to perform the mechanical tests. The mechanical behaviour of samples such as tensile strength, wear rate, micro hardness was investigated. The effect of the reinforcement's particles on the mechanical behaviour and the microstructure was observed. Further the experimental work was extended to study the effect of heat treatment of composites on their mechanical behaviour as well as on the micro structure of the same. The mechanical tests were performed on both non heat treated and heat treated samples.

Heat Treatment

First of all, the specimens were heated at 520°C in Tube furnace and they were kept at this temperature for 1 hr. Then, the specimens were quenched in water and finally, artificial aging was done on the specimens in the second step at 180°C for 6 hr.

Results and Discussion

Tensile Test

All tensile tests were carried out on Universal Tensile Testing Machine. The tensile properties of composite materials were evaluated according to the ASTM-B557-06 standard.

Table 3: Shows the Average Value of Ultimate Tensile Strength Obtained from Tensile Test

Sample No.	Ultimate Tensile Strength (N/mm^2)	
	Un-Heat Treated	Heat Treated
Sample 1	152	187
Sample 2	192	223
Sample 3	201	231
Sample 4	209	242
Sample 5	206	241
Sample 6	214	248
Sample 7	227	260

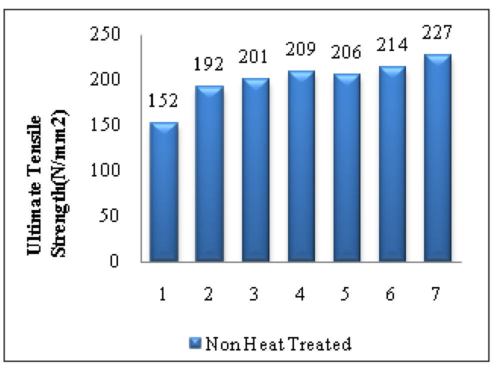

Fig. 1: Variation of the Ultimate Tensile Strength with Reinforcement

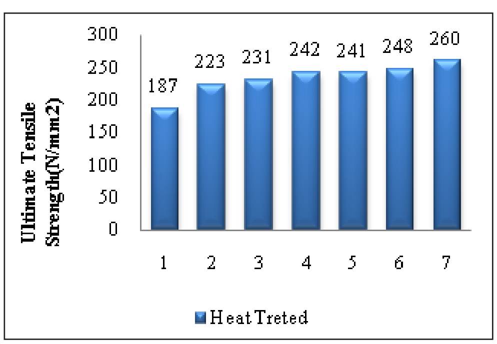

Fig. 2: Variation of the Ultimate Tensile Strength with Heat Treatment

It is observed that the tensile strength increases with increase in percentage of SiC. The effect of Mg particles as reinforcements is to enhance the ultimate tensile strength of the composites. The increase in ultimate tensile strength is due to the presence of SiC particles embedded in the Al(6063) Matrix.

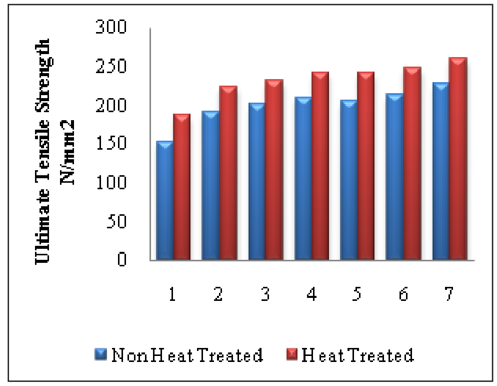

Fig. 3: Variation of the Ultimate Tensile Strength with Reinforcement and Heat Treatment

The heat treated samples have higher ultimate strength than the un-heat treated samples for same percentage of SiC and Mg. The ultimate tensile strength for heat treated specimen with 11% SiC is 223 N/mm^{2}and ultimate tensile strength un heat treated specimen with 14% SiC is 241 N/mm^2

Hardness Test

Vickers hardness test was performed on all specimens. A diamond–square pyramid indenter is pressed into the surface under a steady load, the load is maintained500 gm for 15 seconds for a steady state then the indenter is removed. Each value here is the average of sixteen measurements.

Table 4: Micro-Hardness of Developed Composites

Sample No.	Micro-Hardness (VHN)	
	Un-Heat Treated	Heat Treated
Sample 1	26	58
Sample 2	50	84
Sample 3	61	96
Sample 4	73	106
Sample 5	63	99
Sample 6	78	113
Sample 7	89	124

It is observed that with increased content of SiC in the matrix alloy, there is a significant improvement in micro-hardness of the composite. The micro-hardness for 11%SiC is 50 VHN and 14% SiC is 63VHN.The effect of Mg particle as reinforcement is to enhance the micro-hardness of the composite. Micro-harness of 11%Sic + 0.7% Mg is 61 VHN and 14% SiC+0.7% Mg is 78VHN.

It is found that with increase in percentage of SiC in the metal matrix, the micro-hardness of composite, increases linearly.

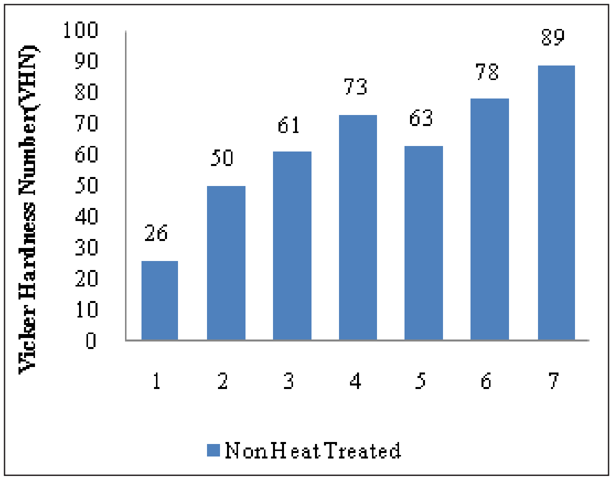

Fig. 4: Variation of the Hardness with Reinforcement

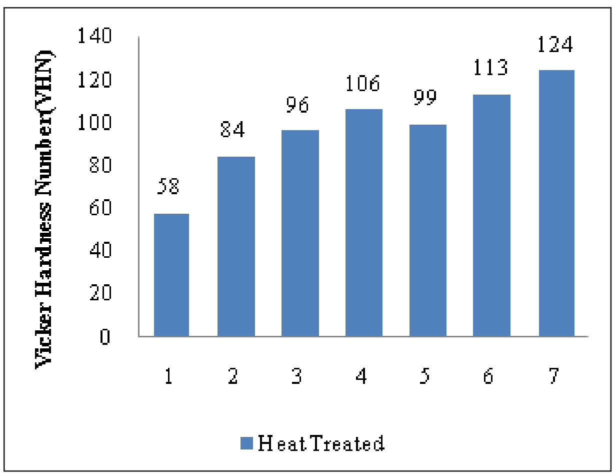

Fig. 5: Variation of the Hardness with Heat Treatment

Wear Test

The wear test was carried out using sample pin on disc method (weight loss in gram method). All samples were weighted using electronic balance. The square specimen of size 10mm x 10mm and 2cm length were prepared and were allowed to wear on disc under normal load 10N. Each specimen was made to wear for 30 minutes on disc by allowing the same to run for distance of 4500m. Each specimen were checked after the interval of 10 minutes .After checking the loss weight in 10 minutes specimen was again loaded and run for next 10 minutes and so on. The cumulative wear rates for the materials were calculated using following formula.

$$W = \Delta w / L\rho F$$

Where W denotes cumulative wear rates in m^3/Nm, Δw is the weight loss measured in grams, L is the sliding distance in meters, ρ is the density of the worn material in kg/m^3, and F is the applied load in N. It is observed from Fig. 6. Al 6063 as a cast has higher wear rate as compared to composite specimens this is due to the presence of SiC particles which are harder than cast Al 6063 Aluminium Metal Matrix. It is observed that the wear rate goes on increasing the distance moved by the specimen increase. From Fig. 6 the highest wear rate is $8.85(m^3/Nm)*10^{-1}$. It is seen from Fig. 6 that composite having the higher percentage of SiC has more wear resistance.

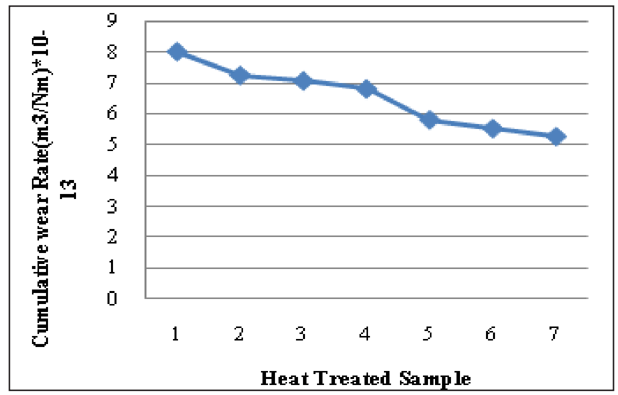

Fig. 6: Variation of the Wear Rate with Reinforcement

The wear rate decrease with increase in percentage composition of SiC in the composite. The cumulative wear for specimen with 11% SiCis7.97 $(m^3/Nm)*10^{-13}$and 14% SiC is $6.64(m^3/Nm)*10^{-13}$. It is also seen that the presence of Mg particles as a reinforcements increases the wear resistance of the composites. More over heat treatment also plays the important role in the improvement of wear resistance of the composites .The wear volume for un-heat treated specimen with SiC 14%+Mg 0.7% is $6.28(m^3/Nm)*10^{-13}$and heat treated specimen with SiC 14%+Mg 0.7% is $5.54(m^3/Nm)*10^{-13}$.

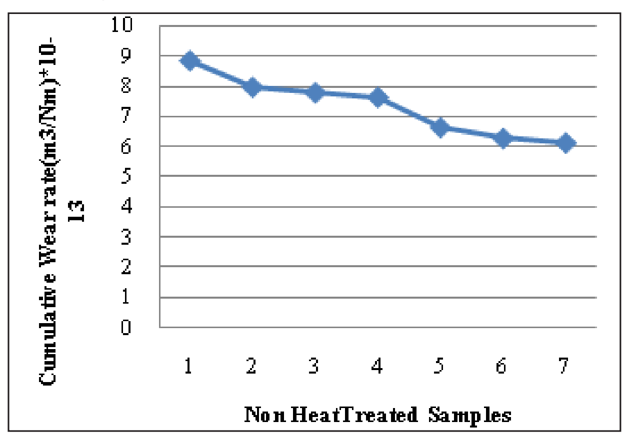

Fig. 7: Variation of the Wear Rate with Heat Treatment

Microstructure

The microstructure was examined under the optical microscope at a magnification 100X of heat treated and non-heat treated composites samples. The samples were prepared after grinding using emery paper of progressive finer grades 200,400,600 and 800 and washed. Then they were polished with polishing machine using fine alumina as the polishing agent to obtain a mirror like surface.

The polishing disk was covered by velvet cloth and there was constant supply of water as lubricant. Then they were washed and dried and etched with using freshly prepared Keller‘s solution and then examined under optical microscope.

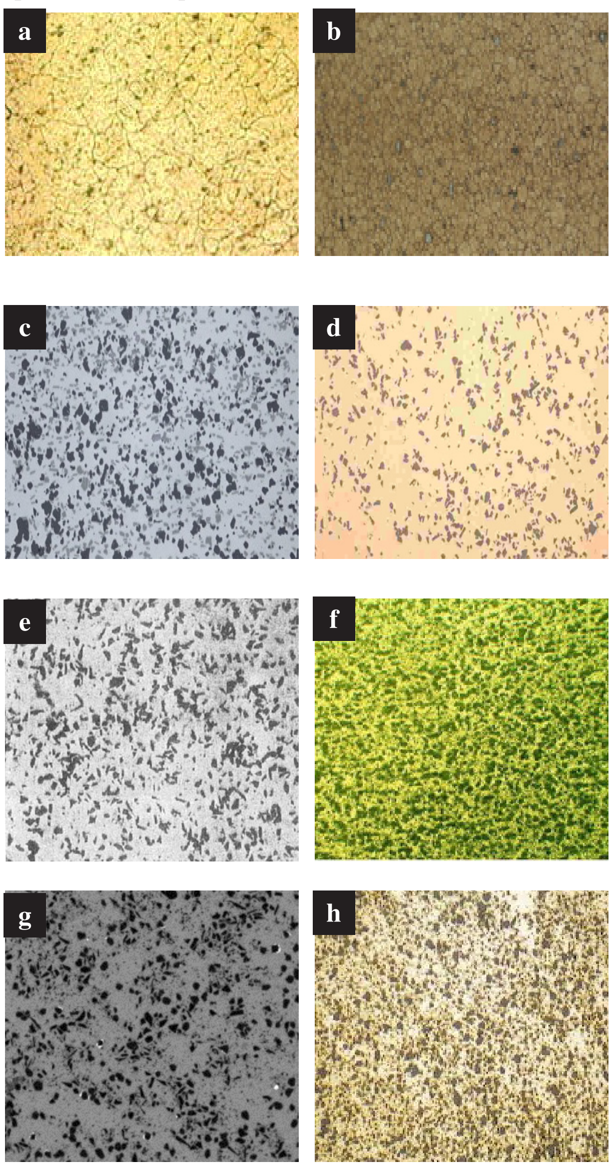

Fig. 8: Micrograph of Different Samples, 100X

(a) Al 6063 (b) Al6063 heat treated(c)Al 6063+ 11% SiC(d) Al 6063+ 11% SiC heat treated(e) Al 6063+ 14% SiC(f) Al 6063+ 14% SiC heat treated (g) Al 6063+ 14% SiC+0.7%Mg (h) Al 6063+ 14% SiC+0.7%Mg heat treated.

The micrographs of the composite samples show the uniform distribution of SiC particles into metal matrix. It is seen from micrographs, for the given composition of reinforcement materials, the heat treated samples have finer structure as compared to non-heat treated samples. Formation of finer grains with heat treatment process leads to increase in hardness of composites.

Conclusion

1. The heat treatment has a significant influence on the mechanical properties of the composite material.
2. The tensile strength of composites depends upon matrix composition and heat treatment. The strength increases with increase the SiC and Mg contents and heat treatment.
3. With increasing the wt% of SiC particles wear resistance is also increased.
4. Increase in wt% of Sic particles, increases the hardness of composites.

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