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Evaluation of Mechanical Properties and Characterization of Cryotreated Al6061 Reinforced SiC MMC

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Abstract
This research work aims at developing and mechanical characterization of Al6061 based metal matrix composite reinforced with varying percentage of SiC (3%,5%,7%,9%).The mechanical properties are completely dependent on the microstructural parameters of the system. Also the microstructure further depends on the cooling rates during solidification process. The cryogenation of the samples increases the rate of solidification, which enhances the mechanical properties of the composite. The Cryotreated specimens were subjected to hardness tests followed by microstructure studies. Finer microstructure and better hardness value were seen for specimen's casted using 7% Specimens, whereas as higher percentage specimens exhibited inferior properties which might be due to agglomeration of the reinforcement SiC in matrix.

Keywords: Al6061, SiC, Stir casting, Microstructure, Hardness

1. Introduction

Al based Composite are known for their surface finish, texture and processing choices due to which they are widely used in aviation and automobile sectors[1].With the expansion in the interest for quality composites, it has very crucial to deliver aluminum composites free from unsoundness. Aluminium based composite casting is subjected to microshrinkage, [2-3].

The remarkable capacity of the composite materials for the particular necessities makes these materials more prominent in an assortment of uses, for example, aviation, automobile (cylinders, chamber liners), and auxiliary segments, bringing about saving in material and energy [4,5]

As of late there has been a lot of enthusiasm for creating metal matrix composites (MMC) in view of their special mechanical properties, for example, light weight and high versatile modulus. Spray deposition, fluid metallurgy technique and powder metallurgy are used to develop particulate reinforced MMCs [6,10]. Since costly equipments are required and the processing is difficult and laborious, the expense to deliver MMCs by these techniques is high, which has restricted the utilizations of MMC materials. The hot and cold rolling procedure are used to manufacture specific strengthened MMCs of high complexities [11-12]. A few different procedures used to deliver discontinuous MMCs likewise incorporate rheocasting, compocasting and squeeze casting [13-14].

The characterizations of mechanical properties of discontinuous MMCs are available from various reports [15-16]. With reference to these, the mechanical properties, for example, Young's modulus and quality have been enhanced by 20% - 40% by due to addition of reinforcements. Notwithstanding, pliability has disintegrated amazingly with expanding substance of reinforcements [17-18].There are numerous smaller scale basic variables, for example, base material and reinforcement used, the volume fraction and the size of the particulates, and each of these may impact mechanical properties of the composite [19-21].

Aluminium reinforced with particulates exhibits awesome physical & mechanical properties. On a weight-balanced premise, numerous Al-based metal network composites (MMCs) can outrage cast steel, Al, Mg and for all intents and purposes some other strengthened metal or compound in a wide assortment of utilizations. Thus, it appears to be plausible that such MMCs will replace customary materials in numerous business and modern applications soon [22-23].Apart from having sound mechanical properties, they also have improved fracture crack propagation resistance, show high abrasion resistance, and good micro creep performance [24-25]. Since these materials are being utilized where they are subjected to cyclic loading, it is essential to consider the crack mode and comprehend their harm level utilizing a ruinous assessment strategy. Most imperative stage in a casting procedure is hardening of metal in the mold. Since Al combinations solidify over an extensive variety of temperature, they are subjected to different defects like porosity, breaks, blow openings and so forth. Aluminum based composite castings cast utilizing sand molds face porosity issue as smaller scale shrinkage. Cryotreatment reduce the grain size and ensures uniform grain refinement and hence good mechanical strength.

2. Experimental Work

Composition/properties of the matrix material and the dispersoid

Aluminum alloy Al6061: The expansive utilization of aluminum alloys is managed by an exceptionally attractive blend of properties, combined with the ease with which extraordinary composite can be produced. The chemical composition of matrix material is shown in table 1.

Table 1 Chemical Composition of the Matrix

Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	Be	V	Al
0.92	0.76	0.28	0.22	0.10	0.07	0.06	0.04	0.003	0.01	Bal

Fig.1 Matrix Material: Al Alloy [Al6061]

Table. 2 Properties of matrix alloy as per standard.

Density	2.7 gm/cc
Young's modulus	75 GPa
UTS	170 MPa
Ductility	13.5%
Melting temperature	650°C

Fig.2 Reinforcement Material: SiC

Table.3 Properties of Reinforcement (SiC)

Molecular formula	**SiC**
Molar Mass	101.96 g/mol^{-1}
Density	3.95 g/cm^3
Melting Point	2,072 °C
Boiling Point	2,977 °C
Thermal Conductivity	30 $Wm^{-1}K^{-1}$

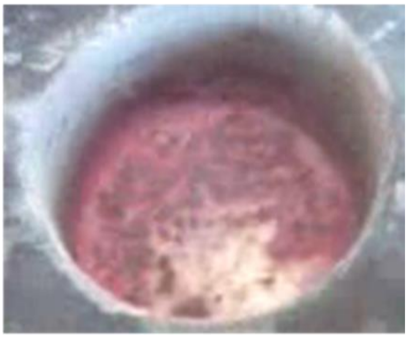
Development of Composites

The Composites were developed by stir casting method (vortex method). Al6061 in the form of ingots were used for trials. The ingots were cut into pieces for accommodating them into graphite crucibles. The matrix material was super-heated to a temperature of 750-800^{0}c in a three phase electrical resistance furnace with temperature controlling device. For each melting 3-4 kg of alloy was used. The super-heated molten metal was degassed using a commercially available chlorine based tablet (hexachloro ethane) and scum powder was used as slag removing agent. SiC was pre heated to around 400-5000c were then added to the molten metal and stirred continuously by a mechanical stirrer at 760 rpm.. The Molten metal was heated to red hot condition and was continuously stirred using a graphite impeller to create a vortex. Vortex was created in the molten metal due to high speed of the stirrer, the speed was around 500rpm.The graphite rod was immersed to a depth of approximately one third the height of the molten metal from the bottom of the crucibleThe pre-heated reinforcement particles were introduced into melt. The wetting of the particles and the matrix was ensured by constant stirring which was carried out for more than 20 minutes to avoid agglomeration. Finally superheated melt is poured into preheated metallic die and then Cryotreated.

Fig .3 Composite Preparation

Electrical Resistance Furnace

Adding scum powder



Slag Formation

Slag Removal

Preheating Furnace

Setting of Stirrer andadding reinforcement

Pre heating the mould box

Al6061-SiC Castings

Cryotreated Al6061-SiC MMC

Mechanical Tests

The uniaxial tensile test is known as a fundamental and all inclusive building test to accomplish material parameters, for example, extreme elasticity, yield quality, % prolongation, % zone of diminishment and Young's modulus. These critical parameters got from the standard tractable testing are valuable for the choice of building materials for any applications needed. The versatile testing is finished by applying longitudinal or significant weight at a specific development rate to a standard flexible sample with known estimations (gage length and burden sectional region inverse to the stack bearing) till complete strain. The associated tractable weight and extension are recorded in the midst of the test for the figuring of tension and strain. The results from the test are for the most part used to pick a material for an application, for quality control, and to anticipate how a material will react under diverse sorts of qualities. Properties that are particularly measured through a tractable test are a conclusive flexibility, most prominent stretching and diminishment in region.

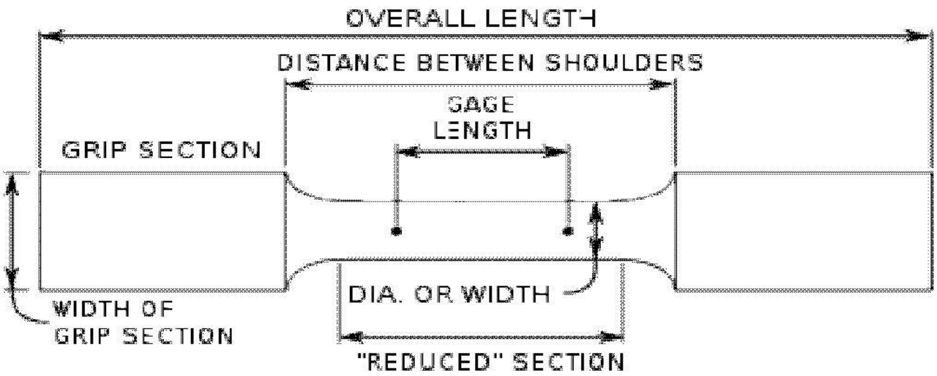


Fig.4 Standard Dimension of Tensile Specimen

A definitive elasticity was measured utilizing 10-ton limit servo-water powered widespread testing machine as indicated in Fig.5. The test samples are in a course parallel to the associated weight. In a tension strain chart, the beginning portion of the twist is a straight line and identifies with the proportionality of uneasiness to strain according to Hooke's law. As the store is extended past which the tension is not any more relating to the strain. Quite far is the best nervousness that can be joined with the material without making an interminable plastic deformation when the store is cleared. The yield point is the best tension at which the case is misshaped without a discernible addition in weight. Amazing versatility is the best uneasiness that a test case can continue before split and is in perspective of the interesting locale.

All tests were led as per ASTM norms. Tensile tests were directed at room temperature utilizing the all inclusive testing machine as a part of understanding with ASTM E8M-04 in Fig.4. The tensile test specimens diameter of 9 mm and gage length are 5times diameter of specimen i.e. 45 mm were prepared from the cast composites with the gage length of the specimen is parallel to the longitudinal hub of the castings. Five examples were tried and the normal estimations of Ultimate Tensile Strength (UTS) and its ductility (regarding rate of prolongation)

Universal Testing Machine

Fig.5 Universal Testing Machine

Fig.6 Specimens for Tensile test

Compression test

The Compression test was done utilizing a standard 10-ton limit universal testing machine. The All inclusive testing machine utilized for the Compression test is indicated in Fig. 5 Compression tests were led on examples of 20 mm measurement and 30 mm length prepared from the cast composites. The compression test specimens prepared according to ASTM E9 principles. According to this standard length of the specimen, should be 1.5 times the diameter of the specimen. By gradually applied loads and its corresponding strains were measured until a failure of the specimens. The compression test specimens are shown in Fig.7. The 5 Compression samples tests were conducted according to the ASTM E9 at room temperature.

Fig.7 Specimens before and after Compression test

Brinell hardness Test

Among the various types of estimations that are done in a lab, hardness testing is a standout amongst the most complex ones. From one perspective, there are distinctive estimation systems; then again, it is important to quantify vast, little, hard, delicate, slight or thick metal parts. Considering the diverse systems and the extensive number of scales, it is reasonable that even extremely experienced persons can be tested by hardness testing undertakings.

As in such a large number of different territories of utilization, electronic advancement has prompted a noteworthy improvement of hardness testing. With Brinell hardness analyzers, a higher exactness amid result readout, information stockpiling and the likelihood of information handling to insights, realistic representations, documentation, and so on have turned into an anticipated result.

The Brinell (Fig.8) technique includes ball penetrators of distinctive breadths (dependable in mm, rather than the Rockwell measurements in inch), which are squeezed with a certain heap onto a smooth and even surface for a certain measure of time (10 to 15 seconds).

The specimens of cylindrical crossection (Fig.9) with dia of 20 mm and height 20mm were used for hardness testing and average of 3 readings were taken to finalize the hardness.

Fig.8 Brinell Hardness Testing Machine

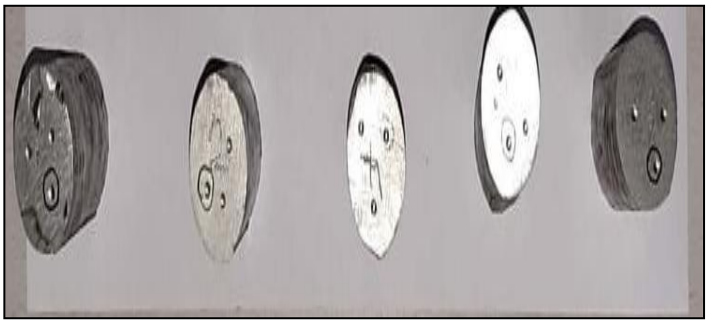


Fig.9 Specimens after Hardness Test

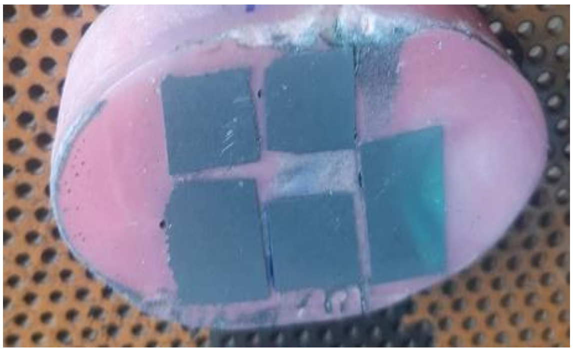
Microstructure

The optical metallurgical magnifying lens (Metallurgical Microscope (Zesis) Clemex Picture Analyzer optical magnifying lens) was utilized for microstructure characterization of the Al6061 matrix alloy reinforced with SiC to study the effect of reinforcement in the matrix. The specimens were held immovably close by and rubbed easily against the SiC papers, practicing adequate consideration to evade any profound scratches since the Al amalgams are similarly delicate. Intemperate warmth arrangement amid cleaning was maintained a strategic distance from as Al amalgams contain numerous Metastable stages. Fine polishing was performed utilizing magnesium oxide glue took after by precious stone glue utilizing

cleaning machine indicated as a part of Fig 10. The stage was secured with billiard material. Separate stages were utilized for magnesium oxide and precious stone cleaning. Amid fine polishing with magnesium oxide glue, hands, and in addition the examples, were washed with water in the middle of to keep vestige of coarser coarseness from past steps. Subsequent to polishing with magnesium oxide, the examples were at last cleaned with 1-micron flimsy jewel glue in the wake of changing the stage. The examples were then cleaned with liquor and dried in air.

Metallurgical Microscope (Zesis)

Polishing Machine



Microstructure Specimens

Fig.10 Microstructure Analysis setup

3. Results and Discussions

Tensile Test:

The Tensile tests were carried out on the composites developed by varying the wt% of SiC, to understand the variation of Ultimate Tensile Strength.

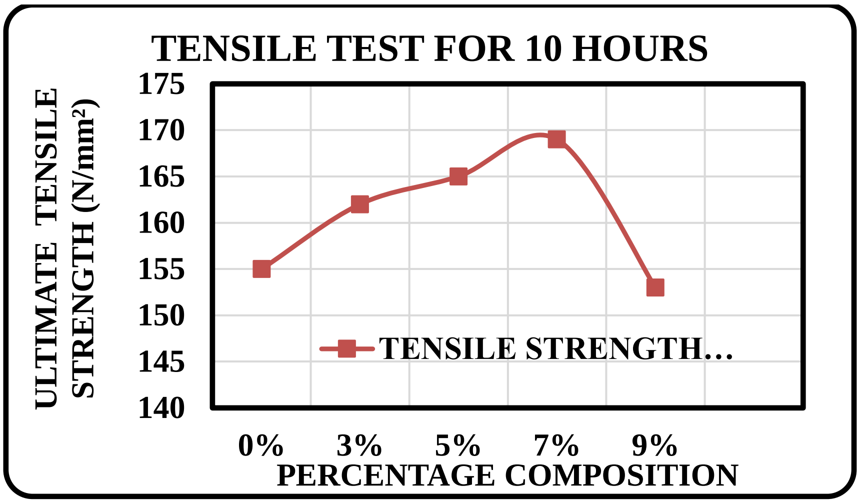


Fig.11 Graph of UTS versus % of SiC reinforcement

There is increase in UTS (Fig.11) upto 7 Wt% SiC, further with increasing the reinforcement there is decrease in strength. This might be due to cluster formation.

Compression Strength

The Compression tests were carried out on the composites developed by varying the wt% of Flyash and Graphite, to understand the variation of Ultimate compression Strength. Fig 8, Fig 9 and Fig10 shows the effect of reinforcement particulate content on the compressive strength of the composites.

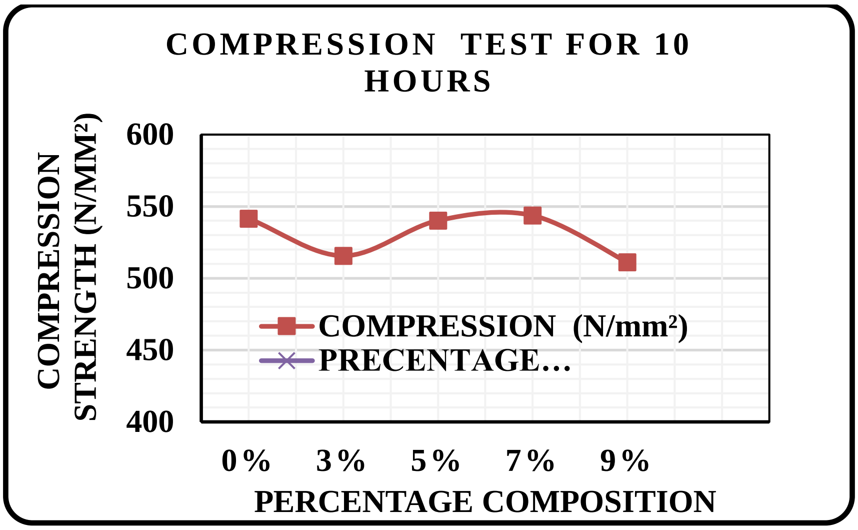


Fig.12 Graph of UTS versus % of SiC reinforcement

The improvement of UCS (Fig.12) is due to enhancement of dislocation density which leads to attributed to secondary hard phase and hence Al6061 reinforced with SiC (3%,5%,7%,9%,),composites become brittle, which were evident from the results obtained.

Hardness

The hardness variation of Al 6061 composite is shown in Fig.13 The hardness of the composite increases marginally with the increase of reinforcement's addition.

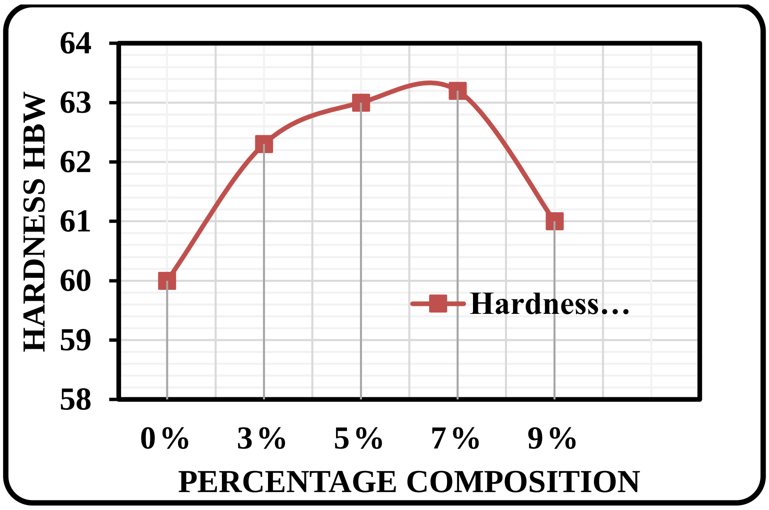


Fig.13 Graph of Hardness versus % of SiC reinforcement

There is increase in hardness Owing to higher percentage & densification of the tough particles of SiC in composites.

4. Conclusions

- The composite castings with Al 6061 as base material and Flyash-Graphite reinforcements with varying particles of 44µm mesh size (3 % to 9%) were successfully prepared by using stir casting technique.

- The Ultimate Tensile Strength of the Al6061 7Wt% SiC composite is 169 MPa. This might me due to uniform distribution of SiC in the matrix.
- The Compression Al6061 7Wt% SiC composite is 548 MPa. This might me due to hard particles of SiC in the matrix.
- The Hardness of Al6061 7Wt% SiC composite is 63.6. This might me due to uniform distribution of hard particles of SiC in the matrix.
- Fine grain structure, uniform distribution of dispersoid and good bonding between the matrix and the dispersoid is obtained due to Cryotreatment.

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