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Effect of Heat treatment and Cryogenic treatment on Mechanical Properties and Microstructure of Aluminum Alloy 356 Reinforced with Silicon Carbide

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Abstract:
Metal matrix composites are gaining widespread acceptance in recent times due to its importance of application in the field of automobile, aerospace, agriculture farm machinery and many other industrial application, because of its essential properties such as high strength, low density, wear and corrosion resistance which are not available in single conventional material. the wide use of particular metal matrix for engineering application has been obstructed by the exact use of silicon carbide(Sic) by weight % , hence high cost of components .The present study deals with the addition of reinforcement such as silicon carbide to aluminum in various proportion. Each reinforcement properties which when added enhances the property of aluminum alloy. Improvement of mixture metal network composites has turned into a significant zone of research enthusiasm for material science, this paper manages assessing mechanical properties of aluminum fortified with various Development of hybrid metal matrix composites of silicon carbide (4%,6%,8%,10%) combination .stir casting method was used for fabrication of aluminum metal matrix composites. To investigate the properties of AlSic for varied % of silicon carbide under heat treatment and cryogenic treatment, test like –tensile test, hardness test, corrosion test were conducted. The result obtained indicates the properties of AlSic were quite beneficial according to the requirements.

Keywords: Aluminum, Silicon Carbide, Stir casting, Heat treatment, Cryogenic treatment.

1. INTRODUCTION

In recent days, there is an increasing demand for developing advanced engineering materials which are multifunctional and these materials are gaining wide popularity because of their contribution towards various applications. A Composite material is defined as a combination of two or more individual materials with different physical or chemical properties, and which remain separate and distinct on a microscopic or macroscopic level within the finished structure such a way that the resulting material have a desired design properties and improved mechanical properties. Aluminum MMC are sought after because of their properties like low thickness, high explicit quality, high damping limit, high warm conductivity, high explicit modulus, and high scraped area and wear obstruction. However, it has lower obstruction, ductile, less strength and hardness. To overcome this problem, silicon carbide is added as a reinforcement particle to enhance the mechanical behavior of Al MMC.

The reinforcing phase provides the strength and stiffness In this investigation, the experiments were performed on different composition of Sic, the reinforcement particles are added at 4, 6, 8 and 10 of weight percentage. Al-Sic composites can be more easily produced by the stir casting technique due to its good casting ability and relatively inexpensive.

2.MATERIAL SELECTION

Aluminum is chosen as the base material because of its wider engineering application. Aluminum A356 was purchased through online at amazon. Silicon carbide is used as reinforcement for its good temperature resistance and abrasive resistance, Silicon Carbide 1kg (80 microns) was bought at Ananya Flour polymer Coating 2nd stage Peenya. Composite fabrication is one the most challenging and subsequent difficult task. Stir casting technique of liquid metallurgy is used to prepare A356 Hybrid composite.

3. EXPERIMENTAL WORK

In the stir casting process, the alloy matrix, is melted at controlled temperature and the desired quantity of reinforcement material is added to the molten alloy. The molten alloy is stirred continuously to create a vortex to force the slightly lighter particles in to the metal. Stirring continues to disperse the reinforcement particles as uniformly as possible in short time The mixture is stirred again and then poured into preheated permanent mould having the desired shape of the composite to be produced. Sufficient time is allowed for solidification of the material.[1] A356.

Aluminum alloy was reinforced with Silicon Carbide materials at different wt. % ratios (4 ,6, 8 and10) of samples. It was fabricated using a furnace equipped with a stirring system. Stirring process was carried out at constant speed of 300-400 rpm with a stirring duration of about 4-5hrs, and at casting temperature of 850±50°C. Aluminum coated stainless steel impeller was used to stir the molten.

The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, Stirring was continued until interface degassed using degassing tablet and after rehearsing to superheated temperature it was poured into the preheated die. .Samples were shaped in the form of cylindrical rod of 20 mm diameter and with the height of 200 mm.

Figure.3.1 Stir casting process

Figure.3.2.casted rods

4. HEAT TREATMENT PROCESS

Heat treating processes for aluminum are precision processes. They must be carried out in furnaces properly designed and built to provide the thermal conditions required, and adequately equipped with control instruments to insure the desired continuity and uniformity of temperature time cycles. The application of the term heat treatable to aluminum alloy, is limited to the specific operations employed to increase strength and hardness by precipitation hardening thus the term heat treatable serves to select the heat treatable alloys from those alloys in which no significant strength improvement can be achieved by heating and cooling. T6 heat treatment cycle is preferred, because during this condition the microstructure of aluminum is solutionized. (is the process of heating the metal to relatively high temperature i.e. above 500^0c for about 7-8hrs, and second cycle, specimens are treated to 190^0c for about 4hrs.and, finally quenched in cold water)[2]. heat treatment cycle is preferred, because during this condition the microstructure of aluminum is finely distributed.

5. CRYOGENIC PROCESS TREATMENT

Cryogenic treatment (CT) is the supplementary process to conventional heat treatment proces, by deep–freezing materials at cryogenic temperatures to enhance the mechanical and physical properties of materials being treated. Cryogenic treatment (CT) of materials has shown significant improvement in their properties. Cryogenics is the science of production and effects of very low temperatures. It is clear from the above definition that, in the studies of cryogenics lowest temperatures below the freezing of water (0^0 C) to be considered. The basic CT consists of a gradual cooling of the component until the defined temperature, holding it for a given time (freezing time) and then progressively leading it back to the room temperature. The aim is to obtain an improvement of mechanical properties, typically hardness and wear resistance, but in recent tests fatigue limit too, and to achieve an optimal ratio between conflicting properties, like hardness and toughness.

here helium is used as a cryogenic liquid, specimens are cryogenic treated for about 72hrs maintained at -340^0F within a closed a chamber[3].

6.MECHANICAL PROPERTIES

6.1 HARDNESS TEST

Hardness tests serve an important need in industry, theses test are based on experiments and observation, they are able to detect certain differences between the materials. Hardness is defined as the material's resistance to the indentation of an object; that is, to the impression that the object causes on the materials' surface, Brinell hardness test is accomplished for the examination of hardness of Al SiC with various percentage (4%, 6%, 8% &10) The Brinell hardness testing method was the first hardness testing method to be used in the industry. Usually, this testing process takes between 10 to 30 seconds. The Brinell hardness test was one of the most widely used hardness tests . For measuring a rod or plate hardness the test is usually conducted by pressing a diamond sphere of 2.5mm in diameter into the test surface for 10 seconds with a load of 60kg, then measuring the diameter of the resulting impression. The BHN is calculated according to the following formula: [4].

$$BHN = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$$

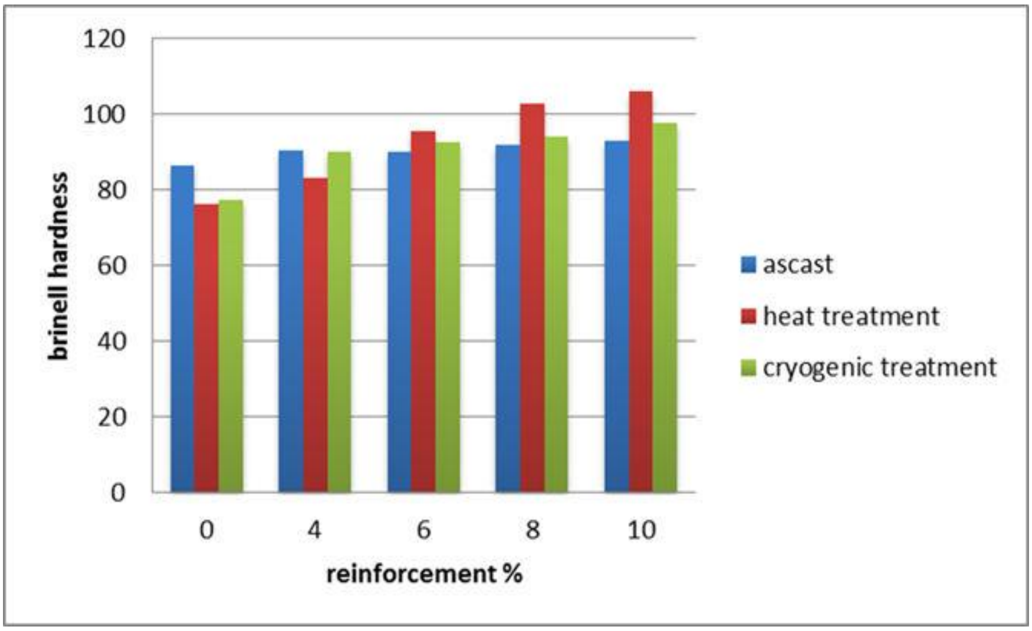
Where,
BHN = Brinell hardness number
P = imposed load in kg
D = diameter of the spherical indenter in mm
d = diameter of resulting indenter impression in mm

Figure.6.1.1 Specimen before hardness test

Figure.6.1.2 Specimen after hardness test

Table.1. Comparing the hardness result for ascast, heat treated and cryogenic treated

Reinforcement %	ascast	Heat treated	Cryogenic treated
0	86.549	76.39	77.55
4	90.314	83.32	89.951
6	89.903	95.54	92.685
8	91.737	102.63	94.207
10	93.126	106.21	97.825



From the above table and graph we can conclude that hardness is more in specimen which are heat treated when compared to ascast and cryogenic treated. .hence the graph proved that increase in reinforcement results in increase in hardness.

6.2 TENSILE TEST

Tensile test is also known as tension testing. The results from the test are commonly used to select a material for an application and to predict how a material will react under other types of forces. . A tensile specimen is a standardized sample cross-sec- tion. It has two shoulders and a gauge in between, A standard specimen is prepared in a round or a square section along the gauge length, depending on the standard used. Both ends of the specimens should have sufficient length and a surface condition such that they are firmly gripped during testing. The initial gauge length Lo is standardized (in several countries) and varies with the diameter (Do) or the cross-sec- tional area (Ao) of the specimen

The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force. During tensile deformation the material decreases in cross-sectional area. The data is manipulated so that it is not specific to the geometry of the test sample. The elongation measurement is used to calculate the engineering strain (ε), using the following equation [4]:

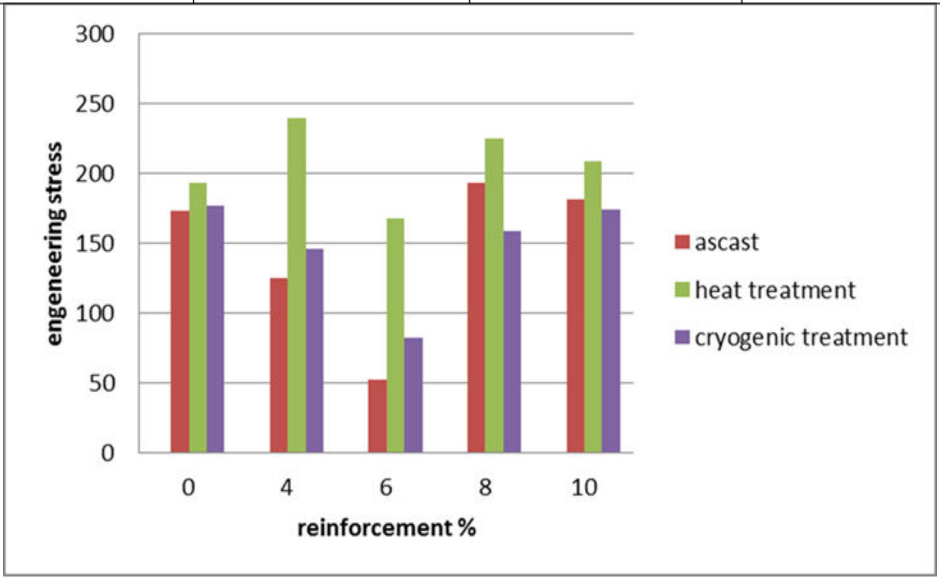
$$\varepsilon = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0}$$

Where, ΔL is the difference in gauge length, Lo is initial gauge length, and L is final length.

Figure.6.2.1 Specimen before tensile test **Figure.6.2.2 Specimen after tensile test**

Table.2. Comparing the tensile test result for ascast, heat treated and cryogenic treated

Reinforcement%	ascast	Heat treated	Cryogenic treated
0	173.3	193.2	177.1
4	125.1	239.0	145.5
6	52.6	167.2	82.6
8	192.8	224.7	158.5
10	181.4	208.0	174.3



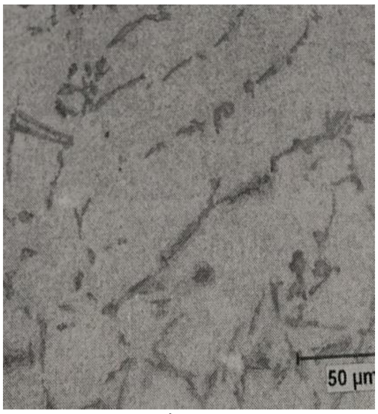
Thus the best tensile result are found in heat treated specimen , proper distribution of reinforcement in found in heat treated tensile rods. hence the graph proved that increase in reinforcement leads to increase in hardness. But as per the above graph tensile strength at 6%shows a great difference when compared to all others.

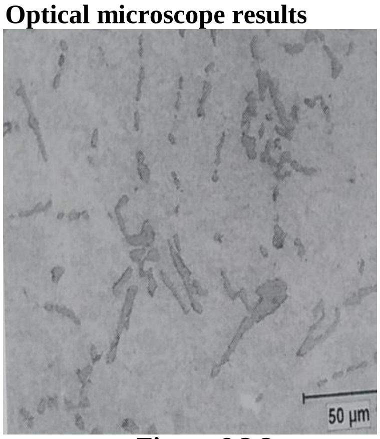
6.3 STRUCTURAL ANALYSIS

The optical microscope, often referred to as the light microscope, is a type of microscope that commonly uses visible light and a system of lenses to magnify images of small objects All technological properties of materials are directly connected to their microstructure. Among these properties are their strength and deformation characteristics

The cross sections of specimens were ground using 150 grade Silicon carbide papers. Then the specimens were emeried with water proof emery sheets of grid respectively in the order, on the rotating grinding disc. The specimen were cleaned and dried. . The intensity of amplification of a compound optical magnifying lens relies upon the visual and the goal focal points. The specimens for microstructure were prepared as per the standard metallurgical procedure, etched and photographed with magnification 500X. The beneath figure demonstrates the stage structure. [5]

Optical microscope results





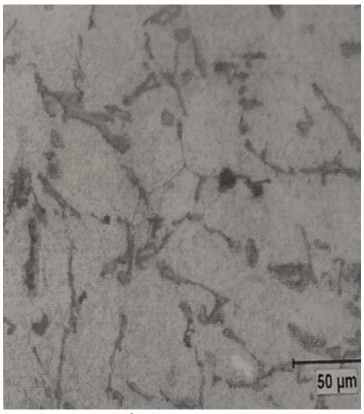


Figure.6.3.1 **Figure.6.3.2** **Figure.6.3.3**

The above figures represents the images showing the results for arrangement of grain structure of Aluminum with 0% reinforcement for ascast(Fig.6.3.1), heat treated(Fig.6.3.2) and cryogenic treated(Fig.6.3.3)

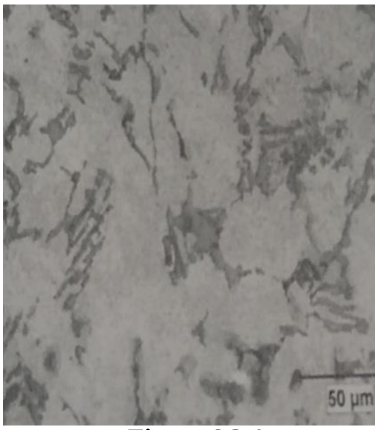


Figure.6.3.4

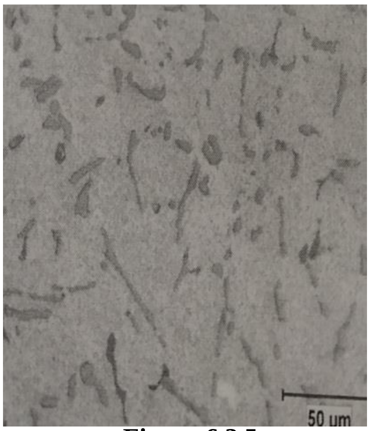


Figure.6.3.5

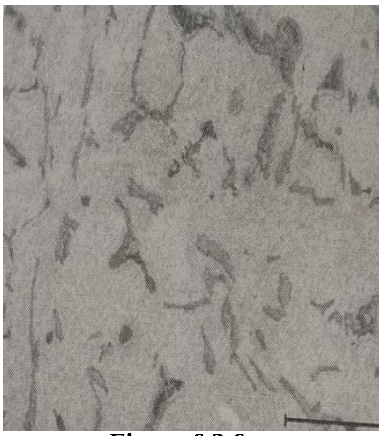


Figure.6.3.6

The above figures represents the images showing the results for silicon carbide distribution of about 6% in aluminum for ascast(Fig.6.3.4), heat treated(Fig.6.3.5) and cryogenic treated(Fig.6.3.6)

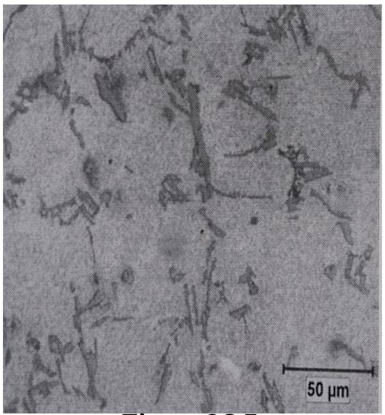


Figure.6.3.7

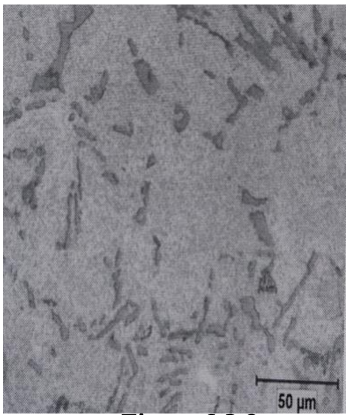


Figure.6.3.8

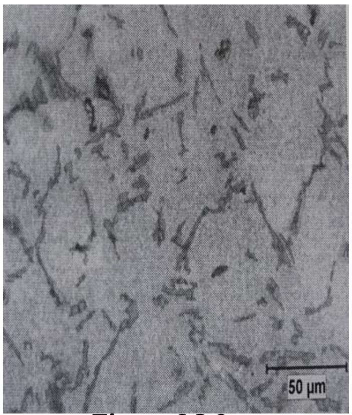


Figure.6.3.9

The above figures represents the images showing the results for silicon carbide distribution of about 10% in aluminum for ascast(Fig.6.3.7), heat treated(Fig.6.3.8) and cryo treated(Fig.6.3.9)

6.4 CORROSION TEST OF ALUMINIUM ALLOYS REINFORCED WITH SILICON CARBIDE

The simple test for measuring Corrosion is weight loss method, this method involves exposing a clean weighed specimen of alloy to the Corrosion environment[6]

Corrosion with HCL media-The beaker has to be cleaned properly with distilled water, the beaker has to filled with 0.1N HCL of about 50 ml, the pre-cleaned and weighed specimens (ascast, heat treated, cryogenic treated) were suspended in beakers containing the test solutions using glass hooks and rods. Tests were conducted under total immersion condition for about 8 days in 0.1 N HLl. After 8 days the weight loss was taken to be the difference between the weight of the specimens at present time and its initial weight.

CORROSION with Nacl media - The beaker has to be cleaned properly with distilled water, 3.5% of Nacl has to be measured and mixed with 96.5% of distilled water ,and are stirred properly,the rods after weighing are immeresed completely in the solution ,and are allowed to corred for about 8days. after 8days the specimens are removed from the solution and are weighed to check the weight loss[7].

Figure.6.4 Corroded rods

Table.3. Corrosion rate result of ascas, heat treated and cryogenic treated after treating with Hcl

Reinforcement %	Ascast	Heat treated	Cryogenic treated
0	**0.3986**	**0.2905**	**0.3245**
4	**0.5712**	**0.2838**	**0.3499**
6	**0.8683**	**0.5928**	**0.4908**
8	**0.4718**	**0.2281**	**0.3341**
10	**0.5293**	**0.3293**	**0.3948**

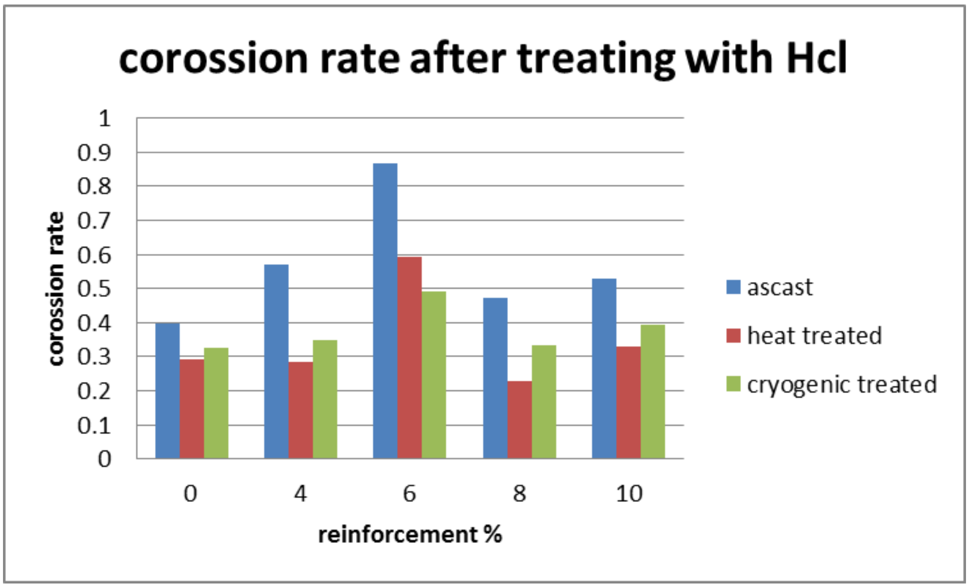
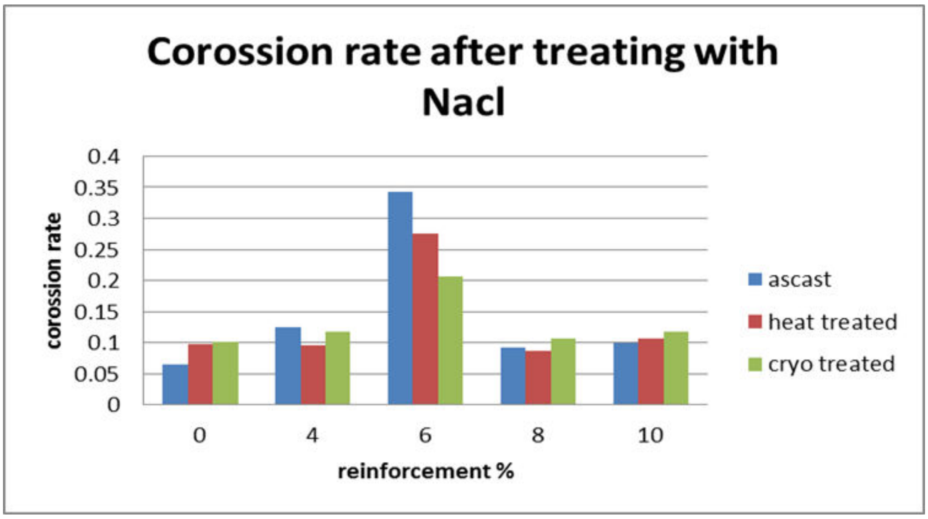


Table.4. Corrosion rate result of ascast, heat treated and cryogenic treated after treating with Nacl

Reinforcement %	Ascast	Heat treated	Cryogenic treated
0	0.0653	0.0981	0.1004
4	0.1246	0.0950	0.1180
6	0.3420	0.2746	0.2062
8	0.0924	0.0870	0.1057
10	0.0996	0.1069	0.1180



7. CONCLUSION

A356 alloys reinforced with silicon carbide are cryogenic treated and heat treated, were tested for microstructure, mechanical properties such as ultimate tensile strength (UTS), hardness, and corrosion characteristics by subjecting specimens to ASTM standards of their respective testing. The improvement in mechanical properties is better in heat treatment when compared to cryogenic treated, 6% reinforcement shows an Improved Microstructure in heat treated condition with grain refinement and grain modification compared to all other reinforcement percentage with A356 alloy The heat treated alloys offered better resistance to corrosion compared to as-cast alloys and cryogenic treated specimens

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