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INVESTIGATE THE EFFECT OF EXTRUSION PROCESS ON POROSITY AND MECHANICAL CHARACTERISTICS OF AL-SIC$_P$ METAL MATRIX COMPOSITE MATERIAL

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Abstract—
Composite materials are progressively replacing conventional engineering materials because of their benefits over monolithic materials. The fabrication of Aluminium based MMC has been one of the major innovations in the materials technology in recent times. Due to its low density, ability to be strengthened by precipitation, superior corrosion resistance, high thermal and electrical conductivity, and high vibration dampening capacity, Aluminum is the most common matrix for MMCs. The liquid state processing method, or stir casting, is proven to be more practical and less complicated for processing MMCs than other methods. However, one of the major disadvantages of primary processing of composites, such as casting, is the presence of porosity in the structure, which can cause numerous mechanical qualities to degrade. Extrusion, rolling, and forging are examples of secondary processing methods that can reduce the structure's amount of porosity. In present study fabrication of Al-SiC$_p$ composites with 0, 4, 8 and 12% and followed by extrusion of 8% SiC$_p$ with extrusion ratio of 12.25 and extrusion temperature of 300°C, 350°C and 400°C. In comparison to equivalent cast material, test results show that extruded material is denser and has less porosity. When compared to composites extruded at 350°C and 400°C, test findings for mechanical characterization demonstrate higher values for hardness and tensile strength for composites extruded at 300°C.

***Index Terms*—**Aluminium, Composite, stir casting, Porosity, Extrusion, Extrusion temperature.

I. INTRODUCTION

Technology development, particularly in the space industry, led to a demand in the engineering industry for novel materials with qualities significantly superior to those found in conventional materials. Materials with improved thermal characteristics, greater wear and corrosion resistance, higher strength to weight ratios, and operating in harsh conditions are crucial for the aerospace and automotive industries. Composite materials have developed as a result of the search for novel materials with greater qualities. MMC reinforced with particulates materials are particularly attractive because of near isotropic in nature. Hence, they are being increasingly used in the automobile industry, aeronautical, naval etc[1,2].

The tensile strength and hardness of the composites are increased by adding ceramic particles to the matrix material, but the composites' ductility is reduced. To solve this issue, the composites can be improved by adding the appropriate reinforcement material.

To experimentally investigate the changes in behavior in the resulting composite, aluminum was reinforced with varying weight percentages of SiC_p, TiC, B_4C, and Al_2O_3. It was discovered that because the reinforcing material carries the load applied to the composite material, an increase in the weight percentage of the reinforcements led to an increase in the mechanical qualities, such as hardness, yield strength, and ultimate strength. With the addition of reinforcement, the ductile nature of ceramic materials turns brittle, resulting in a loss in elongation [3,4].

The porosity of composite initiates mainly due to air bubbles entering the slurry either independently or as an air envelope to the reinforcement particles. Oxygen and hydrogen are the main sources of porosity in the cast components. Porosity level can increases because of gas entrapment during mixing, Hydrogen evolution, Shrinkage during solidification. The vol. fraction of porosity, its size and distribution play a vital role in determines the mechanical behavior of the cast component. Complete elimination of Porosity cannot possible during the casting, but it can be diminished by appropriate selection of the casting parameters. The main drawbacks of the stir casting method are presence of porosity and accumulation of reinforcement particles in matrix material. Because of the vortex formation in molten matrix, the gas molecules are easily get deceived in the cast composites [5,6].

Extrusion is a type of metalworking that typically happens after casting. Extrusion involves squeezing the material in a die with the aid of a ram that passes through a small aperture. The benefits of the extrusion process are reduced or eliminated machining, higher strength, increased density with less porosity, and the flexibility to produce a wide range of cross section configurations and shapes[7,8].

The impact of extrusion temperature on the porosity of A356 with 10% SiC_p composites has been researched by Rahmani Fard et al[9]. Compocasting was used to create the composites, which were subsequently extruded at temperatures of 450°C, 500°C, and 550°C with an extrusion ratio of 18:1. According to the findings, the porosity level has decreased as compared to cast composite. Redistributing and aligning particle agglomerates in the direction of the extrusion operation[10].

The effects of reinforcing % and size during the extrusion of Al-SiC composite were investigated by Tham et al.[11]. By using the disintegrating melt deposition approach, composites are created with 6, 10, and 16 volume percentages of SiC with a particle size of 34

m. Extrusion of composite materials is done at 350 °C at 3.2 mm/s at a 12:1 extrusion ratio. The results show that the extrusion process was used to refine the reinforcing particulates, which resulted in a reduction in particulate size due to the breaking up of big particles. The increased shear stresses on the reinforcements as a result of the higher extrusion forces induce more instances of particle breakages.

II. MATERIALS AND METHODS

A356 is one of the most often used cast alloys out of the several series of aluminum alloys due to its exceptional qualities. A356 is a strong, ductile alloy made of aluminum, magnesium, and silicon that is highly resistant to corrosion. The fluidity and castability of A356 are imposed by the material's increased silicon content. SiC_p particles with a diameter of 23 microns are used as reinforcement in the current experiment. The chemical makeup and key characteristics of the alloy A356 are shown in table1.

TABLE.1. A356-CHEMICAL COMPOSITION

Elements	Al	Cu	Iron	Mg	Mn	Silicon	Titanium	Zinc	Others
Percentage of composition	91.1-93.3	≤0.2	≤0.2	0.25-0.45	≤0.1	6.5-7.5	≤0.2	≤0.1	<0.05

Particulate-reinforced Al-SiC_p composites are made using the stir casting. Figure.1 depicts the stir casting setup.

Due to the existence of voids inside the structure, the material structure produced after stir casting metal matrix composites won't be entirely dense. Both the development of reinforcing particle agglomerates and the evolution of gases during the melting process are responsible for the formation of these voids. By reducing the component cross section under external pressure and promoting the material's plastic flow, extrusion aids in the densification of cast material. By extruding the cast composite specimen with different temperatures—300°C, 350°C, and 400°C—while maintaining a constant extrusion ratio of 12.25, the effect of extrusion temperature has been examined. Figure 2 shows the extrusion setup, its components and extruded composite material samples.

In order to examine the particle distribution and the existence of voids in the treated material, a microstructure examination of the test specimen was performed using a SEM and density measurement by Archimedes principle. The cast and extruded composite material have been assessed for hardness and tensile strength.

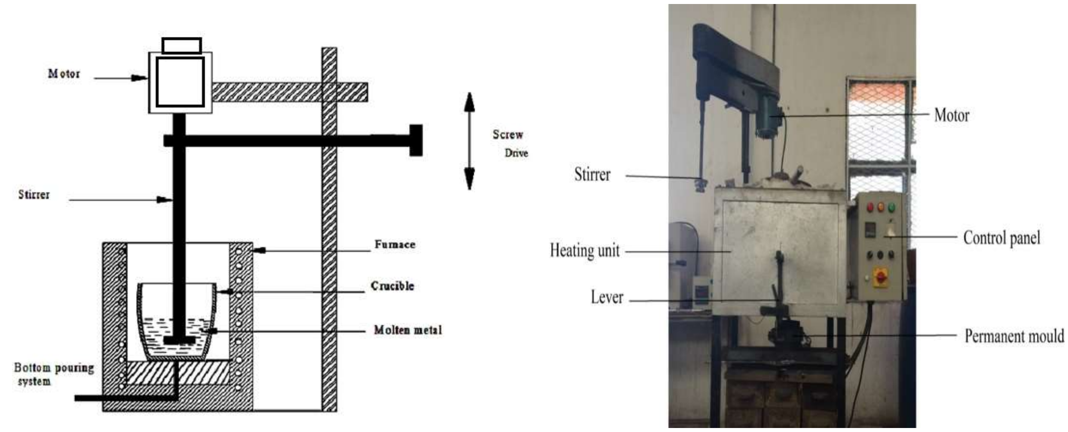


Figure 1. Stir casting process

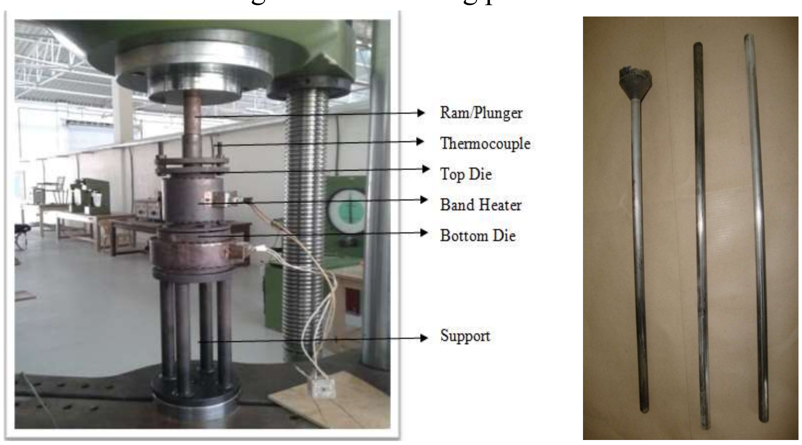
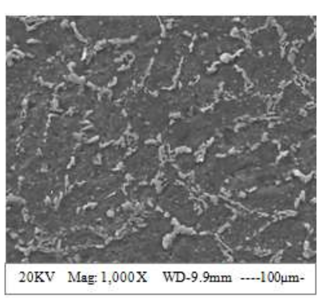


Figure 2. Extrusion setup and Extruded Specimens

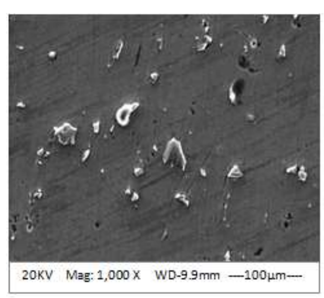
III. REAULTS AND DISCUSION

A. SEM Analysis of cast Al-SiCp composites

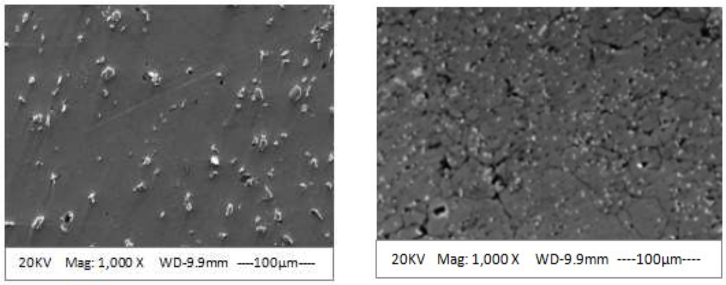
Figure.3 displays SEM images of various cast Al-SiC$_p$ composite specimens. The dendritic structure of the base alloy can be seen in the SEM image, and there is secondary silicon phase present at the grain boundaries. The SiC$_p$ particles are consistently distributed in specimens with 4% and 8% SiC$_p$ particulates, as seen from the SEM pictures of Al-SiC$_p$ cast composite specimens. While agglomerates may be seen forming in specimens with 12% SiC$_p$ particles. Additionally, it has been noted that the composite structure containing 12% SiC$_p$ particles contains significant amounts of voids.



(a) Base Alloy(0% SiC$_p$)



(b) 4% SiC$_p$



(c) 8% SiC_p **(d) 12% SiC_p**

Figure.3. SEM as cast composites

B. *Density and Porosity of as cast Al-SiCp composites*

TABLE.2. THEORETICAL AND ACTUAL DENSITY OF AS-CAST COMPOSITES

Sl.No.	**Composites**	**Density g/cc^3 Theoretical**	**Density g/cc^3 Actual**	**Percentage of Porosity**
1	Base Alloy-A356	2.700	2.634	2.44
2	A356+4% SiC_p	2.714	2.628	3.16
3	A356+8% SiC_p	2.728	2.620	3.96
4	A356+12% SiC_p	2.742	2.580	5.90

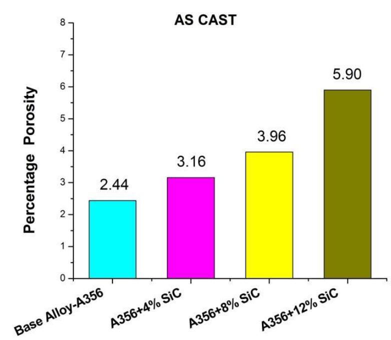


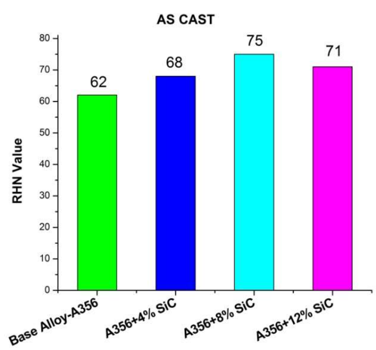
Figure.4. Percentage porosity of as-cast composites

The density of composite materials is influenced by the compositional proportion and the chosen processing technique. The density of the composite material will actually be lower than its theoretical density because of the pores present in the produced material. The Archimedes method was used to calculate the actual densities of different cast Al-SiC_p composite compositions, whereas the law of mixture was utilized to get the theoretical densities. The percentage of porosity in various compositions has been evaluated using the relevant theoretical and determined actual densities.

The cast composite material's test results for porosity show an increase as the proportion of SiCp reinforcing particles increases. With an increase in the percentage of SiCp reinforcement and an increase in the quantity of particles in the composites structure, a larger surface area is present at the interface between the matrix and reinforcement phase. When there is an adsorbed gas layer on the surface of the reinforcing particles, porosity levels increase along with the interfacial surface area. When particulate agglomerates are present, voids develop in the structure because the molten matrix phase is unable to completely fill the gaps left by the particulates. When there is a higher percentage of, it is difficult to achieve uniform particle distribution by stir casting.

C. Hardness and tensile strength of cast Al-SiC$_p$ composites

In figure.5 comparison to the basic alloy, test results for composite materials show higher hardness levels. This is due to the reinforcement particles, which have a harder composition than the base alloy, reinforcing the matrix phase. Comparing composite specimens with 4%, 8%, and 12% SiC particles to those with 8% reinforcement, it is discovered that the hardness values are higher for the former, while the latter show a reduction.



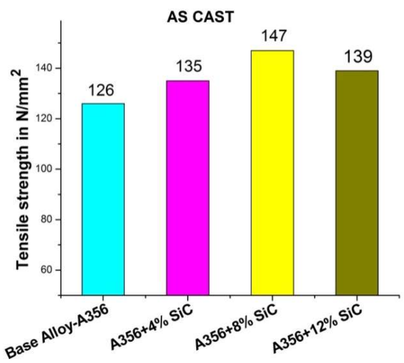
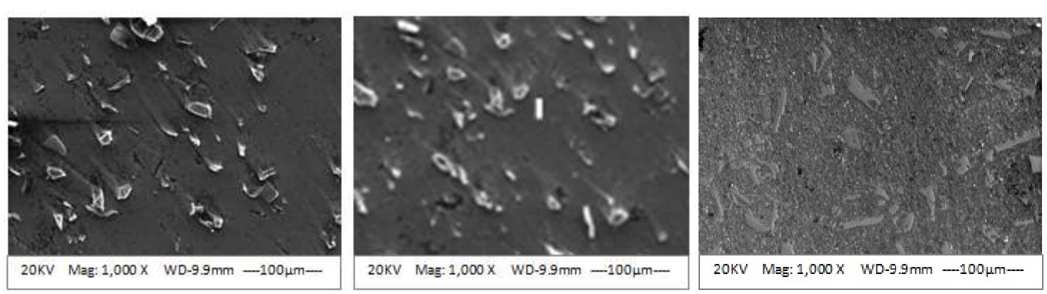


Figure.5 RHN -as cast   Figure.6 Tensile strength -as cast

The explanations for why a material responds to a hardness test can also be used to explain why test specimens react to tensile tests. In figure.6, the change in tensile strength of composites with various compositions is displayed. According to the test's results, composites with 8% SiCp reinforcing particles have achieved the greatest increase in mechanical properties among the test specimens.

D. SEM Analysis of Extruded Al-SiC$_p$ composites

The longitudinal segment of the specimens extruded at various temperatures is shown in SEM photos in Figure.7 In every case, the reinforcing particles are distributed uniformly, and they tend to align along the path of extrusion. The SEM pictures also show the presence of a modest number of pores.



300^0 C   **350^0 C**   **400^0 C**

Figure.7 SEM of Extruded Al+8%SiCp with extrusion temperatures

E. Density and Porosity of Extruded Al-SiC$_p$ composites

The actual density values of extruded specimens are found to rise with extrusion temperature. The matrix phase will experience free material flow as the temperature rises while experiencing plastic deformation during extrusion, promoting enhanced closure of the preexisting voids. Additionally, any pre-existing particle agglomerates may be disrupted during the extrusion process, allowing for uniform particulate distribution and a decrease in porosity.

TABLE.3. DENSITY AND POROSITY OF EXTRUDED COMPOSITES

Sl. No.	Extrusion temperature	Theoretical Density g/cc^3	Actual Density g/cc^3	Percentage of Porosity	Percentage of decrease in Porosity
1	300°C	2.728	2.654	2.71	31.39
2	350°C	2.728	2.661	2.4	39.24
3	400°C	2.728	2.675	1.94	50.88

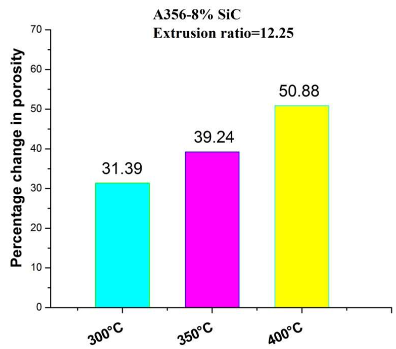
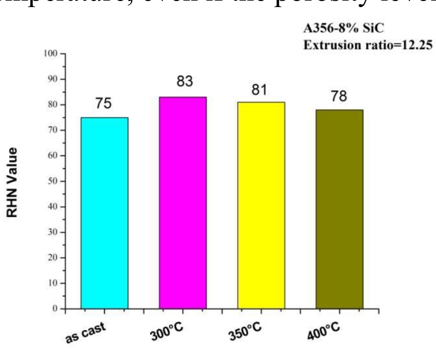


Figure.8. Percentage porosity of as-cast composites

F. Hardness and tensile strength of extruded Al-SiCp composites

Al-SiC$_p$ composites (8%) that were extruded at extrusion temperatures of 300°C, 350°C, and 400°C using an extrusion ratio of 12.25 are shown in Figure.9 to have hardness values. The results show that the hardness levels of extruded specimens are higher than those of cast specimens. This is explained by the decreased porosity of the extruded specimens in comparison to the cast specimens. The hardness value of the extruded specimens is found to be higher in the case of specimens extruded at 300°C and to decrease with rise in extrusion temperature, even if the porosity levels are found to decrease at higher extrusion temperatures.



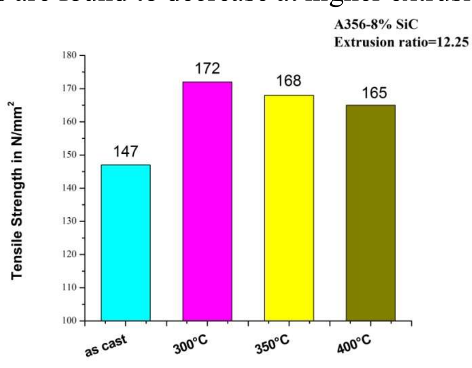


Figure.9 RHN -extruded Figure.10 Tensile strength -extruded

The results of the tests show that extruded specimens have higher tensile strength than as-cast specimens. Due to the above-described factors, it can be seen that the tensile strength change with extrusion temperature follows a pattern resembling that of hardness values. Cast and extruded specimens' tensile strength values are compared for various temperatures in Figure.10.

IV. CONCLUSION

The results of the tests show that the porosity content of the composite specimens increases as the percentage of SiC_p particles increases during casting.

Addition of ceramic SiC_p particles, which have superior mechanical properties, offer a strengthening effect, the hardness and tensile strength of the cast Al-SiC_p composites are found to be higher than those of the cast base material. However, it is noted that the mechanical properties are at their peak in composites containing 8% SiC_p and start to deteriorate in cases where the percentage reaches 12%. This may be due to the existence of agglomerates and increased porosity levels in the composites with 12% SiC_p, which cancel out the SiC_p, advantageous effects on the composite.

In comparison to equivalent cast material, test results show that extruded material is denser and has less porosity. When compared to other temperatures, the extrusion temperature of 450°C resulted in the greatest reduction in porosity (50.88%). However, when compared to composites extruded at 350°C and 400°C, the mechanical characterization test results for the extruded composite at 300°C indicate greater values of hardness and tensile strength.

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