International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Ultimate Tensile Strength of Heat Treated Hybrid Metal Matrix Composites

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Abstract: ***In recent years, there has been an ever-increasing demand for enhancing mechanical properties of Aluminum Matrix Composites (AMCs), which are finding wide applications in the field of aerospace, automobile, defence etc,. Among all available aluminium alloys, Al6061 is extensively used owing to its excellent wear resistance and ease of processing. Newer techniques of improving the hardness and wear resistance of Al6061 by dispersing an appropriate mixture of hard ceramic powder and whiskers in the aluminium alloy are gaining popularity. The conventional aluminium based composites possess only one type of reinforcements. Addition of hard reinforcements such as silicon carbide, alumina, titanium carbide, improves hardness, strength and wear resistance of the composites. However, these composites possessing hard reinforcement do posses several problems during their machining operation. AMCs reinforced with particles of Gr have been reported to be possessing better wear characteristics owing to the reduced wear because of formation of a thin layer of Gr particles, which prevents metal to metal contact of the sliding surfaces. Further, heat treatment has a profound influence on mechanical properties of heat treatable aluminium alloys and its composites. For a solutionising temperature of 530^{0}C, solutionising duration of 1hr, ageing temperature of 175^{0}C, quenching media and ageing duration significantly alters mechanical properties of both aluminium alloy and its composites. In the light of the above, the present paper aims at developing aluminium based hybrid metal matrix composites containing both silicon carbide and graphite and characterize their mechanical properties by subjecting it to heat treatment. Results indicate that increase of graphite content decreases ultimate tensile strength of hybrid composites reinforced with constant SiC reinforcement. Further heat treatment has a profound influence on the ultimate tensile strength of the matrix alloy as well as its hybrid composites. For all the heat treatment processes studied ice quenching with ageing duration of 6hrs resulted in improved ultimate tensile strength of both the unreinforced matrix alloy and its hybrid composites.***

Keywords: Hybrid Metal Matrix Composites, Ultimate tensile strength, Heat treatment, Vortex casting technique.

1. Introduction

In recent years aluminium matrix composites (AMCs) are gaining widespread popularity in several technological sectors owing to their excellent corrosion and wear resistance, higher fatigue life, good high temperature oxidation resistance in addition to being light in weight when compared with conventional alloys. At present AMCs are attractive alternatives for aerospace and automotive applications because of their high stiffness-to-weight characteristics. Currently, focus on development of aluminium, copper, magnesium, titanium based metal matrix composites is carried out to explore their possible applications in several high-tech areas. The various reinforcements that have been tried out to develop AMCs are graphite, silicon carbide, titanium carbide, tungsten, boron, Al_2O_3, flyash, Zr, Si_3N_4, TiB_2. The conventional aluminium based composites possess only one type of reinforcements. Addition of hard reinforcements such as silicon carbide, alumina, titanium carbide, improves hardness, strength and wear resistance of the composites. However, these composites possessing hard reinforcement do posses several problems during their machining operation. AMCs reinforced with particles of Gr have been reported to be possessing better wear characteristics owing to the reduced wear because of formation of a thin layer of Gr particles, which prevents metal to metal contact of the sliding surfaces. AMCs reinforced with SiC particulates are known for higher modulus, strength and wear resistance compared to conventional alloys. Addition of SiC particulates increases both mechanical strength and wear resistance of Al alloy. But the consequent increase in hardness makes the machining difficult. On the other hand, addition of Gr particulates facilitates easy machining and results in reduced wear of Al–Gr composites compared to Al alloy [1]. It is reported that the surface finish of the hard reinforced metal matrix composites are inferior when compared with the matrix alloy. Further it is absorbed that during turning, the hard reinforced metal matrix composites resulted in higher flank wear with increased content of the reinforcement. It is reported that composites possessing softer reinforcement-possess good machinability index.

Hence the current interest is to produce Hybrid Metal Matrix Composites (HMMCs) were in more than one type, shape and size of the reinforcement are used to obtain synergistic properties of the reinforcement and the matrix chosen. It is reported that hybridization of reinforcement has enhanced structural, physical, mechanical and tribological behavior of HMMC's when compared with metal matrix alloy. Hence attempts are made to develop aluminum based hybrid metal matrix composites consisting of both hard reinforcement (SiC) and soft reinforcement (Gr) in the present paper. Further to enhance the mechanical properties, the specimens are subjected to heat treatment processes.

2. Experimental Details

2.1 Composite Preparation

Al6061 based composites were prepared by vortex method of liquid metallurgy route. A quantity of 3kgs of Al6061 alloy was used each time in an electric melting furnace with graphite crucible for melting with furnace temperature set at 710^{0}C. Silicon carbide particles of 10 micron size and graphite particles of 60 micron size were used. The permanent molds of cast iron along with the reinforcements were heated in order to reduce the effect of chilling during solidification. Degassing of the melt was done with commercially available tablets of hexachloroethane (C_2Cl_6). After degassing, the preheated SiC and Gr were added slowly into the vortex while continuing the stirring process up to 10 minutes. The amount of reinforcement was varied from 1wt% to 4wt% in steps of 1wt% of Gr keeping constant 7wt%SiC.

2.2 Heat Treatment

Heat treatment was carried out in an electric furnace as shown in fig.2.1

Figure 2.1: Electric furnace

Table 2.1: Specification of electric furnace

Make	Pyromaniac, Madras
Max. temperature	1000°C
Heating rate	10°C per minute
Dimensions of heating chamber	60mm x 60mm x 300mm

The specimens were heat treated for a solutionising temperature of 530^{0}C, for duration of 1hr. After that they were cooled in air, water and ice medium respectively. They were further subjected to secondary heat treatment at ageing temperature of 175^{0}C for duration of upto 6 hrs for ice and water quenched specimen while about 8 hrs for air quenched specimen. They were further cooled in air under normal room temperature.

2.3 Evaluation of Ultimate Tensile Strength

Test specimens were prepared according to ASTM E8-82 standards, specimen diameter of 12.5 mm and 60 mm gauge length was used as shown if fig. 2.2. The specimen was loaded in computerized universal testing machine. Tests were conducted on composites of different combinations of reinforcing materials and ultimate tensile strength was measured. Simultaneous readings of load and elongation were taken at uniform intervals of load.

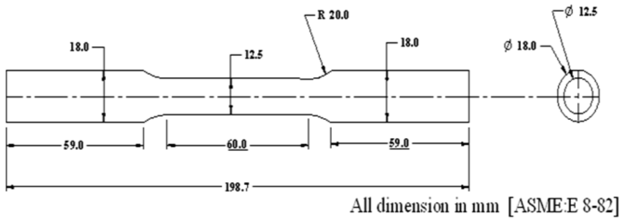


Figure 2.2: ASME standard specification for tensile test.

3. Results and Discussion

3.1 Tensile Test

3.1.1 Effect of reinforcements without heat treatment.

The effect of reinforcements on ultimate tensile strength of AL6061 alloy and its composites is as shown in fig. 3.1

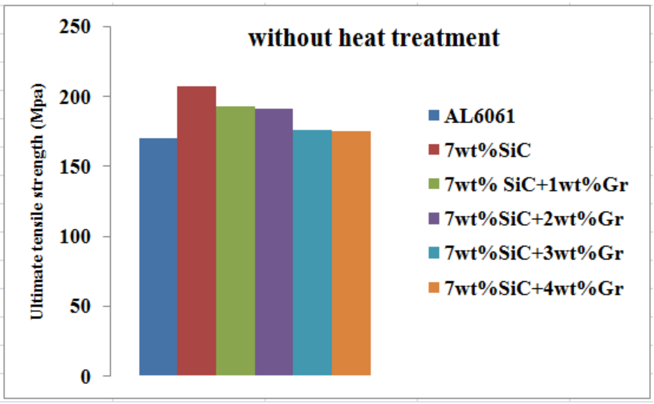


Figure 3.1: Effect of reinforcements on ultimate tensile strength of AL6061 alloy and its composites

It is observed from fig. 3.1 that the ultimate tensile strength of the AL6061 increases with addition of silicon carbide. But with addition of graphite the ultimate tensile strength decreases [16]. To overcome this, the SiC hard ceramic particle was added and was maintained constant 7wt%. SiC particles can act as the obstacles to the movement of dislocation. The SiC particles in the matrix alloy provide protection to the softer matrix. Thus, limiting the deformation and also resists the penetration and cutting of slides on the surface of the composites. Ultimate tensile strength of all the hybrid composites was significantly greater than that of the base alloy characterized to the hard nature of SiC particles. The higher ultimate tensile strength values for the hybrid composites containing 7 wt. % of SiC is due to the presence of hard SiC particles [19].

3.1.2 Effect of Reinforcements with Heat Treatment

The effect of reinforcements with variation of ageing time on ultimate tensile strength of heat treated AL6061 alloy and its composites is shown in Fig. 3.2

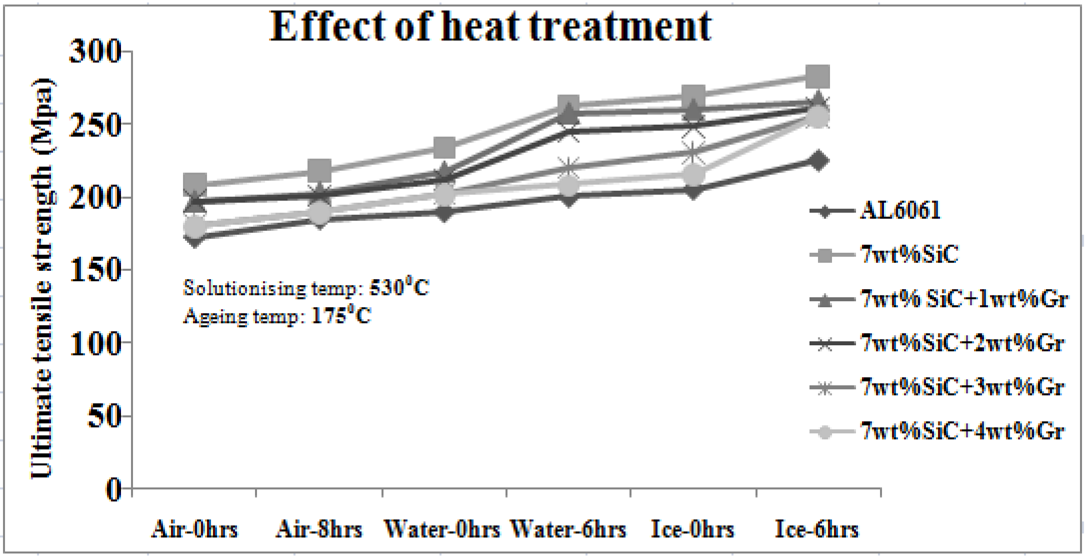
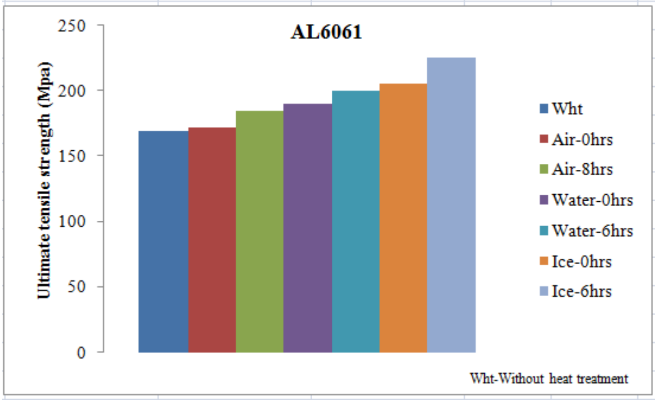


Figure 3.2: Effect of reinforcements with variation of ageing time on ultimate tensile strength of heat treated AL6061 alloy and its composites

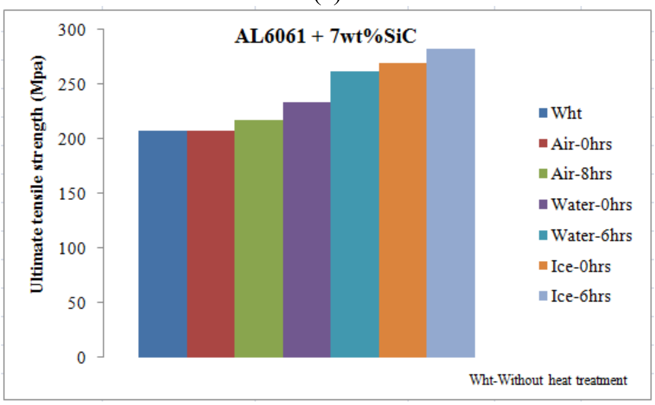
It is observed from fig. 3.2 that the ultimate tensile strength increases with heat treatment. Heat treatment has a profound influence on the ultimate tensile strength of the matrix alloy as well as its hybrid composites. For a solutionising temperature of 530^{0}C, for duration of 1hr, ageing temperature of 175^{0}C, quenching media and ageing duration significantly enhances the ultimate tensile strength of both the matrix alloy and its composites.

3.1.3 Effect of heat treatment

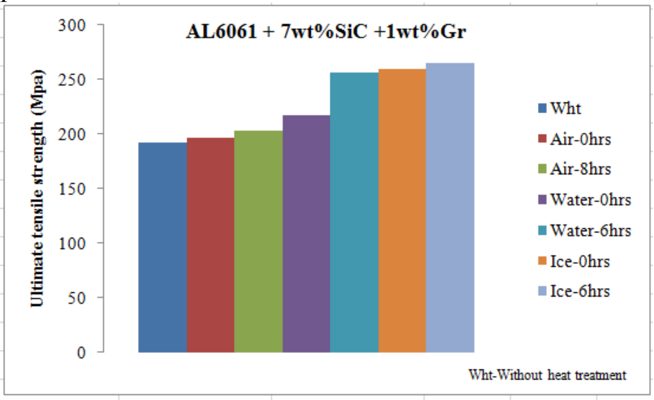
The effect of heat treatment with variation of ageing time on ultimate tensile strength of AL6061 alloy and its composites is shown in fig. 3.3 (a – f)



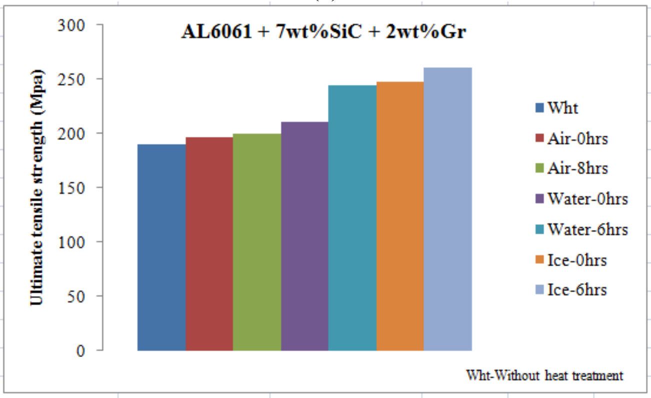
(a)



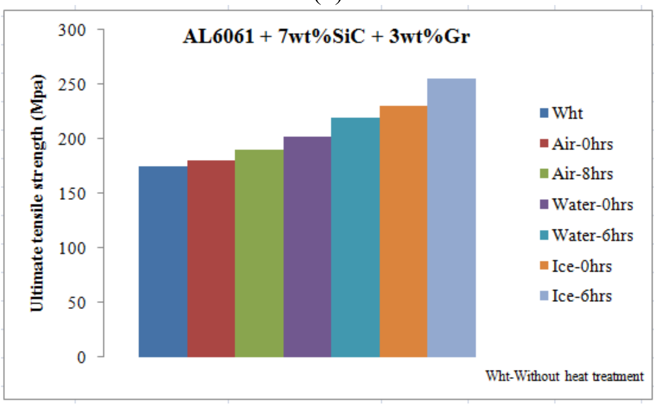
(b)



(c)



(d)



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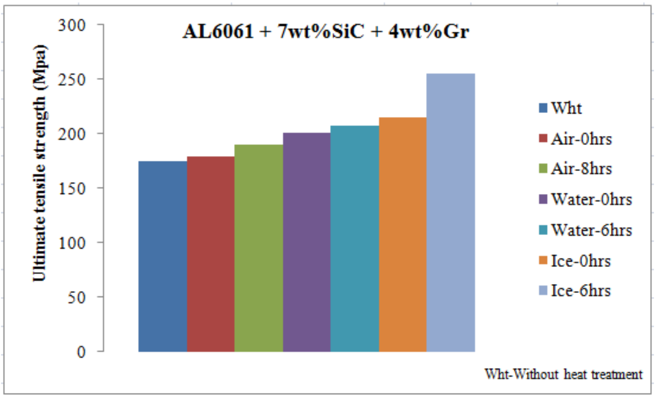


(f)

Figure 3.3: (a – f) Effect of heat treatment with variation of ageing time on ultimate tensile strength of AL6061 alloy and its composites

From the fig. 3.3 (a-f) it is observed that ice quenched specimen posses higher ultimate tensile strength compared to that of water and air quenched specimen. Heat treatment has a profound influence on the ultimate tensile strength of the matrix alloy as well as its hybrid composites. For a solutionising temperature of 530^{0}C, for duration of 1hr, ageing temperature of 175^{0}C, quenching media and ageing duration significantly alters the ultimate tensile strength of both the matrix alloy and its composites. Maximum ultimate tensile strength was observed for the Al6061 matrix alloy and its composites for ageing duration of 6hrs when the quenching media was ice and water, while the maximum ultimate tensile strength for the Al6061 matrix alloy and its composites was achieved only after 8hrs of ageing on air quenching. The effect of reinforcements and heat treatment with variation of ageing time on ultimate tensile strength of AL6061 alloy and its composites is shown in fig. 3.4

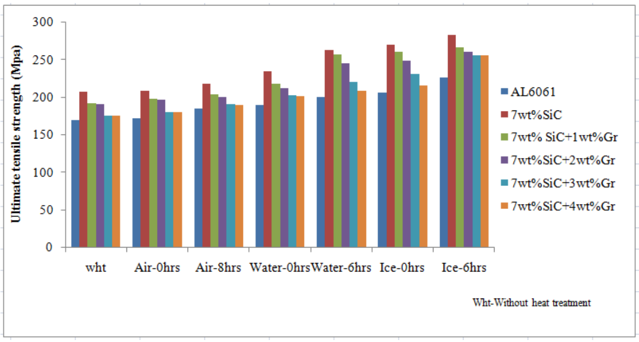
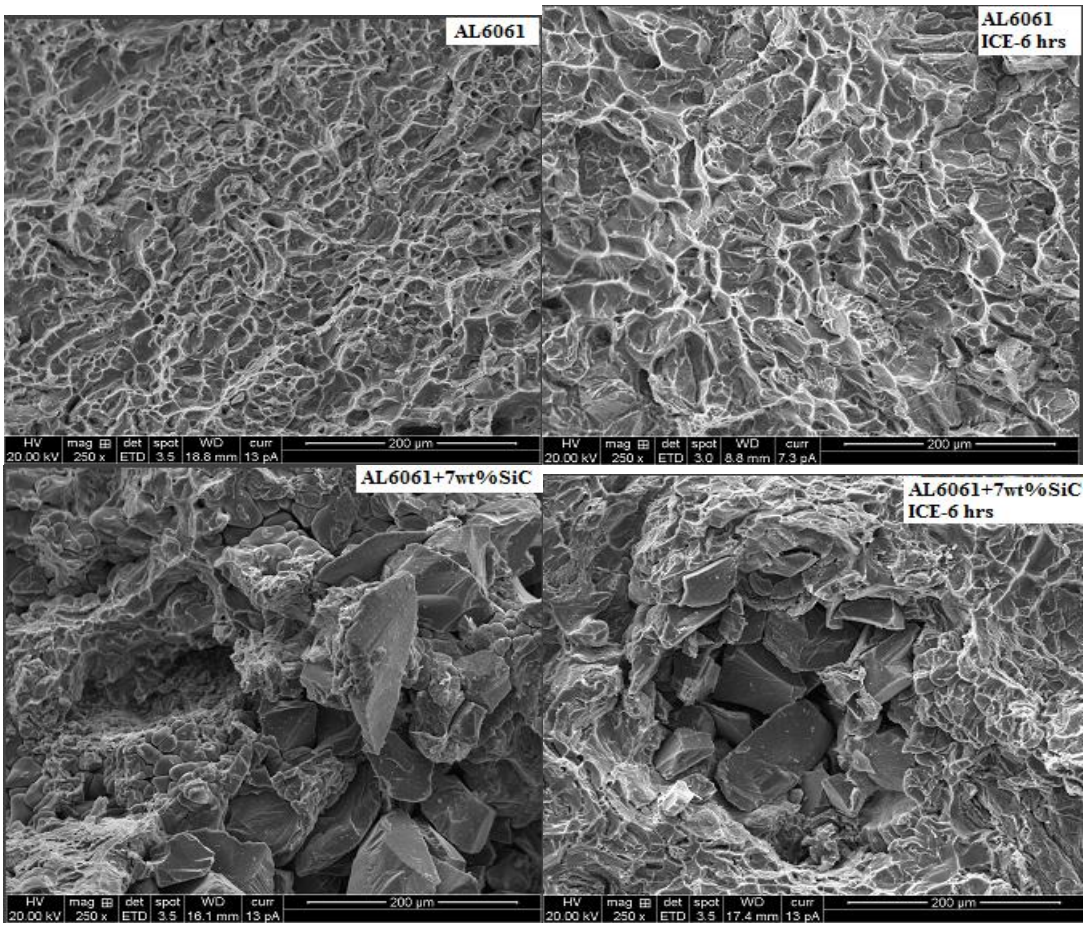


Figure 3.4: Effect of reinforcements and heat treatment with variation of ageing time on ultimate tensile strength of AL6061 alloy and its composites

4. Fractography

Scanning electron micrographs of tested specimen for AL 6061 alloy and its composites not subjected to heat treatment and subjected to heat treatment (ice quenched) is shown in fig. 4.1



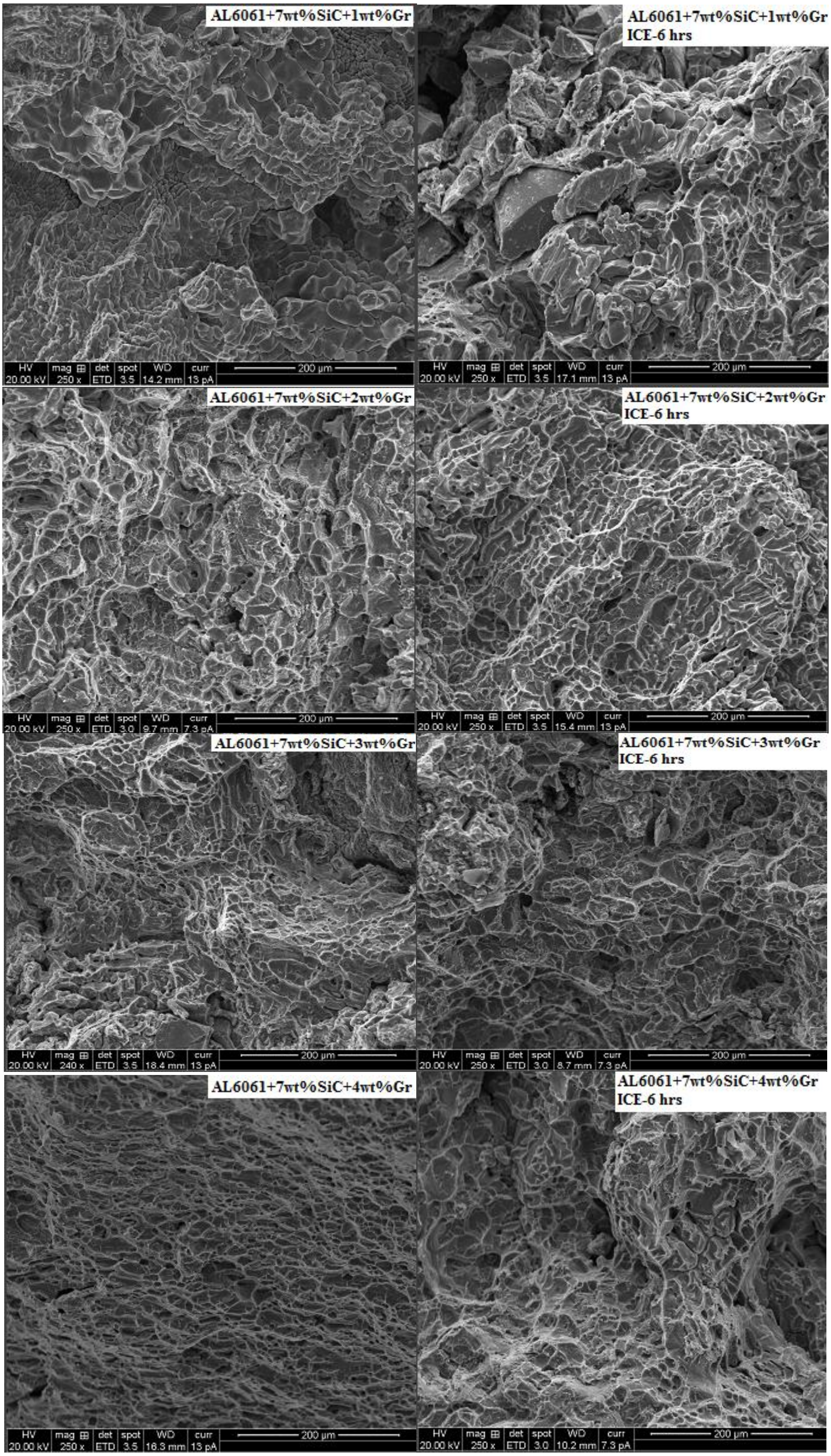


Figure 4.4: SEM of Al6061 and its composite

5. Conclusion

Al6061-SiC-Gr hybrid composites have been successfully produced by vortex method upto 4wt% Gr with constant 7wt% SiC. Fabrication of hybrid composites with more than 4wt% of Gr with constant 7wt% SiC was not achieved successfully due to low density of graphite. Ultimate tensile strength of Al6061 increases with addition of 7wt%SiC. But ultimate tensile strength of Al6061 decreases with increase in graphite content. However, ultimate tensile strength of Al6061 based hybrid composites was higher when compared with that of the matrix alloy. Presence of content of hard silicon carbide reinforcement in the hybrid composites leads to enhancement in ultimate tensile strength of hybrid composites reinforced with graphite. Further heat treatment has a profound influence on the ultimate tensile strength of the matrix alloy as well as its hybrid composites. For all the heat treatment processes studied ice quenching with ageing duration of 6hrs resulted in improved ultimate tensile strength of both the unreinforced matrix alloy and its hybrid composites.

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