

The Influence of the Mechanical Properties of Gravity Die Cast, Grain Refined and Modified A357 Reinforced With Triple Size Silicon Carbide and Graphite

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ABSTRACT: This project deals with the fabrication and mechanical investigation of metal matrix composites of Aluminium A357 reinforced with triple size Silicon Carbide (SiC) with Graphite. This project is aimed to investigate the results on reinforcement effects on the hybrid composite material that could enhance the mechanical properties. Aluminium A357 is the matrix metal having properties like good toughness, excellent corrosion resistance. Silicon Carbide as Reinforcement has excellent thermal and chemical stability and also high hardness. Here, the fabrication is done by stir casting which involves mixing of the required quantities of reinforcements into stirred molten A357. After solidification, the specimens are prepared as per ASTM standards in the form of cylindrical rods to determine the mechanical properties like tensile strength and hardness. The microstructure of the composite is observed by optical microscope (OM).

KEYWORDS: Aluminium A357, Silicon Carbide, Graphite, Gravity Die Casting, Mechanical properties.

I. INTRODUCTION

Aluminium-silicon alloys possess light weight, high specific strength and heat transfer ability which makes them suitable materials to replace components made of ferrous materials. The other important properties, viz., low melting temperature, ease of handling, easy formability and recycling had led to increased demand for Al-Si alloy components. This can be achieved by making use of one matrix and two or more reinforcing materials which is known as Hybrid composite material. Al-Si alloys are widely used in all types of IC engine parts such as cylinder block, cylinder head and pistons. They find applications in aircraft pump parts, aircraft structure and control parts, automotive transmission, aircraft fittings, water cooled cylinder blocks and nuclear energy installations.

Rheocasting of Semi-Solid A357 Aluminum- Tim Basner [1]- the most popular aluminum alloys for semi-solid automotive components are A356 and A357. The density of rheocast semi-solid A357 is higher than die cast A357 and allows for both T5 and T6 heat treatment.

Effect of hot isostatic pressing on cast A357 aluminium alloy with and without SiC particle reinforcement- A. ZULFIA, H. V. ATKINSON, H. JONES [2]- the effect of Hot Isostatic Pressing treatments on porosity in the aluminium casting alloy A357 and stir-cast A357/15 vol% SiC particulate Metal Matrix Composite has been investigated. Densitometry and image analysis have been used to determine the apparent percentage porosity. Four temperature profiles have been investigated (103 MPa pressure) and mechanical testing has been carried out by single notch four-point bending.

The effect of mischmetal and heat treatment on the microstructure and tensile properties of A357 Al-Si casting alloy- G.S. Mousavi, M. Emamyn, J. Rassizadehghani [3]- The effects of La-based mischmetal (MM) and heat treatment on the microstructure and tensile properties of two different sections of A357 Al-Si casting alloy have been investigated in this study. Different concentrations (0–1 wt%) of the MM were added to the molten alloy directly. T6 heat treatment was applied before tensile testing. The results showed that the optimum levels of added mischmetal are 0.1 wt% and 0.3 wt% for thin and thick section castings respectively. A new Al-Si-La intermetallic was detected through the microstructural studies at higher MM levels. Further results demonstrated that T6 heat treatment improves tensile properties of the modified alloy significantly. The differences observed in the fracture behavior were attributed to the microstructural changes as well as morphological aspects of Si particles.

Review on the influence of alloying elements on the microstructure and mechanical properties of aluminum alloys and aluminum alloy composites- R. S. Rana, Rajesh Purohit, and S Das [4]- In recent year's aluminum and aluminum alloys are widely used in automotive industries. These are light weight (density of about 2.7g/cc), having good malleability and formability, high corrosion resistance and high electrical and thermal conductivity. High machinability and workability of aluminum alloys are prone to porosity due to gases dissolved during melting processes. However, in the engineering application pure aluminum and its alloys still have some problems such as relatively low strength, unstable mechanical properties. The microstructure can be modified and mechanical properties can be improved by alloying, cold working and heat treatment in this regards, this paper reports the influences of some alloying elements on the microstructures and mechanical properties of Aluminum alloys and aluminum alloy composites.

II. EXPERIMENTAL DETAILS

A. Materials

In this work for preparing metal matrix composite, aluminium A357 is used as base material. Silicon carbide of three different sizes (80,100,120 Microns) in the powder form is used as the reinforcements. Graphite used as lubricant, Strontium as Grain Modifier and Titanium Boron as Grain Refiner.

i. Aluminium A357

300.0 series alloy such as A357 are often used in transport applications, including marine, automotive and aviation, due to their high strength-to-density ratio. The strength and light weight is also desirable in other fields. Rock climbing equipment, bicycle components and hang glider airframes are commonly made from A357 aluminium alloy. A357 remains the baseline with a good balance of properties required for aerospace and automobile applications.

ii. Silicon Carbide

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years It is used in abrasives, refractories, ceramics, and numerous high-performance applications. Silicon carbide is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice.

iii. Graphite

Graphite is a crystalline allotrope of carbon, a semimetal and a native element mineral. Graphite is the most stable form of carbon under standard conditions. Therefore, it is used in thermo-chemistry as the standard state for defining the heat of formation of carbon compounds. It can be used as a dry powder, in water or oil, or as colloidal graphite.

B. Composite Preparation

Stir casting method is used for the preparation of composite. A stir casting setup consists of an Electrical Resistance Furnace and a stirrer assembly, was used to synthesize the composite. Aluminium A357 was heated up to 850⁰C in an electric furnace where SiC, Graphite, Grain modifier and refiner are added. Aluminium coated stainless steel impeller

was used to stir (300-400 Rpm) the molten to create a vertex. Stirring was continued until interface degassed using degassing tablet and after rehearsing to superheated temperature it was poured into the preheated Finger Mould. After few minutes of stirring the, liquid metals with reinforcements are poured into dies to get the required castings. The dies were preheated to ease the process of removing castings. A357 and its composites are casted in the form of cylindrical bars. Various cast compositions produced are,

Table 1: Cast Compositions

CAST	Cast Composition
AS CAST	A357 Alloy Only
SAMPLE C1	A357 Alloy+ 1.5% Grain Modifier +1.5% Grain Refiner+ 1.5% Graphite
SAMPLE C2	A357 Alloy + 1.5% Grain Modifier + 1.5% Grain Refiner + 1.5% Graphite + 5% Silicon Carbide (80 Microns)
SAMPLE C3	A357 Alloy + 1.5% Grain Modifier + 1.5% Grain Refiner + 1.5% Graphite + 5% Silicon Carbide (100 Microns)
SAMPLE C4	A357 Alloy + 1.5% Grain Modifier + 1.5% Grain Refiner + 1.5% Graphite + 5% Silicon Carbide (120 Microns)

C. Testing of composites

Samples for microstructure examination are prepared and analysed using ASTM E407-07 standard metallurgical procedures. For the micro structural analysis, optical microscope was used and the specimens were polished by different grades of emery paper, Keller's reagent and diamond paste and etched. Brinell hardness test was conducted to determine the hardness of the composites and base metal as per ASTM E10. The tensile test was conducted on a Universal Testing Machine (UTM) to determine the tensile strength and the percentage elongation. The specimens were prepared as per ASTM E8 standard for tensile test.

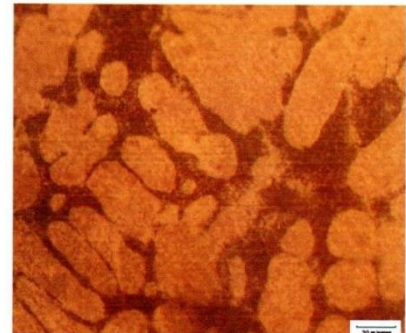
III. RESULTS AND DISCUSSION

A. Micro structural Study

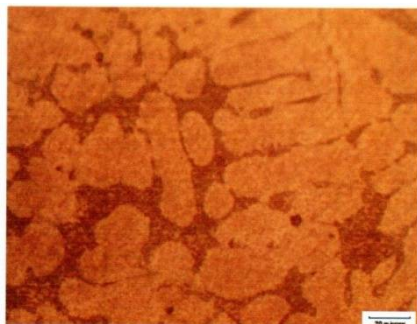
The study of microstructure helps in the analysis of the distribution of distinct phases in the A357 metal matrix phase. Figures 1,2,3,4 and 5 shows the microstructure of composite of As-Cast, Sample C1, C2, C3 and C4 which was observed by using optical metallurgical microscope.



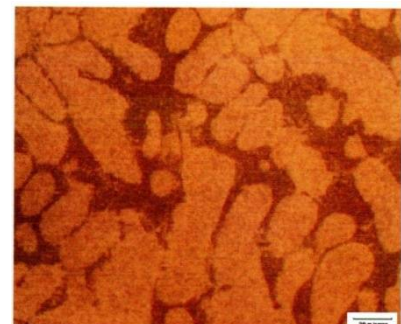
500X keller's
Figure 1: Microstructure of A357 As-Cast



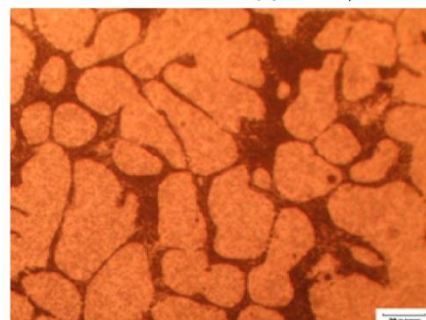
500X keller's
Figure 2: Microstructure of Sample C1



500X keller's
Figure 3: Microstructure of Sample C2



500X keller's
Figure 4: Microstructure of Sample C3



500X Keller's reagent
Figure 5: Microstructure of Sample C4

Microstructure consists of inter dendritic eutectic Silicon in a matrix of aluminium solid solution. No segregation or porosity was seen in the section.

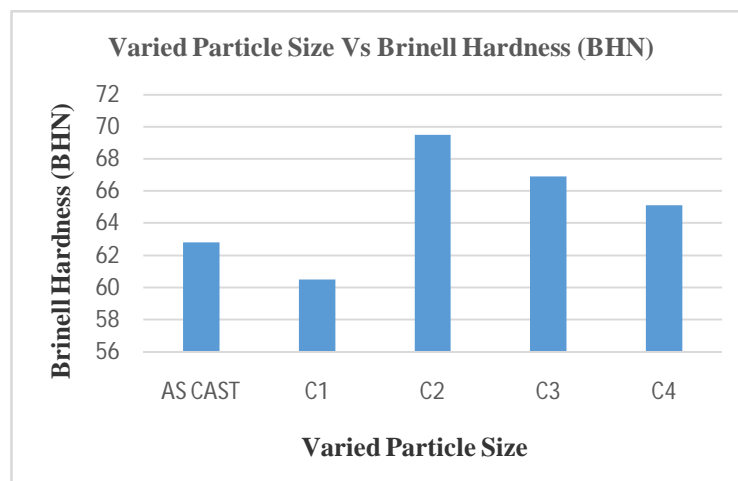
B. Hardness Results

Hardness is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds. There are three types of tests used with accuracy by the metals industry; they are the Brinell hardness test, the Rockwell hardness test, and the Vickers hardness test. But in our present work we considered only Brinell hardness test as per ASTM E10 Standards. The Brinell scale is a hardness scale based on the indentation hardness of a material.

The Brinell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. Table 2 and Graph 1 shows the Brinell hardness values for different particle sizes.

Table 2: Hardness Test Results

SPECIMEN	BRINELL HARDNESS NUMBER (BHN)
AS CAST	62.8
SAMPLE C1	60.5
SAMPLE C2	69.5
SAMPLE C3	66.9
SAMPLE C4	65.1



Graph 1: Varied Particle Size Vs Brinell Hardness (BHN)

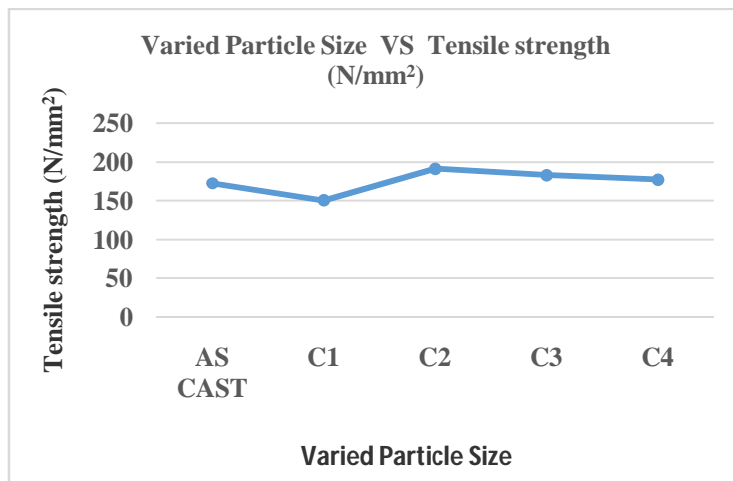
C. Tensile Results

The tensile tests are conducted on a computerized UTM which has a capacity of 1000 kN. Tensile specimen was prepared and the test was conducted as per ASTM E8 Standards. The tensile strength of samples viz. ultimate tensile strength, yield strength and ductility were evaluated on universal testing machine. Tensile strength resists tension (being pulled apart), whereas compressive strength resists compression (being pushed together). Ultimate tensile strength is measured by the maximum stress that a material can withstand while being stretched or pulled before breaking.

The tensile specimens of diameter 12.53 mm and gauge length 50 mm were machined from the cast specimens with the gauge length of the specimen parallel to the longitudinal axis of the casting. The machined tensile test samples were held, with suitable grips between the cross yoke and the actuator of the machine. Gauge length on the sample was marked. Uniaxial load at a uniform rate was applied to the test sample through the actuator until it failed. The variation of applied load vs. the displacement was recorded. The tensile strength of specimen was determined in terms of N/mm².

Table 3: Tensile Test Results

SPECIMEN	TENSILE STRENGTH (N/mm ²)
AS CAST	172.298
SAMPLE C1	150.384
SAMPLE C2	190.989
SAMPLE C3	182.531
SAMPLE C4	176.781



Graph 2: Varied Particle Size Vs Tensile Strength (N/mm²)

IV. CONCLUSION

1. Gravity die casting method is used to obtain homogeneous microstructure of A357 alloy with Al-Sr as grain refiner and Al-Ti-B as modifier.
2. Microstructure reveals the uniform distribution of grain refiners in the aluminium solid structure.
3. Compared to all specimens prepared, Sample C2 with Silicon Carbide Size of 80 Microns gave the best possible results.
4. It Showcases Better Hardness due to addition Silicon Carbide of 80 Microns as a reinforcement particle which improves the Hardness Properties.
5. Tensile Strength of the material increases substantially due to the addition of Reinforcement material.
6. Hence, we can consider Sample C2 for the Further scope of work due to its comparatively better properties than all the casts prepared.

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