JOURNAL OF MODERN MANUFACTURING SYSTEMS AND TECHNOLOGY (JMMST)
e-ISSN: 2636-9575
VOL. 4, ISSUE 2, 98 – 105
DOI: https://doi.org/10.15282/jmmst.v4i2.7156

ORIGINAL ARTICLE

Fabrication And Characterization of Al/ Sic/Gr Hybrid Metal Matrix Composite Fabricated By Powder

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ABSTRACT – This research focuses on the impact of reinforcing particle size in Metal Matrix Composites (MMC). Because of its comprehensive mechanical qualities, MMC is widely employed in the aerospace and automobile industries. In order to increase the mechanical qualities of MMC, researchers are looking into ways to improve its performance. The research aims to use powder metallurgy to fabricate an Al-SiC-Gr hybrid composite and explore its microstructure and mechanical characteristics, such as hardness and impact strength. Powder metallurgy will be utilised in this study, with pure aluminium, silicon carbide, and graphite being mixed in proportion to the volume of the specimen. For Pure Al, 85 %, 80 %, and % were used, while for SiC, 10%, 15%, and 20% were used, and for Gr, 5% was utilised. Tensile, hardness Vickers testing and impact testing are among the experiments conducted. The microstructural analysis will also be carried out to assess the particle distribution in the MMC. The microhardness value of HRV 36.94 was discovered to be improved by reinforcing in Al+15% SiC+5% Gr. Furthermore, the result also showed an improvement in the tensile strength with the highest value 195.22Mpa in the Al+15%SiC+5%Gr.

ARTICLE HISTORY
Received: 22nd November 2021
Revised: 9th February 2022
Accepted: 9th February 2022

KEYWORDS
Metal Matric Composite
Aluminium
Silicon Carbide
Graphite
Mechanical Properties

INTRODUCTION

Metal Matrix Composites (MMC) are metals that have been reinforced with ceramics and organic compounds. Al-SiC-Gr (MMCs) are Al matrix composites with SiC-Gr reinforcement [1]–[5] The matrix is generally light in weight and serves to support the reinforcement, whereas the reinforcing material alters the matrix's physical and mechanical characteristics. MMCs have strong strength, low density, high elastic modulus, high toughness, and impact characteristics [2].

Aluminium is a popular material for structural applications, particularly in the automobile sector, due to its high strength-to-weight ratio, low density, lightweight, and excellent thermal conductivity [6]–[11]. However, pure Al has a poor friction resistance and hardness level, making it unsuitable for use in service conditions requiring high hardness[12], [13]. SiC is a ceramic substance with high hardness, and graphite is regarded as a solid lubricant. As a result, incorporating SiC and Gr into Al will increase mechanical properties[4], [14], [15].

Another issue in composite manufacturing is maintaining the homogeneity of the reinforcing particles on the metallic matrix. Because of the lack of homogeneity, reinforcement clusters develop on the matrix, reducing the overall strength of the composite[16]. Powder metallurgy can be utilized to keep MMC uniform. As a result, this method is employed in this study.

The purpose of this study is to construct an Al/SiC/Gr hybrid metal matrix composite using powder metallurgy and to evaluate the microstructure and mechanical characteristics of the produced hybrid composite, including hardness, tensile, and impact strength[17].

EXPERIMENTS PROCEDURE

In this section materials selection and fabrication process are described. Aluminium is used as matrix material and Silicon Carbide and Graphite are reinforcement materials. Al/SiC/Gr hybrid metal matrix composites are fabricated by using the powder metallurgy method. The mechanical and microstructure of the Al/SiC/Gr particles were investigated by using optical microscopy (OM) and mechanical properties test.

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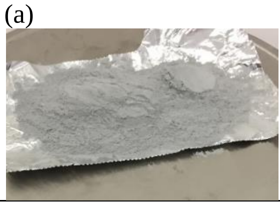
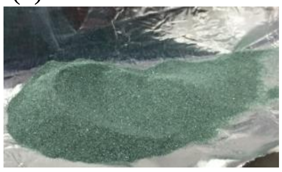
Materials

The matrix Aluminium (Al) micro-powder and reinforcement's Silicon Carbide (SiC) micro-powder, Graphite (Gr) was procured from Sigma-Aldrich, Malaysia. Properties and physical appearance are presented in table 1 according to the supplier's recommendation.

Table 1. Properties of composite materials.

Properties	**Aluminium Powder**	**Silicon Carbide**	**Graphite**
Material	(a) 	(b) 	(c) 
Purify	99%	99%	99%
Particle size	74 µm	74 µm	<20 µm
Molecular weight (g/mol)	26.98 g/mol	40.10 g/mol	12.01 g/mol
Melting point	660.3 °C	2700 °C	3652-3697 °C
Density (g/cm³)	2.70g/cm³ at 25°C	3.21 g/cm³ at 25°C	2.27g/cm³ at 25°C

Fabrication Process

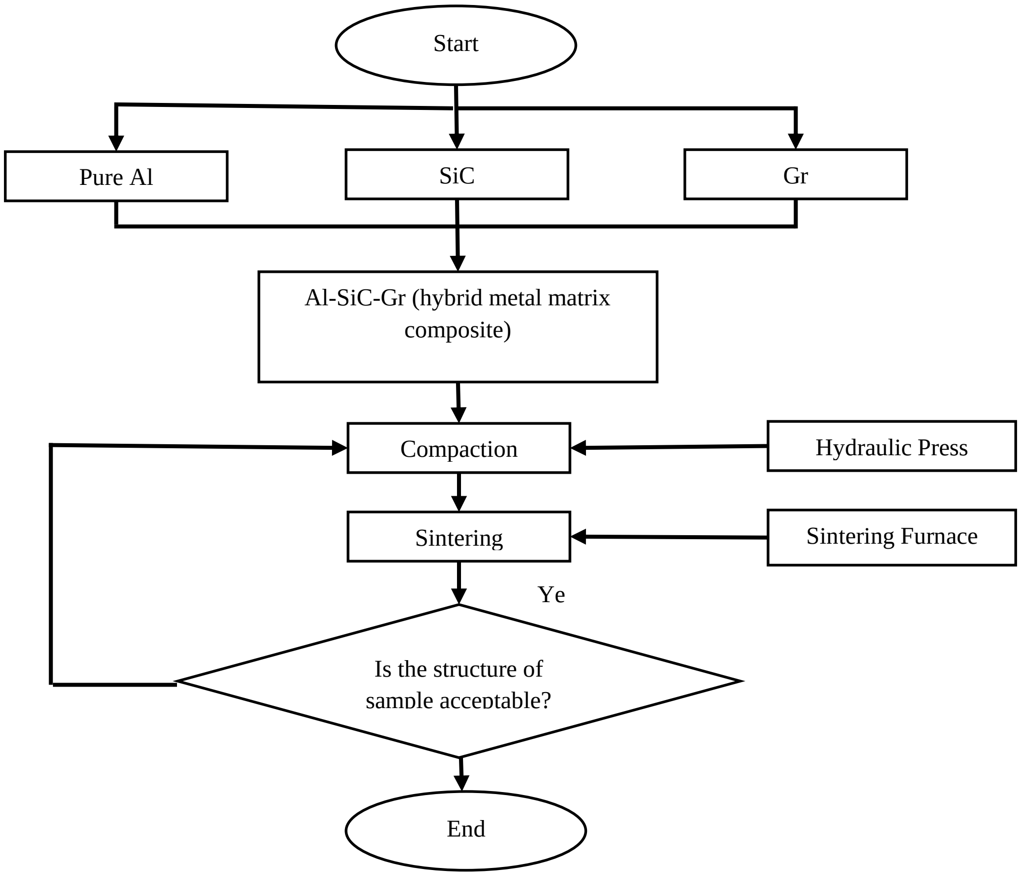


Figure 1. Overall Flow Chart

This study is divided into two sections. The initial step in the approach would be the powder metallurgy production of the AL-SiC-Gr composite. The microstructure observation mechanical testing of the Al-SiC-Gr composite would be the second element of the technique. The whole project process flowchart is given in figure 1 beginning with fabrication and ending with mechanical testing of the composites. First, the powders of each raw material are carefully measured using an electronic weighing scale. Second, the raw materials are ready to be mixed. The mixing procedure is done manually for an hour using a mortar and pestle to combine all the basic ingredients. After mixing, the mixture is sealed and stored in a sealed container to prevent moisture from influencing the mixture. Third, the mixture will be subjected to a heated compaction procedure. The mixture will be poured into the die cavity, and then punched until the mixture is compacted within the die. The green compact will next go through the sintering process.

Sintering Process

The sintering process is a thermal treatment that improves the strength of the compact. The sintering cycle was performed at a high temperature of 630℃. This sintering is carried out in a furnace that heats up at a rate of 10 ℃ each minute. The first sintering cycle is for deoxidization, while the second is for removing moisture from the green compact and bonding the raw material particles together. After sintering, the specimens were cooled and prepared for the following procedure. The specimens are then cold mounted, ground, and polished. Sixth, the item was examined using an optical microscope and mechanical tests.

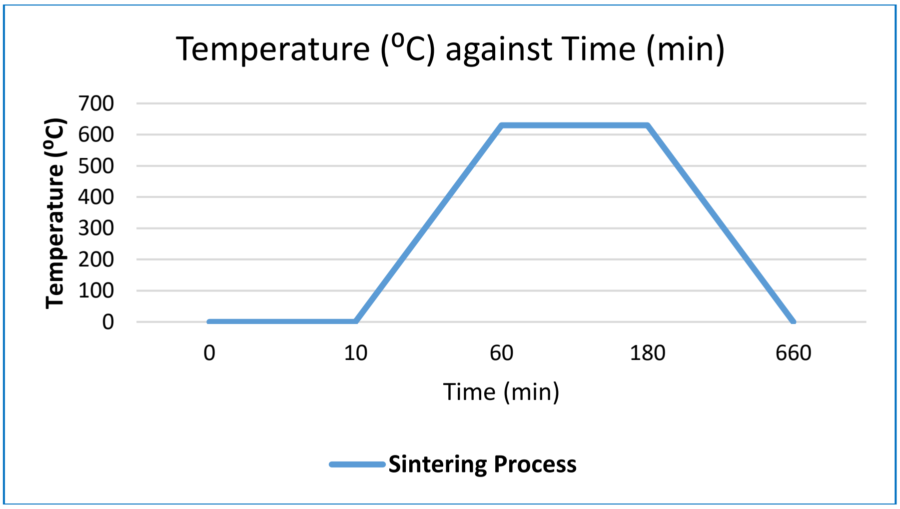


Figure 2. Heating Curve graph for Sintering Process

Microstructural Analysis

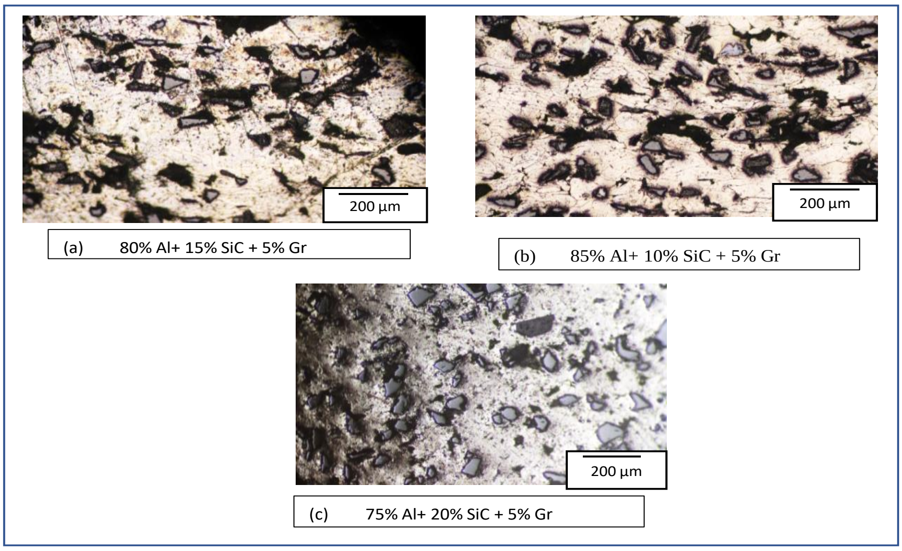


Figure 3. Optical Microstructure View of (85%-10%-5%), (80%-15%-5%) and (75%-20%-5%) Al-SiC-Gr.

The figure 3 showed the microstructure of the MMC particles. It showed the optical microstructure of (85%-10%-5%), (80%-15%-5%) and (75%-20%-5%) composition Al-SiC-Gr. It showed that the Al particle was well distributed in all composition. From the observation, it can be concluded that uniform dispersion of filler loading in the composite make the material stronger.

Density Test

The volume and density of the fabricated composites were estimated after measuring the thickness, diameter, and mass with a vernier calliper and digital weighing scale. Data were entered into a database and then compared before and after sintering the specimen in a bar chart figure 4.

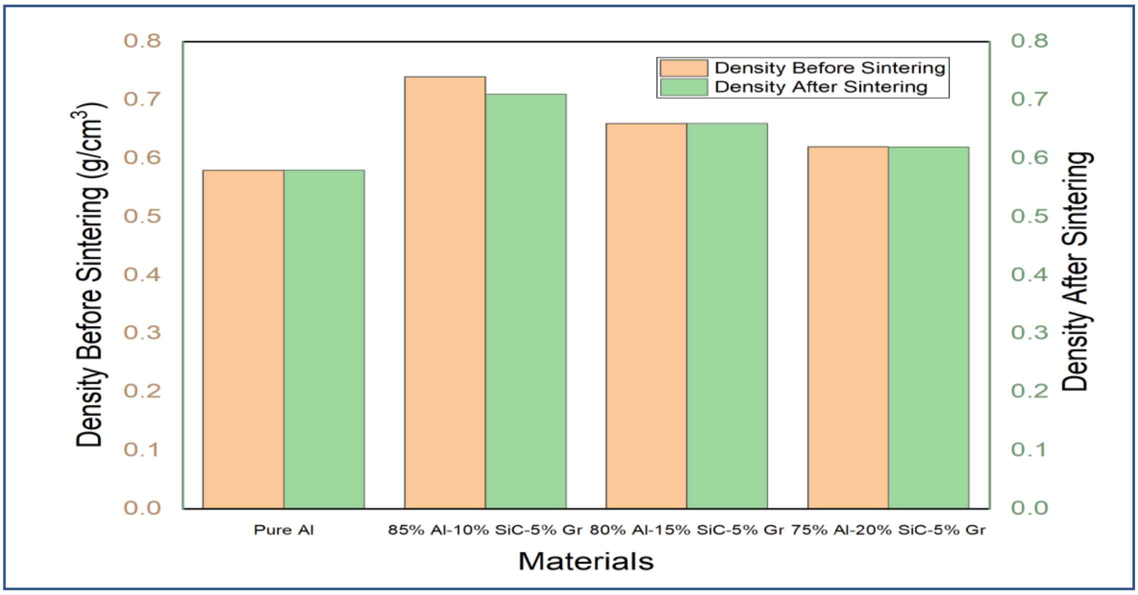


Figure 4. Density (g/cm ^{3}) versus Composition of SiC and Gr (%).

The density was calculated for pure aluminium, (85-10-5) %, (80-15-5) % and (75-20-5) % composition of Al-SiC-Gr composite before and after sintering. The measured value before sintering are 0.58 g/cm^3 for pure aluminium, 0.74 g/cm^3 for (85-10-5) % of Al-SiC-Gr, 0.66 g/cm^3 for (80-15-5) % of Al-SiC-Gr and 0.62 g/cm^3 for (75-20-5) % of Al-SiC-Gr. After completing the sintering process, the dimensions of the specimen were measured, and density was calculated. The density of pure aluminium, (85-10-5) %, (80-15-5) % and (75-20-5) % composition of Al-SiC-Gr are 0.58 g/cm^3, 0.71 g/cm^3, 0.63 g/cm^3, and 0.62 g/cm^3 respectively. The inclusion of both SiC and Gr particles in composites has been found to boost their density [18]. The addition of higher-density reinforcements to the aluminum matrix accounts for the increase in density. The porosities of all samples were measured and are displayed in figure 4 based on the before and after sintering densities. The porosity of the composite is increased by including micro-sized SiC in the aluminum matrix. The high hardness of SiC, which makes correct compaction of composite powders difficult, is to blame for the increase in porosity. Other investigators have noticed an increase in porosity in Al/SiC composites[19][20].

Hardness Test

The composites are subjected to a hardness test using a Vickers Micro Hardness Tester. This tester is utilized because it can test all types of metals and has the widest scales among other hardness tests. The applied force is between 1 and 10 N, according to the ASTM E384 standard. The applied force was 3N and the unit for hardness are (HV). Four various ratios, including pure aluminum, were tested, with measurements recorded and an average computed.

Figure 5 showed that the average hardness of each ratio increases steadily until it reaches the (80-15-5) % of Al-SiC-Gr composition. The addition of graphite into pure aluminium does not result in much improvement in hardness due to the soft nature of graphite [21]. The SiC hard ceramic components were added to improve the mechanical strength. Furthermore, the peak hardness increases as the volume percentage of SiC increases. Previous investigations had similar findings. Because of the significant mismatch in the thermal expansion coefficient between the matrix and the SiC particles, the hard SiC particles can generate a higher dislocation density [22].

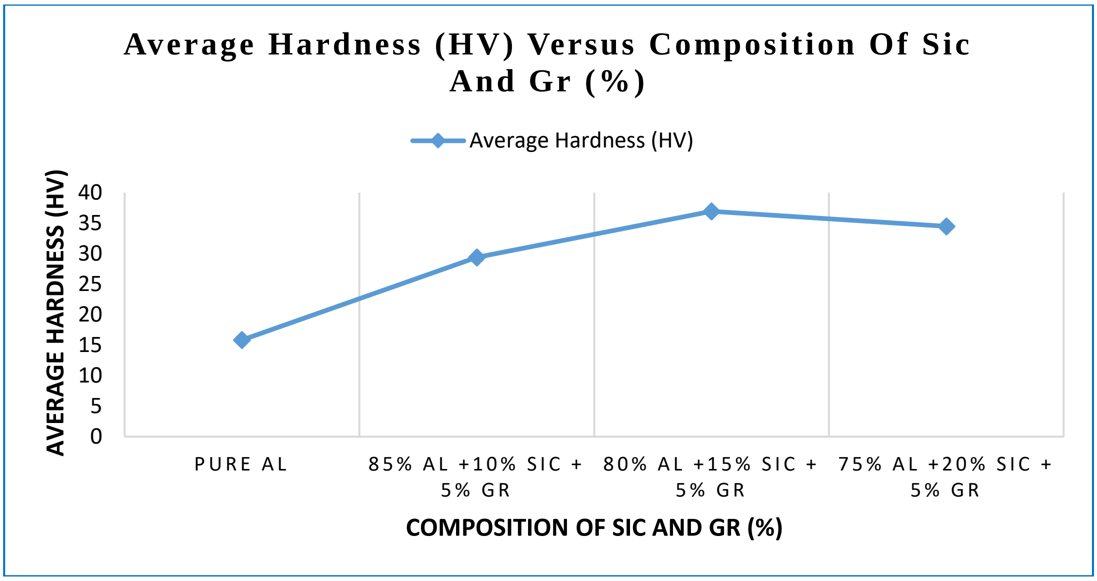


Figure 5. Average hardness (HV) versus Composition of SiC and Gr (%)

In the hardness test, (80-15-5) % of Al-SiC-Gr composite has the highest HV, 36.94. The reason for the high strength is influenced by the small reinforcement size. As reinforcement size decreases, the particle will be well distributed creating greater strength. In the impact test, it can be concluded the more energy absorbed by the specimen, the tougher the materials will be. If less energy is absorbed during the impact tests it means the material fracture in a brittle manner. In contrast, if the absorbed energy is high, the ductile fracture will result and the specimen has high fracturing toughness. Toughness is the capacity of a material to absorb energy and deform plastically before [23].

Impact Test

The composites are subjected to an impact test using a Pendulum Impact Tester according to IS 1757. The impact test is a method of determining the material's strength. Both ductility and strength of materials are connected to toughness. The impact stress is intended to create a crack in the specimen, which is used to determine its strength. The ductility and strength of a material are connected to its durability. The energy is absorbed in the impact test by shattering the specimen. When less energy is absorbed during impact testing, it indicates that the material is fragile. When the absorbed energy is high, however, ductile fracture occurs, and the specimen has high toughness.

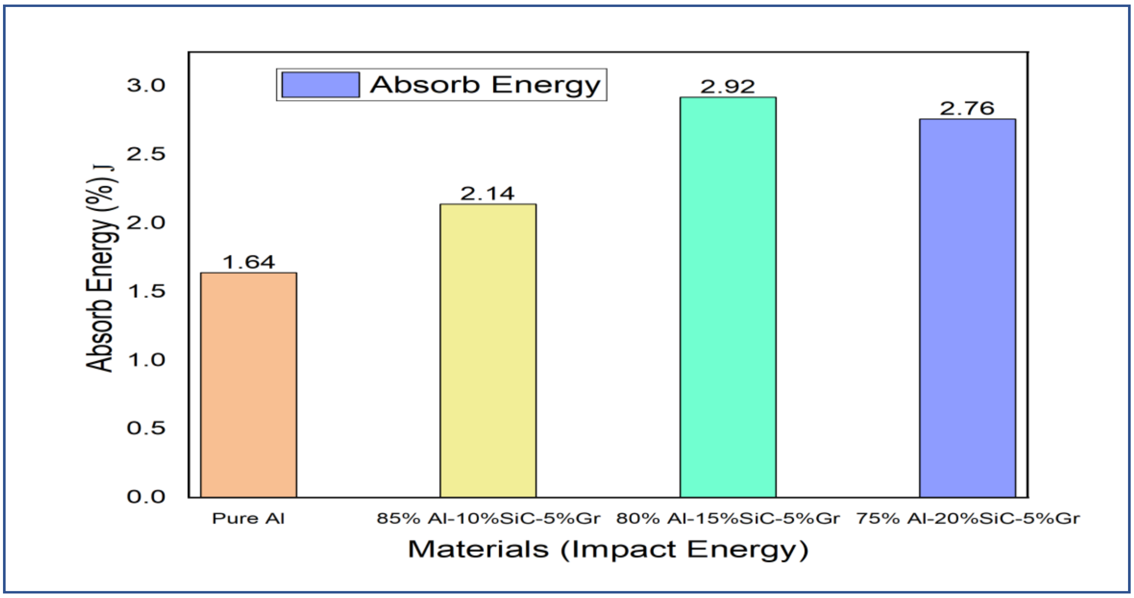


Figure 6. Impact Test Bar Chart

Figure 6 showed impact properties values for four different types of the ratio of different compositions including pure aluminium. Pure Aluminium shoed 1.64% energy absorbed. (80-15-5) % of Al-SiC-Gr composition showed the highest impact energy with energy absorbed by 2.92%. This means that the specimen only absorbs 2.92% from 100%. Whereas for (85-10-5) % of Al-SiC-Gr was only absorbed 2.14% and (75-20-5) % of Al-SiC-Gr absorbed 2.76%. From the graph, it is shown that the impact energy increased with the incorporation of SiC and Gr components [24]–[26]. But for the too large amount of SiC composite showed little, smaller than the large amount due to the lack of homogeneous mixing of the powders. (80-15-5) % of Al-SiC-Gr composition obtained the highest impact value in this study.

Tensile Test

In this study tensile test was conducted according to the ASTM E8 test and presents data on the strength and E-modulus of metals under uniaxial tensile forces. The tensile properties of the fabricated composite samples are presented in Table 2. The results demonstrate that the tensile strength of Pure Aluminium, (85-10-5) % of Al-SiC-Gr, (80-15-5) % of Al-SiC-Gr and (75-20-5) % of Al-SiC-Gr are 91.39MPa, 120.43 MPa, 195.22 MPa and 181.45 respectively.

Table 2. Tensile properties of the composite materials

SL NO	Percentage in Specimen (%)	E- Modulus (GPa)	Tensile Strength (Mpa)	% Increase Tensile Strength
1	Pure Aluminium	1.62	91.39	0
2	85% Al +10% SiC + 5% Gr	1.97	120.43	31.78
3	80% Al +15% SiC + 5% Gr	2.98	195.22	113.61
4	75% Al +20% SiC + 5% Gr	2.36	181.45	98.54

The tensile strength increased dramatically with SiC and Gr filler addition to the Aluminium matrix materials, as shown in Figure 7. (a).

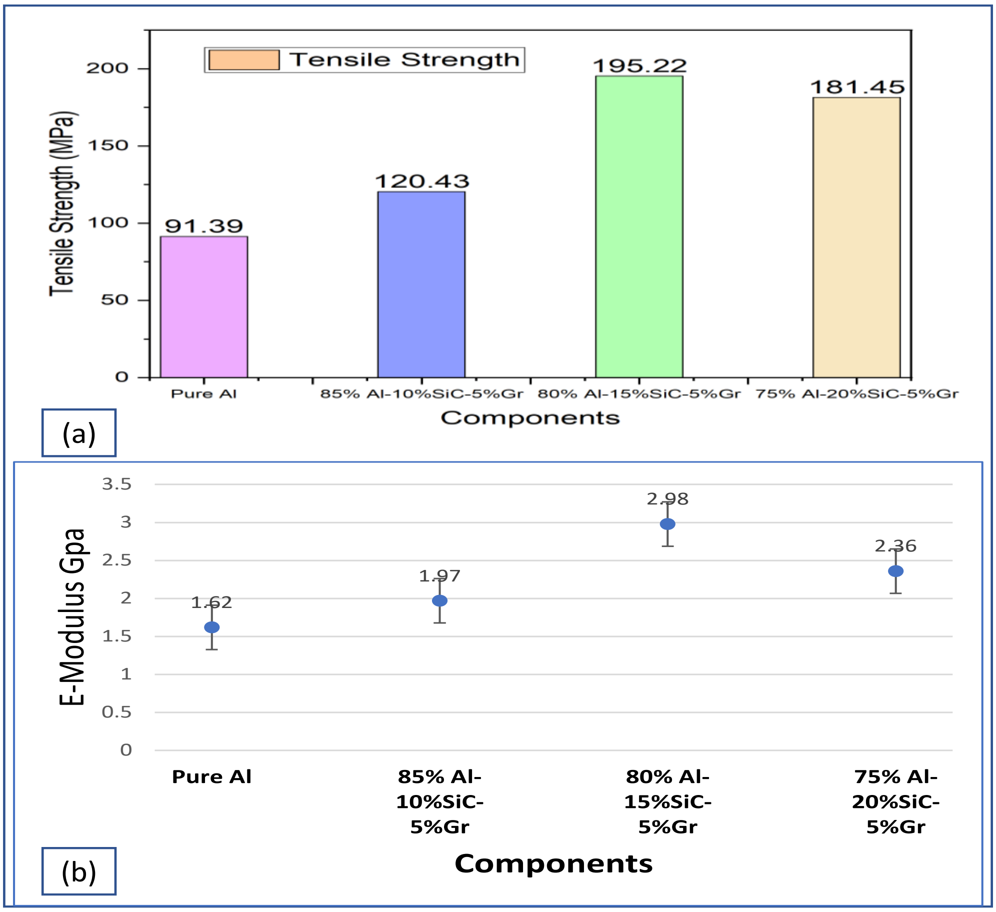


Figure 7. (a) Specimen Composition vs Tensile Strength (b) Specimen Composition vs E-Modulus.

Among the fabricated composite materials, the highest strength was observed in the (80-15-5) % of Al-SiC-Gr sample. This composite exhibits around a 113.61% increase in tensile strength than that of the pure Al. Besides, the composite was composed of (85-10-5) % of Al-SiC-Gr and (75-20-5) % of Al-SiC-Gr show around 31.78% and 98.54% tensile strength increments respectively than that of the pure aluminium matrix material. The addition of Gr particles in the Al- SiC composite enhanced the tensile strength of the nanocomposites. The E-modulus was also measured and plotted in a point chart shown in figure 7 (b). The highest modulus for the (80-15-5) % of Al-SiC-Gr composite, was calculated 2.98 GPa, which was an 83.95% increase than pure aluminium. All Data have been listed in table 2. Pure Aluminium, (85-10-5) % of Al-SiC-Gr, and (75-20-5) % of Al-SiC-Gr are 1.62 GPa, 1.97 GPa, and 2.36 GPa respectively. It was found that the tensile strength and E- modulus increased with the increase of the mass fraction of the reinforcement particles, whereas the elongation decreased with the increase of the reinforcements [25]. As indicated above, the Gr has a greater impact on the elongation of the composites than the SiC. On the one hand, increasing the volume fraction of particles leads to smaller particle spacing and introduces more porosities which deteriorate the mechanical properties of composites.

CONCLUSION

This research's purpose is to study the effect of particle size on the mechanical properties of the composite. The materials used are Al-SiC-Gr with different ratios of composition. Powder Metallurgy Process was done to fabricate three specimens which are (85-10-5) %, (80-15-5) % and (75-20-5) % Al-SiC-Gr. In the hardness, impact, and tensile test, (80-15-5) % of Al-SiC-Gr composite showed the highest mechanical properties than the pure aluminium and other composite materials. The reason for the high strength is influenced by the small reinforcement size. As reinforcement size decreases, the particle will be well distributed creating greater strength. The authors are recommended this composition (80-15-5) % of Al-SiC-Gr composite for the automotive and aerospace application due to good mechanical properties.

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