Research & Reviews: Journal of Material Sciences e-ISSN: 2321-6212

Fabrication and Property Investigation of Silicon Carbide Reinforced Aluminium-based Metal Matrix Composite for Aerospace Materials

Tanvir Hasan Fahim*, Md Shariful Islam

Department of Aeronautical Engineering, Military Institute of Science & Technology, Dhaka, Bangladesh

Research Article

Received: 27-Apr-2022, Manuscript No. JOMS-22-61930; **Editor assigned:** 2-May-2022, PreQC No. JOMS-22-61930(PQ); **Reviewed:** 16-May-2022, QC No. JOMS-22-61930; **Revised:** 23-May-2022, Manuscript No. JOMS-22-61930(R); **Published:** 30-May-2022, DOI: 10.4172/2321-6212.10.5.004.

***For Correspondence:**

Tanvir Hasan Fahim, Department of Aeronautical Engineering, Military Institute of Science & Technology, Dhaka, Bangladesh

E-mail: **tanvirfahimresearcher@gmail.com**

Keywords: Aluminium; Hardness; Metal matrix composite; Silicon carbide; Stir casting method; Tensile strength

ABSTRACT

The modern development in the field of science and technology has created a demand for many advanced engineering materials. In recent days, Aluminium-related metal matrix composite is a probable material for many applications such as transport, aerospace, marine, and automobile applications. The stir casting method is generally used in the production of Silicon carbide reinforced Aluminium metal matrix composite to enhance the properties of base metal. The objectives of the study were fabrication and characterizations of physical and mechanical properties of Silicon carbide reinforced Aluminium-based metal matrix composite for aerospace materials. Different weight fractions of Silicon carbide, (Silicon carbide: 5 weights%, 7 weights%, and 9 weights%) particulate-reinforced Aluminium metal matrix composites are fabricated using the stir casting method, and characterizations of the physical and mechanical properties of the materials are performed based on the experiments. Characterization studies were conducted on the Aluminium 5083 and composite samples to assess. The hardness properties were evaluated using the Rockwell hardness machine. The computer interfaced INSTRON Universal Testing Machine was used to evaluate tensile strength. At all diameters of the ball indicator, hardness was increased with the increase of% value of Silicon carbide. Also, higher than those of standard Aluminium used in aerospace materials. Ultimate tensile strengths for 5 weights%, 7 weight%, and 9 weight% particulate-reinforced Aluminium metal matrix composites had 275 MPa, 287.77 MPa, and 296.96 MPa, respectively. Young's modulus of elasticity was highest for specimen 3 (Silicon carbide 9% and Aluminium-5083 91%). Tensile strength and hardness of Aluminium metal matrix composites are enhanced by the increment of the weight fraction of the reinforcing phase (Silicon carbide).

INTRODUCTION

Metal matrix composite is an engineered combination of the metal (matrix) and hard particle or ceramic (reinforcement) to get tailored properties. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics. Aluminium metal matrix composites are being considered as a group of new advanced materials for their lightweight, high strength, high specific modulus, low coefficient of thermal expansion, and good wear resistance properties. A combination of these properties is not available in a conventional material. The most important property of an Aluminium matrix composite reinforced with Silicon carbide in the aerospace industry is its strength to weight ratio, which is three times more than mild steel [1]. In addition, composites containing Silicon carbide (reinforcing material) and Aluminium (matrix) have high modulus, strength values, wear resistance, high thermal stability, less weight, and a more effective load carrying capacity compared to many other materials [2,3]. This composite is also expected to exhibit good corrosion/oxidation properties since Silicon carbide forms a protective coating of Silicon oxide at 1200°C [4] and, Aluminium also displays a similar reaction. Therefore, it is evident that this material offers considerable advantages to the aerospace industry, especially in applications that require good thermal and tensile properties. The manufacturing of silicon carbide nanowires (SiC NWs)/epoxy resin composites was investigated in an experimental study. This material could have excellent mechanical features such as hardness, wear resistance, and lightweight, making it ideal for replacing metal parts in cars. Ultrasonic mixing and casting processes were used to make the SiC NWs/epoxy resin composites. The physical and mechanical parameters of composite samples, such as density, tensile strength, hardness, and wear test, were investigated.

Nanocomposites made up of conducting polymers and a non-conducting PU matrix have sparked interest in the current technology. Electronic devices, actuators, batteries, chemical/biological sensors, and other nanocomposites applications are on the rise. Conducive polymers are used to create polymeric materials with outstanding mechanical characteristics, processability, and conductivity. The goal is to make conducting polymeric materials with strong mechanical qualities and processability that are also high in conductivity or electrochromism. The integration of a conducting polymer in a PU matrix can be done covalently or non-covalently, resulting in increased conductivity.

The objectives of the study were fabrication and characterizations of physical and mechanical properties of Silicon carbide reinforced Aluminium-based metal matrix composite for aerospace materials.

MATERIALS AND METHODS

Fabrication method

For the fabrication method, a stir casting arrangement is used. A stir casting arrangement is completed with the help of a preheater, electric furnace with stirrer assembly. A total of 12 KW capacity furnace of three-phase electrical resistance type was used. The temperature range of the pre-heater was about 850°C and the temperature range of the furnace is 1000°C. Melting range of aluminium was 750°C-850°C. When setting up the stir caster before an experiment the rotor was first lowered into the crucible. Its height was accurately adjusted to form a partial seal at the exit such that it was held concentrically during stirring. Only a partial sealing of the outlet was allowed to ensure that torque pick-up from the rotor-crucible interaction was negligible. An external plug attached to the batch casting trolley provided a full seal at the exit. Porosity, poor wettability, and inappropriate reinforcing particle distribution are all issues with metal matrix composite fabrication. For the composite, achieving a homogeneous reinforcing distribution is critical. Stir casting is a common fabrication processing technology that is both affordable and versatile in terms of materials and processing conditions. Because particles are stirred into the melt, it provides superior matrix particle reinforcement.

After the caster set-up, metal melted in an induction furnace and was transferred to a resistance holding furnace where it was stabilized at a temperature 25°C above the temperature of liquids. The melt was then poured into the stir caster furnace which had been preheated to 575°C to 590°C for Aluminium-5083-weight% Silicon carbide. The different casting compositions for Aluminium-5083 metal matrix composites are presented in Table 1.

Table 1. Chemical component (weight%) metal matrix composites

Specimen	Silicon carbide (weight%)	Aluminium-5083 (weight%)
1	5	95
2	7	93
3	9	91

Stir casting arrangement method

A 12 KW capacity furnace of three-phase electrical resistance type was used. The temperature range of the pre-heater was about 850°C. The temperature range of the furnace was 1000°C. Melting range of Aluminium: 750°C-850°C.

Characterizations of metal matrix composite

Hardness: Hardness was evaluated through the ASTM E18-03 Rockwell hardness tester with hardness scale B.

Tensile strength: The computer interfaced INSTRON Universal Testing Machine (UTM) was used for the tensile strength testing. The ASTM E8 standard was used for the testing. The hydraulic pressurized system was used for loading the specimens. The load reading at the yield point and the broken point was noted down. The elongation was measured by the extensometer. The load-deflection curve was also obtained with the help of a computer attached to the machine.

Young's modulus: It is a measure of the ability of a material to withstand changes in length when under lengthwise tension or compression. It measures the resistance of a material to elastic (recoverable) deformation under load. A stiff material has a high Young's modulus and changes its shape only slightly under elastic loads. A flexible material has a low Young's modulus and changes its shape considerably. For determining the Young's modulus, we used the generic formula which is as per Eq. (1):

Young's modulous=Stress/Strain (1)

RESULTS

Hardness

Hardness was increased with the increase of % value of Silicon carbide. Silicon carbide reinforced Aluminium metal matrix composites have higher wear resistance than Al O, reinforced metal matrix composites (Table 2).

Table 2. Measurements of hardness.

Diameter of ball indicator	SiC 5%	SiC 7%	SiC 9%	Standard aluminium used aerospace materials
1/16	77	78.59	85	66
1/8	74	76	86	63
1/4	72	81	85	64
*Note: Diameter of ball=lit in. (1.588 mm). Preliminary Test Force=10 kgf (98 N). Additional force=90 kgf(883 N). SiC: Silicon carbide.				

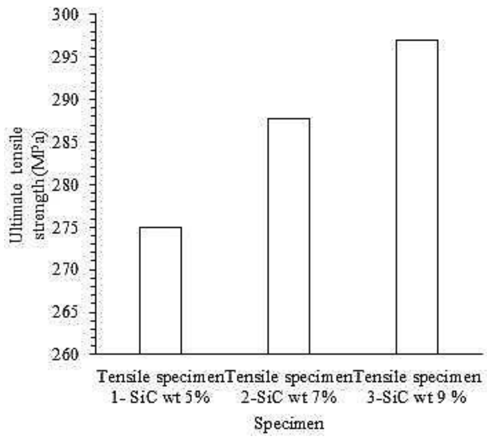
Tensile strength

Ultimate tensile strength was increased with the increase of % value of Silicon carbide (Table 3). The ultimate tensile strength was highest for specimen 3 (Silicon carbide 9% and Aluminium-5083 91%; Figure 1).

Table 3. Result of tensile test.

Specimen	SiC wt%	Tensile stress-(MPa)	Tensile strain (%)	Ultimate tensile strength (MPa)	Breaking load(KN)
1	5%	266.75	3.35%	275	3.39
2	7%	275.58	4.58%	287.77	3.52
3	9%	286.56	5.56%	296.96	1.63
*Note: SiC: Silicon carbide, wt: weight.					

Figure 1. The comparison of the ultimate strength between the specimens. **Note:** siC: Silicon carbide, wt: Weight.



Young's modulus

Young's modulus of elasticity was also highest for specimen 3 (Silicon carbide 9% and Aluminium-5083 91%). That means the specimen which was reinforced with the highest Silicon carbide weight% had high tensile strength and stiffness. The Stress versus Strain relation for each specimen is shown in Figures 2-4, respectively.

Figure 2. The stress versus the strain relation for specimen 1 (silicon earbide 5 weights% and aluminium-5083 95 weights%).

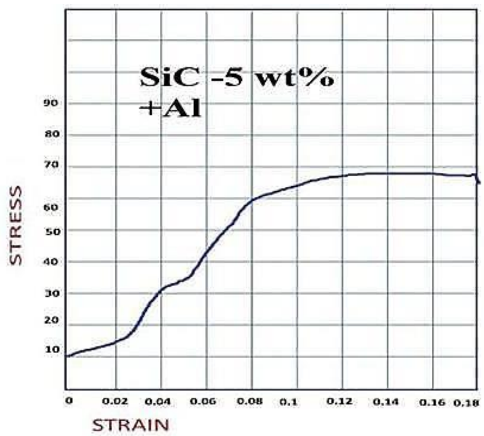


Figure 3. The stress versus the strain relation for specimen 2 (silicon carbide 7 weights% and aluminium-5083 93 weights%).

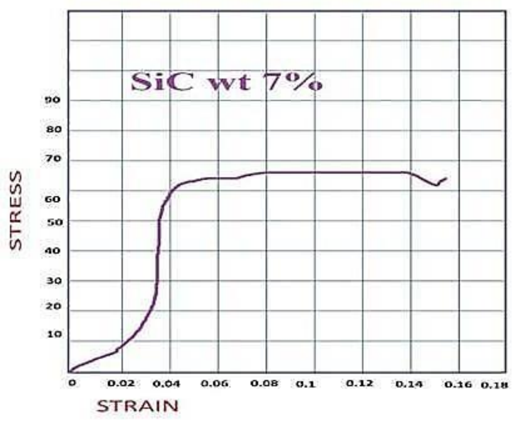
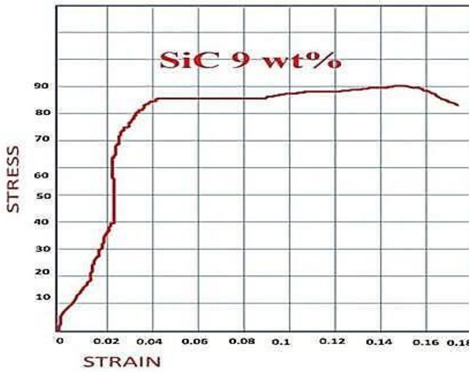


Figure 4. The stress versus the strain relation for specimen 3 (silicon carbide 9 weights% and aluminium-5083 91 weights%).



DISCUSSION

The current study makes a few recommendations regarding the use of Aluminium Silicon carbide metal matrix composites. However, it is felt that Aluminium Silicon carbide metal matrix composites look promising as materials for fuselage skins in high-performance aircraft. The main reason for its consideration was its high strength-to-weight ratio and good tensile properties. According to current literature [5], the tensile strength of pure Aluminium IS 13,000 S1 (89.6 N/mm^2), which IS lower than the value of Aluminium Silicon carbide metal matrix composites, from most of the studies, for 9% Silicon carbide, from our findings we calculated the value at 286.56 N/mm^2. Aluminium Silicon carbide's better strength weight ratio makes it a more efficient choice for aerospace usage [6].

In addition, these metal matrix composites also offer good corrosion/wear resistance and thermal stability (which becomes important in supersonic applications). Nevertheless, it must be noted that data for other critical properties such as fatigue and fracture toughness were not available. Therefore, before any concrete predictions regarding its applications are made, effort must be taken to determine these as well [7,8].

CONCLUSION

Although several fabrication methods have been discussed by Chou, et al. Stir casting is recommended as the most viable process because of its simplicity and its ability to produce large quantities. Another advantage of this method is that, in principle, it allows a conventional metal processing route to be used, hence reducing the final cost of the product. Uniform distribution of the reinforced material is challenging but stir casting made it easier to produce composites with uniform distribution. According to mechanical properties, Aluminium Silicon carbide metal matrix composites are a more efficient choice for aerospace usage.

REFERENCES

1. Devi NC, et al. Mechanical characterization of aluminium silicon carbide composite. Int J Appl Eng Res. 2011;1:793-799.
2. Arsenault RJ. The strengthening of aluminum alloy 6061 by fiber and platelet silicon carbide. Mater Sci Eng 1984;64:171-181.
3. Dave M, et al. Composite material-aluminium silicon alloy: A Review. Indian J Res. 2013;2:148-150.
4. Boopathi MM, et al. Evaluation of mechanical properties of aluminium Alloy 2024 reinforced with silicon carbide and fly ash hybrid metal matrix composites. American J App Sci 2013;10:219-229.
5. Avner S. Introduction to physical metallurgy. 2nd ed., New Delhi: Tata McGraw-Hill. 1997:481-497.
6. Chou TW, et al. Fibre-reinforced metal-matrix composites. Composites 1985;16:187-206.

7. Skibo D, et al. Process for preparation of composite materials containing nonmetallic particles in a metallic matrix, and composite materials made thereby. US Patent No. 4,786,467. 1988.
8. Tham L, et al. Effect of limited matrix–reinforcement interfacial reaction on enhancing the mechanical properties of aluminium–silicon carbide composites. Acta Mater. 2001;49:3243-3253.