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Effect of Carbon Fiber on Mechanical Properties and Corrosion Behavior of Aluminium-6061 for Aerospace Applications

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Abstract

Composite materials have brought about a revolution in numerous industries due to their superior mechanical, electrical, and thermal properties. As a result, composites have emerged as a promising class of materials. In the present experimental study, we will compare sandwiched composite panels made from aluminum 6061 alloy and aluminum-carbon fiber-reinforced polymer (CFRP) with varying load-carrying capacities in terms of their mechanical properties and corrosion behavior. These specimens are prepared using a hand-layup process followed by vacuum bagging, and they are allowed to cure for a minimum of 24 hours. Several configurations were tested, and specimen samples were created to assess mechanical properties and corrosion behavior. To perform these assessments, a Universal Testing Machine (UTM)was used with the dial gauges placed on both sides of the panel to measure displacement around the panel's center. Additionally, the test was carried out on the corrosion behavior of various specimens and analyzed to compare the outcomes between the two types of panels.

Keywords: Composites, Aluminium Alloy, Carbon Fiber, Hand Lay-Up, Corrosion

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INTRODUCTION

The strength of aluminium 6061 alloy cannot be compared with 2-series or 7-series of aluminium alloy with low hardness, and simultaneously, wear resistance is also poor. Aluminum 6061 alloy are sensitive to torridheat. They tend to lose some of their strength when exposed to hyper torrid heat. To incorporate these and to increase in Hardness, Strength and along with other mechanical properties of aluminium 6061 alloy by adding carbon fiber (CFRP) as the reinforcing material to achieve the above objectives and to achieve less erosion rate of aluminium 6061 alloy.

Aluminium has been extensively utilized in many industries for decades and notable for its higher mechanical properties, low density and resistance to corrosion. However, to further boost its performance characteristics and expand its application potential, researchers apply one self to improving aluminium composites by incorporating reinforcing elements. These composites exhibit improved strength, stiffness, wear resistance, thermal conductivity, and other desirable properties, making them gain attention in sectors such as aerospace, automotive, construction, and packaging. Over the last few years, significant

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advancements built for the development and understanding of aluminium composites [1–4]. These advancements encompass both material design and processing techniques, enabling the tailoring of composite properties to suit specific application requirements. Composite materials are utilized in aerospace industry for both main and derivative parts, including the casting of rocket motors, antenna dishes, engine nacelles, aircraft wings, pressure bulkheads, landing gear doors, and more [5–8].

Aluminium 6061 alloy exhibits excellent tensile strength typically ranging from 180-290 MPa. The strength can be further enchanced through precipitation hardening, commonly known as age hardening, which requires solution heat treatment subsequently, quenching and natural or artificial aging. Here in this paper the aluminium 6061 alloy is sandwiched with carbon fiber to make sandwich composite which enhances the tensile strength [9–11]. Aluminium 6061 alloys exhibits excellent corrosion resistance in various environments as a result of self-passivating nature. When exposed to oxygen, aluminium forms a thin oxide layer on the surface, which acts as a protective barrier against further corrosion. Some kinds of corrosion are atmospheric corrosion, chemical corrosion and galvanic corrosion. But the corrosion resistance is much more increased by adding carbon fiber to aluminium 6061 alloy [12-15]. This paper delivers a full review of the mechanical properties and corrosion behavior of aluminium 6061 alloy and aluminium-carbon composites. It discusses the alloys composition and the composite processing technique that contributes the study [16–18]. This paper makes one of the vital source for engineers and researchers working on this versatile material. Aluminium 6061 alloy offers a remarkable combination of mechanical properties and corrosion resistance, making it a favored material for numerous engineering applications. As technology and research advance, aluminium 6061 alloy continues to play a vital role in modern engineering and fabrication process [19–20].

EXPERIMENTAL WORK

Fabrication of MMC

Metal lattice composites is created by sandwiching carbon fiber (CFRP) between aluminium 6061 alloy by wet-hand lay-up method followed by vacuum bagging process with the assistance of Bhor-Bond EPCH resin for metal to carbon fiber bonding and Remilac resin for metal-to-metal bonding. 100:35 is the ratio taken to mix resin and hardner respectively to bond aluminium 6061 alloy and carbon fiber,70:30 is the ratio taken to mix resin and hardner respectively to bond aluminium and aluminium 6061 alloy sheet. Different configurations/patterns were made to fabricate the MMC's are shown in Figures 1(a),(b),(c),(d),(e).

Wet-hand lay-up technique, followed by vacuum bagging, was used to create these various structures (configurations/patterns) of composites using carbon fiber and aluminium 6061 alloy. A proper pre-coat is applied on the mold table before starting the process, it is done because to release the composite material off the table after curing without undergoing any cuts or damages. The resin is applied properly to the materials and placed inside the test mold bench for the further procedure.

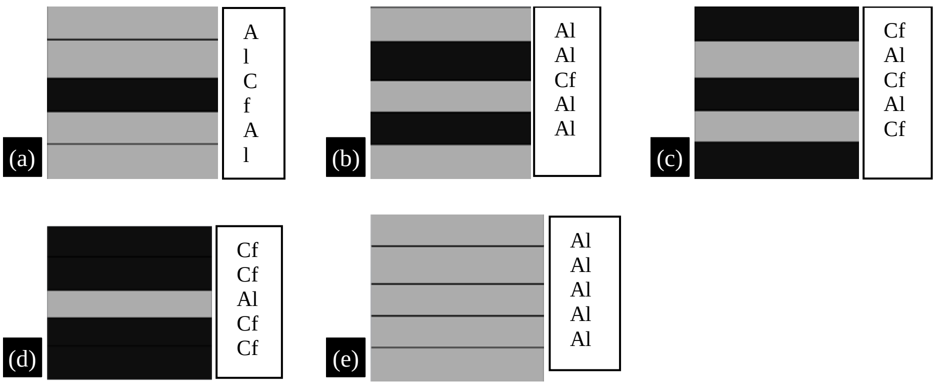

Figure 1. (a-e) are different Configurations of Composite (Specimen) (a) I Configuration (b) II Configuration (c) III Configuration (d) IV Configuration (e) V Configuration.

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Specimen Preparation

As previously mentioned, the sandwiched aluminum-carbon composite material is constructed and sliced utilizing a pressured water jet cutting machine, later sharp edges are polished with emery paper. As observed in the image, the specimen dimensions for the tests on alloys based on aluminium are in accordance with ASTM requirements. Using a water-jet cutting machine, the specimens were prepped and processed. The specimens used for the study is shown in Figure 2 (a),(b),(c),(d), (e) and Figure 3.

RESULTS

Aluminum 6061 alloy materials and sandwiched aluminum-carbon composite material are employed for the inquiry in this paper. Aluminum is the metal used, while carbon fiber is employed with epoxy matrix as reinforcing material. The next sections provide and discuss the experimental findings for the tensile, flexural loadings, and corrosion behavior for the sandwich construction.

Tensile Test

The specimen is prepared in accordance with standards established by researchers. The specimen is fixed in the UTM (FSA M-100) computer control device using the appropriate fixture before a tensile stress is applied until the fracture or breaking point. It measures the tensile strength.

DISCUSSIONS

In Figure 4, Tensile strength analysis for various specimens and configurations of the sandwich composite structure and parent metal is shown. Distinctive curves regarding with stress and strain are obtained.The results indicates, the strength of aluminium-carbon composite is increasing and is now greater than aluminium metal alloy 6061 (Table 1). Aluminium 6061 alloy strength was successfully increased by adding carbon fiber as a reinforcing element. The specimen number IV (CF-Cf-Al-Cf-Cf) have 1.82 times considerably higher tensile strength than the specimen number V (Al-Al-Al-Al-Al). By including carbon fiber, hence the strength is boosted by 54%.

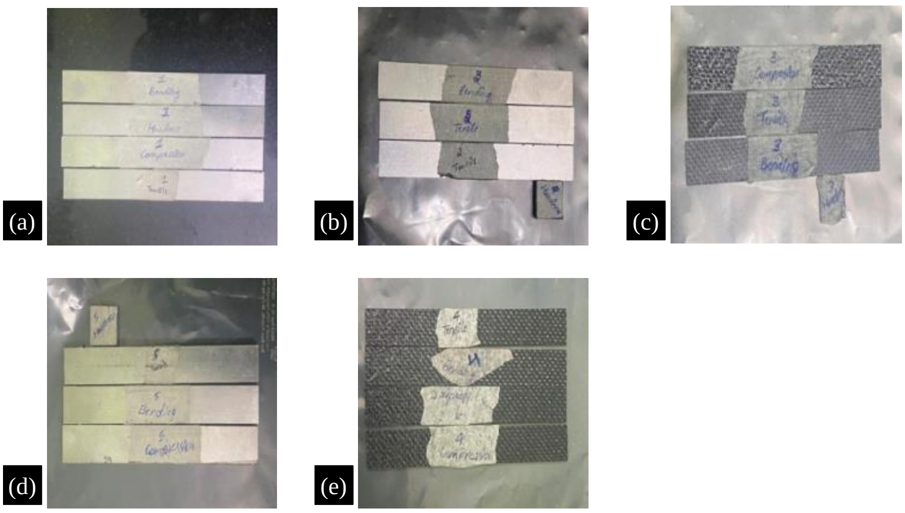

Figure 2. (a-d) are the test samples for Mechanical properties.


Figure 3. Specimens for corrosion test.

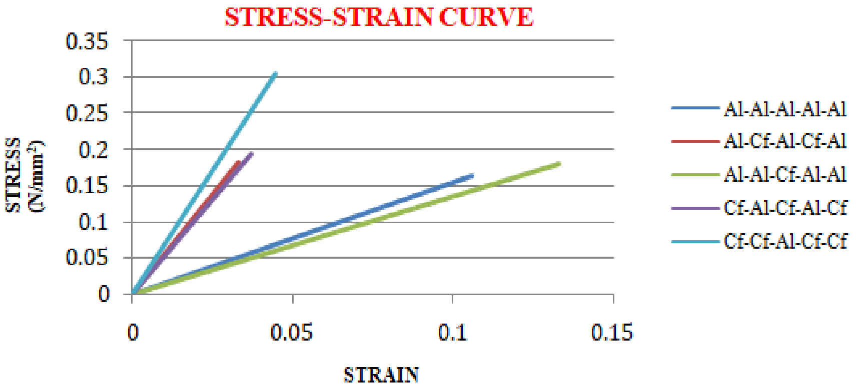

Figure 4. Graph showing the stress vs. strain curve for various combinations of aluminium composites during the tensile test.

Table 1. Tensile test data.

Specimen Number	Load at break (KN)	Tensile Strength (KN/mm^2)	Configuration
I	12.763	183.76	Al-Cf-Al-Cf-Al
II	16.585	180.134	Al-Al-Cf-Al-Al
III	11.413	194.496	Cf-Al-Cf-Al-Cf
IV	12.835	305.924	Cf-Cf-Al-Cf-Cf
V	19.942	164.693	Al-Al-Al-Al-Al

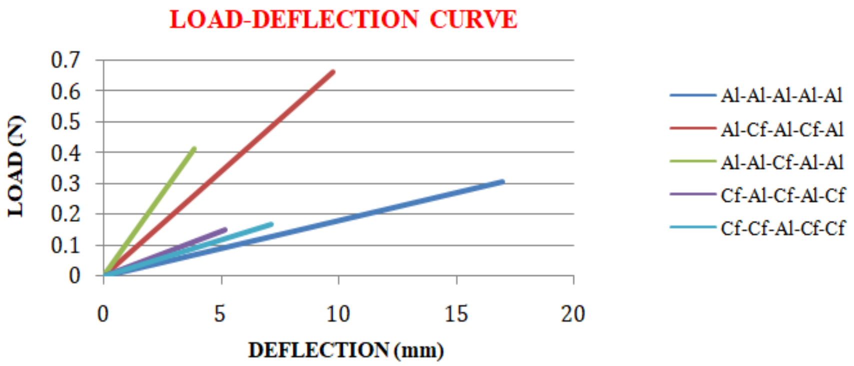

Figure 5. Graph showing the stress vs. strain curve for various combinations of aluminium composites during the bending test.

Bending Test (3-point)

The most typical experimentation method for composite materials is the 3-point bending test, which is employed in the studies. Cross head position is used for estimating the specimen's deflection. Both the deflection and the flexural strength are measured (Table 2).

DISCUSSIONS

In Figure 5, the flexural strength analysis for various specimens and configurations of the sandwich composite structure and parent metal is shown. In accordance with the figure, there exists a fluctuation in the composites' deflection in relation to changes in load.The results indicates that the flexural strength of aluminium-carbon composite is increasing and is now greater than aluminium metal alloy 6061. The bending strength of aluminium 6061 alloy was successfully increased by adding carbon fiber as strengthening element. The specimen I (Al-Cf-Al-Cf-Al) has a flexural strength that is 7.32 times greater than the specimen number V (Al-Al-Al-Al-Al). By using carbon fiber, the strength is boosted by 14%.

Table 2. Bending test data.

Specimen Number	Deflection (mm)	Load at break (KN)	Flexural Strength (KN/mm^2)	Configuration
I	9.747	0.663	230.323	Al-Cf-Al-Cf-Al
II	3.834	0.414	98.798	Al-Al-Cf-Al-Al
III	5.181	0.15	75.188	Cf-Al-Cf-Al-Cf
IV	7.103	0.167	156.127	Cf-Cf-Al-Cf-Cf
V	16.942	0.305	31.428	Al-Al-Al-Al-Al

Table 3. Corrosion test data.

Specimen Number	Corrosion (Observation done after 24 hours)	Configuration
I	Yes	Al-Cf-Al-Cf-Al
II	Yes	Al-Al-Cf-Al-Al
III	No	Cf-Al-Cf-Al-Cf
IV	No	Cf-Cf-Al-Cf-Cf
V	Yes	Al-Al-Al-Al-Al

Corossion Test

Immersion of test specimens and long-term exposure to salt-spray test conductedin compliance with ASTM - B117 test method using sea water or 5% NaCl.

DISCUSSIONS

After 24 hours of duration without interruptions, a white layer of rust is observed in Al-Cf-Al-Cf-Al, Al-Al-Cf-Al-Al and Al-Al-Al-Al-Al configurations (Table 3).

Hence, the results shows a decreased/slower rate in the corrosion rate of Aluminium-Carbon composite than that of Aluminium metal alloy (6061). It was successful in reducing the corrosion behaviour of the aluminium 6061 alloy by adding carbon fiber as augmented material to create an aluminium-carbon composite.

CONCLUSION

1. A wet hand lay-up procedure is suitable for fabrication of metal matrix composites with an aluminium foundation successfully.
2. The mechanical properties of the composite have been modified by the CFRP (carbon fiber) component.
3. Aluminium-Carbon Composites have more strength and hardness than Aluminium 6061 Alloy.
4. By using carbon fiber, the tensile strength is enhanced by 54% and the flexural strength is increased by 20%.
5. Corrosion of the metal is visible as a white layer of rust on the face of the aluminium alloy; however, less corrosion is seen in composite panels made of carbon fiber.

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