Preparation and Characterization of Squeeze Casted 6061 Aluminium Matrix Composite

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***Abstract*:-Aluminium matrix composites (AMC) are effective and qualified material in the industrial domain. They are broadly used in automobile, aerospace, marine and structural applications due to their awesome mechanical properties. In this work, an attempt has been made to fabricate aluminium (A6061) metal reinforced with silicon carbide (SiC) and aluminium oxide (Al_2O_3) particles separately by the stir casting technique. The matrix metal aluminium has many unique properties like high strength, less weight and ease of machinability. Silicon carbide which has splendid hardness and wear resistance and aluminium oxide, which provides good compressive strength and wear resistance. Thus, they are chosen as the matrix and reinforcements. By using the squeeze casting technique, the needful quantities of reinforcements are mixed in the stirred molten stage of aluminium poured into the die under required high pressure on solidification, the fabricated samples are prepared and allowed to test. The purpose of this work is to study and evaluate the mechanical properties like hardness, tensile and compressive strength of the above AMC. The morphological analysis of the composites is observed by the XR-D (X-ray diffraction), SEM (Scanning electron microscope) and EDS (Energy dispersive spectroscopy).**

Key words: Squeeze casting, XR-D, SEM, EDS.

I. INTRODUCTION

Metal matrix composites (MMC) are the metals reinforced with other non-metals such as ceramics and organic compounds. They are fabricated by diffusing the reinforcements in the matrix at molten stage. Usually reinforcements are behaved to improve the properties of the base metal like stiffness, strength, conductivity, hardness, etc. Among the various metals and its alloys have more attention as base metal [1]. Aluminium matrix composites are the effective materials with excellent properties, so they are used in structural and automotive applications [2]. The aluminium matrix acquires strengthened when it is reinforced with arduous ceramic particles like B_4C, SiC, Al_2O_3, ZnO, etc. ensuing in enhanced strength to weight ratio and wear resistance than the mainstream alloys [3]. In the metal oxide family, aluminium oxide (Al_2O_3) is a significant material because of its eminent mechanical, electrical and optical properties and its broad range of applications [4]. The addition of the Al_2O_3 to the matrix increases its wear resistance significantly [5]. The another effective ceramic is silicon carbide (SiC), with the increase in reinforcement ratio, hardness, tensile strength, wear resistance and density to the base metal increases [6]. The prominent number of fabrication methods are presently used to manufacture the AMC materials based on the reinforcements used, like compocasting (or) stir casting, liquid metal infiltration, spray deposition and squeeze casting [7,8]. The broadly used liquid method of fabrication of Aluminium matrix composites (AMC) is stir casting method [9]. A confined research work has been expressed out on aluminium matrix composites (AMC) reinforced with zinc oxide due to their high density [10]. So an attempt has been made to reinforce zinc oxide and silicon carbide separately with aluminium alloy (A6061) to evaluate and characterize the mechanical properties effectively.

II. EXPERIMENTAL DETAILS

2.1. Materials Selection

In this work for grooming metal-matrix composite, aluminium alloy (A6061) is employed as the base metal, silicon carbide and zinc oxide are used individually as reinforcements in powder (particle) form.

2.1.1. Aluminium alloy (A6061)

Aluminium alloy (A6061-T6) is one which is most extensively used in the 6000 series aluminium alloy. It is the heat treated alloy having fairly good properties. The aluminium alloy ingot is in the dimension of ϕ 25 mm X 75 cm (1Kg). So it can be cut into small pieces for easy placement in a graphite crucible for melting.

2.1.2. Aluminium oxide (Al_2O_3)

Aluminium oxide is an inorganic compound with the chemical formula Al_2O_3. It is taken in the form of micro powder of mesh size 200 which is 74 µm.

2.1.3. Silicon carbide (SiC)

Silicon carbide (SiC) exhibit characteristics like high thermal conductivity, good water resistance and high stability. So it is taken as another reinforcing material with the mesh size of 220 which is 63 µm.

2.2. Fabrication procedure

Squeeze casting is a liquid state casting method and one of the chief process of composite production, in which the continuous stirring of molten base in the crucible is done followed by the debut of reinforcement. The ensuing mixture is poured into the die and under required high pressure on the solidification instantly. The rip snorting stirring process which reduces the agglomerate formation of the reinforcement particles in the dispersed phase. In this work, squeeze casting method is used for the fabrication of aluminium metal matrix composite. This twirl technique provides homogeneous and high strength set of aluminium composite material.

3. EXPERIMENTATION

In this work, first the aluminium alloy (A6061) was preheated at 725°C in the preheating section of the furnace for the soaking period of one hour before melting. At the same time reinforcements such as zinc oxide powder is preheated to 300°C and SiC powder to 400°C in the reinforcement preheating furnace for a soaking period of one hour, preheating is very essential to remove the moisture (absorbed hydroxide) and other gases from the surface. Then the melting temperature is set, i.e. 750°C, hence the matrix melts totally. Prior to reinforce addition, a pinch of solid hexa-chloro-ethane is used to degasify the net. Then the reinforcement is mixed in three steps within the gap of 5 minutes with the matrix which is below their melting point.

The matrix reinforcement mixture is stirred continuously for about 10 minutes by an automatic mechanical stirring at 500 RPM. At the same time mould is preheated to 300°C by an electrode to degasify the area. Before casting, the degasser removes all the cornered gases from the mixture present in the crucible. Finally the mixture gets casted in the mould via pouring basin. By repeatedly varying the mixture composition, two samples are fabricated. Apart from the above, a sample of aluminium alloy (A6061) alone is fabricated to compare the properties with the reinforced samples.

In this work, three samples are fabricated. Sample 1 contains only aluminium alloy-100%, sample 2 contains aluminium alloy-90% and silicon carbide-5% and sample 3 contains aluminium alloy-90% and aluminium oxide -10%.

Table 1 samples taken for fabrication

Sample	Matrix	Reinforcement
1.	Aluminium alloy (100%)	No reinforcement
2.	Aluminium alloy (90%)	Silicon carbide (10%)
3.	Aluminium alloy (90%)	Aluminium oxide (10%)

III. TESTING

The mechanical properties and morphological analysis of the aluminium composites are determined by conducting the following tests.

3.1 Tensile test

The tensile test is used to determine the ability of the material to resist a static load. The fundamental properties of the new composites are evaluated only by the means of mechanical testing. Universal testing machine is used to execute the tensile test. The specimen is prepared as per the standard ASTM: B-557M (Standard test methods of tension testing wrought and cast aluminium and magnesium alloy products).

3.2 Compression test

Compression test is also used to evaluate the ability of the material to withstand a static load. The atoms or molecules which gets forced together in compression. The specimen is prepared as per the ASTM: E9 standard.

3.3 Hardness test

Hardness test is essential to measures the resistance of the material to lasting shape change when a force is applied. In this work, brinell hardness test is used to carry out the deformation (hardness) of the fabricated composite. The test is
carry through as per the standard ASTM: E10. In this test, 500 kg load is load is applied for a period of 15 seconds. The test result has been expressed in the format of number called brinell hardness number (BHN).

3.4 X-ray diffraction (X-RD)

X-ray diffraction (X-RD) test is used to determine the crystal structure and orientation of the unknown material. The specimen is fixed in the clamp and allow to scan by the X-RD to analyse the characteristics and morphology. Later it is analysed by the JCPDS (Joint committee on powder diffraction standards) number. In this work, X-RD is used to detect the presence of reinforcement in mixture and whether it is mixed uniformly or in random.

3.5 Scanning electron microscope (SEM)

Scanning electron microscope (SEM) analysis was carryout to determine the crystal structure, particle size and gap, surface morphology, etc. according to the increase of magnification, the clear morphological structure of the material composition has been evaluated. In this work, SEM is used to analyse morphological features of the fabricated specimen.

3.6 Energy dispersive spectroscopy (EDS)

Energy dispersive spectroscopy (EDS) is the test used to analyse the material content of the specimen and clearly displayed in the form of graph and table. The material contents are displayed in the graph by atomic order wise. In this work, EDS is used to detect the amount of materials present in a spotted area. In this work, it is used to find the amount of reinforcement content in the randomized area.

IV. RESULTS AND DISCUSSION

The results of the mechanical and morphological tests conducted are discussed in this part. In this work, three different specimens are tested.

4.1. Tensile test

The tensile test of the specimen is prepared as per the ASTM: B557-M standard. The results are tabulated in table. . The tensile tested specimen is shown in fig..

According to the result, the sample 3 exhibit more tensile strength than sample 2 and sample 1, whereas sample 2 has more tensile strength than sample 1.

Table 2 Mechanical properties of fabricated specimens

Samples	Fabricated specimens	Tensile strength (Mpa)	Compression strength (Mpa)	Brinell hardness (BHN)
1	Al-100%	28.45	491	29
2	Al-100% + SiC-10%	59.36	696.6	40
3	Al-100% + Al_2O_3-10%	60	916	35

Figure. 1. Tensile tested specimen

4.2 Compression test

Compression test of the specimen is prepared as per the ASTM: E9 standard. The results are tabulated in the table. . The compression tested sample is shown in fig. .

Based on the result, sample 3 exhibit more compression strength than the other two samples, while sample 2 reveal more strength than the sample 1.

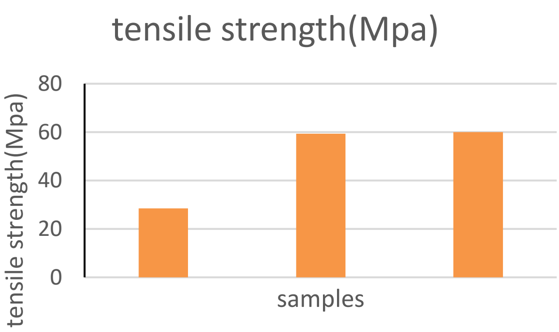


Figure. 3. Samples vs tensile strength bar chart

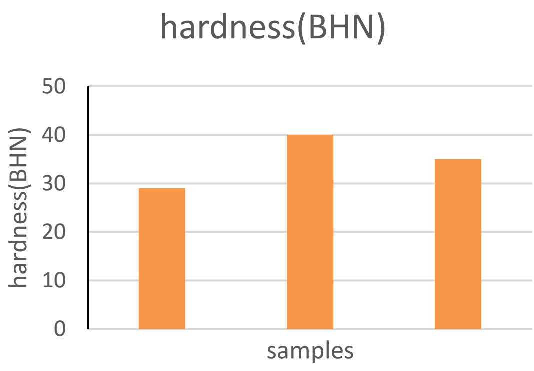


Figure. 4. Compression tested specimen

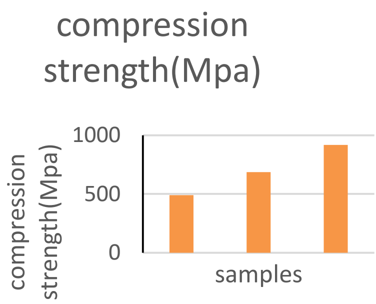


Figure. 5. Samples vs compression strength bar chart

4.3. Hardness test

The hardness tested sample is shown in fig. . Hardness test of the samples are tested as per the standard ASTM: E10. The results of the specimen are tabulated in table.

Brinell hardness test is done by applying the load of 500kg for a period of 15 seconds From the results obtained, sample 2 has more hardness when compared to the sample 3 and sample 1. At the same time, sample 3 have higher hardness than sample 1.

Figure. 6. Samples vs hardness bar chart

4.4. X-ray diffraction analysis

The XR-D patterns of the fabricated composites are showed in fig. . The diffraction peaks in the graph which shows the presence of silicon carbide and zinc oxide particles in the composite specimen. The loudness of those peaks increases while reinforcement content increased. The graph also shows clearly that there is no interfacial reaction between the aluminium and reinforcement particles.

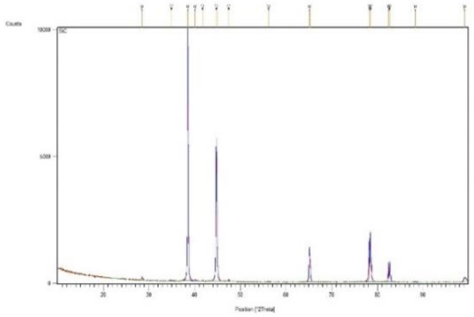
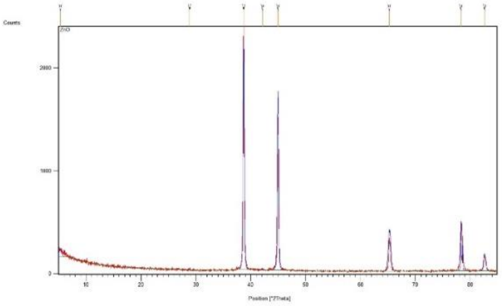
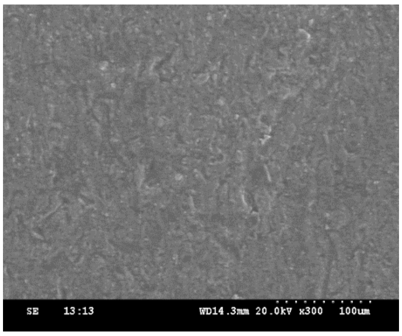


Figure. 8. X-RD image of the Al/SiC sample



4.5. Scanning electron microscope analysis

The microstructure of the samples are shown in fig. . The aluminium molecules and reinforcements general arrangements are faintly seeable in the image. The image clearly shows that the uniform distribution of the reinforcement with the matrix. The microstructure of the samples are visible at varying magnification of 300x and 600x.



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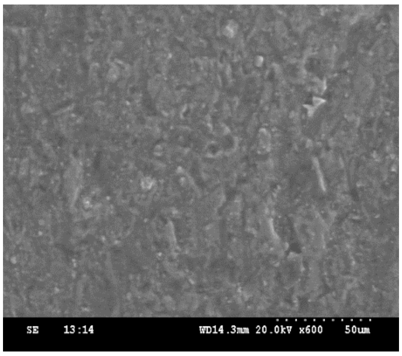

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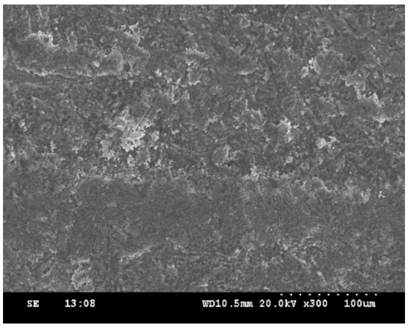

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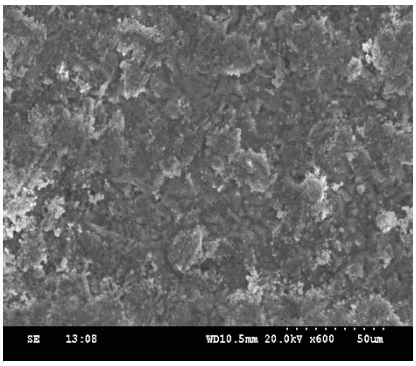

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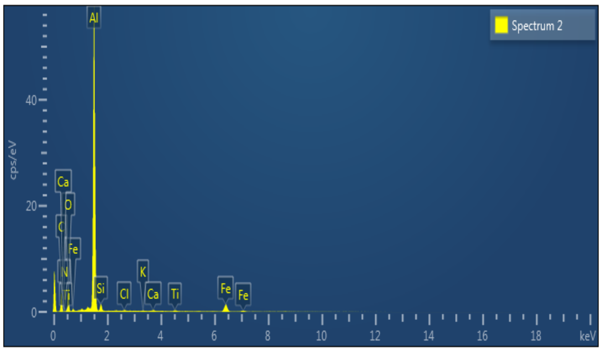
4.6. EDS analysis

The EDS images of the samples are shown in fig. . The percentage contents of aluminium molecules and reinforcements are displayed clearly in graph and table. The results showed the expected presence uniform distribution of the reinforcements in the aluminium matrix.



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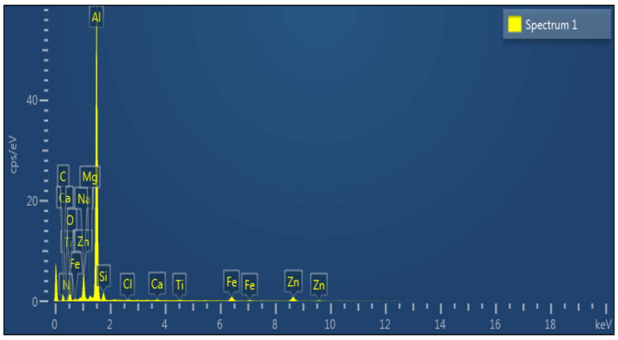

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V. CONCLUSION

Three samples are fabricated in this work and the following illations are made,

[1] It has been illative that the tensile strength of the sample 3 (60Mpa) slightly high when compared to the sample 2 (59.36Mpa) and sample 1 (28.45Mpa). Both the reinforced samples exhibit two fold increase in tensile strength.
[2] It has been inferred that the compressive strength of the sample 3 (916Mpa) is high when compared to the other two samples.
[3] But the brinell hardness test results that the sample 2 has more hardness than the sample 3 and sample 1.
[4] Finally, morphological analysis tests such as XR-D, SEM and EDS reveals the presence and uniform distribution of the reinforcements.

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