Available online at:
Al-Fiziya: Journal of Materials Science, Geophysics, Instrumentation and Theoretical Physics
Website: http://journal.uinjkt.ac.id/index.php/al-fiziya
Vol.6 No. I 2023, 9 - 19

Testing the Bending Strength of Carbon Fiber Composites using the acuum Infusion and Vacuum Bagging Method on the UAV Skywalker 1900 Fuselage Material

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Submitted: January ; Revised: April ; Approved: June ; Available Online: September

Abstract. The growing popularity of Unmanned Aerial Vehicles (UAV) requires modern engineers to create products swiftly and affordably. This study evaluated the Skywalker 1900 UAV's bending strength of carbon fiber composite materials with lycal epoxy resin. Carbon fiber and lycal resin composites will be created utilizing vacuum infusion printing and vacuum bagging techniques for test specimens. To establish the bending strength value of the fuselage material, a sample of specimens for testing will be created utilizing these two techniques. This test will use the three-point bending method. Regarding a different test, microphotos, it can be seen from this microstructure that the second-phase particle size, shape, and distribution are crucial for understanding the material's properties. Vacuum bagging and vacuum infusion printing each produced test specimen results that were compared, and the best result was then sought between the two techniques. Testing produced the results, with the two printing techniques and microphotos producing the best vacuum bagging outcomes. Specimen i1 had the lowest yield in the vacuum bagging procedure, with a bending stress value of 1017.74Mpa, whereas specimen b2 had the most outstanding value (1201.90Mpa). The micro photo test can then be observed in the vacuum bagging printing process; the resin in the bagging has improved fiber penetration.

Keywords: *UAV, Composite, Carbon fiber, Vacuum infusion, Vacuum bagging, Bending test.*

INTRODUCTION

The utilization of Unmanned Aerial Vehicle (UAV) technology has proliferated. UAV, commonly known as drones, are pilotless aircraft that can be operated remotely from a computer system or other vehicles on land, sea, or air [1]–[6]. Drones have various applications, including mapping [7]–[9]. Drone technology has been instrumental in territory mapping in Indonesia, an archipelagic nation [7].

A vehicle's wing development is a multi-stage process that includes wing profile selection, geometric calculations, structural design, material maintenance, numerical analysis, and manufacturing [10], [11]. One of the most challenging difficulties in aviation is determining how to progress. Structures that are lightweight but sufficiently strong to sustain the imposed loads. Materials that can accommodate this are required. Composite materials are an essential component of modern airplane designs. One of the significant factors contributing to the continued development of the UAV industry is the innovation of structures and materials, particularly the advent of composite materials used in UAV construction [12]

Composite is a material made from two or more components, and each composite possesses unique mechanical characteristics based on the materials used to create it. Depending on the type of binding material and the reinforcing material, the mechanical strength characteristics of the composite can vary. Various fiber materials are reinforced in fiber-reinforced composites (reinforcing materials) [13]–[19].

Carbon fibers are used in UAV fuselages to reduce weight while maintaining material strength. Materials with at least 90% carbon by weight are known as carbon fibers. Graphite fibers with a carbon content exceeding 95% are the most commonly used type of carbon fiber. Applications that require strength, rigidity, lightweight, and fatigue resistance are suitable for carbon fibers[20].

Several methods are used to manufacture composite materials, including vacuum bagging, spray-up, hand layup, pressure bagging, infusion, continuous extrusion, and injection molding. This technique involves vacuum infusion and vacuum bagging to create composites, which is relatively straightforward. Manufacturing composite materials using vacuum infusion involves pressing matrix, fiber, and other layers into the mold while utilizing an airtight bag, merging the layers into a composite material[10], [17], [20]–[29].

Vacuum bagging is one of the most commonly used methods, along with hand lay-up. This method is an improvement over the manual hand lay-up method, as it involves lamination and vacuum steps to eliminate excess resin and trapped air from the lamination [21], [22].

RESEARCH METHODS

In this research, vacuum infusion and vacuum bagging methods were used. Figure 1 showed a specimen using the vacuum-assisted resin infusion and vacuum bagging processes. Dry fibers are placed between the fixed mold and a plastic bag in the vacuum-assisted resin infusion. Then, resin is injected after the space inside the plastic bag is put under low pressure, and the process continues until the entire fiber is impregnated with resin. On the other hand, in the vacuum bagging process, dry fibers are placed between the fix mold, and resin is manually applied evenly using a brush onto the fiber surface [10].

Figure 1. Shows The UAV Fuselage For Which Test Specimens Will Be Produced

The specimen manufacturing process utilizes the vacuum infusion method.

The composite manufacturing process begins with determining and preparing carbon fibers. Carbon fibers are purchased online with dimensions of 1.5x0.5 meters. After obtaining the carbon fibers, they are cut and shaped according to the size of the vacuum infusion specimen mold.

The mold used is made of glass and has a box-shaped dimension of 40x35 cm. The mold is then cut on the edges to facilitate the airflow in and out. Before placing the fibers, the mold is coated with a wax mold release to prevent the resin from sticking to the mold. Next, the fibers are arranged in 2 layers. Peel ply is then applied over the carbon fibers and installed flow media. Hoses are connected to the in and out parts and covered with plastic bags sealed with dodol adhesive to ensure no air leakage occurs during infusion.

The resin and catalyst are mixed in a 3:1 ratio (catalyst to resin by weight) and manually stirred for approximately 5 minutes to ensure a uniform mixture. The resin is poured into a glass container, and the vacuum infusion machine is activated. The in-hose is inserted into the glass container to allow the resin to flow into the mold. Once the resin flows through the hose, it is sealed with dodol adhesive to prevent air from entering the mold, ensuring a smooth vacuum process.

The next step is to wait approximately 6 hours for the composite to cure. After the specified time has passed, the vacuum machine is turned off. The composite is left to rest for 18 hours before removing the plastic bag and extracting the composite from the mold. Once removed from the mold, the composite undergoes material forming to meet ASTM testing size requirements using milling machines and sandpaper before being subjected to bending tests. The formed specimens are now ready for bending tests, completing the manufacturing process of the composites [14].

The process of specimen fabrication utilizes the vacuum bagging method.

This research involves several sequential stages. The initial step is to determine and prepare the carbon fibers for the composite. Carbon fibers are purchased online with dimensions of 1.5x0.5 meters. After obtaining the carbon fibers, they are cut and shaped according to the size of the vacuum-bagging specimen mold. The mold used is made of glass and has a box-shaped dimension of 40x35 cm. It is then cut in the middle to allow air to exit. Before placing the fibers, the mold is coated with a wax mold release to prevent the resin from sticking. The following process involves arranging the threads in a single layer. The resin and catalyst are mixed in a 3:1 ratio (based on resin weight) and manually

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P-ISSN: 2621-0215, E-ISSN: 2621-489X

stirred for approximately 5 minutes to ensure a homogeneous mixture. This mixture is then evenly applied to the previously arranged carbon fibers. The carbon fibers are then re-arranged in another single layer, and the resin-catalyst mixture is again evenly spread.

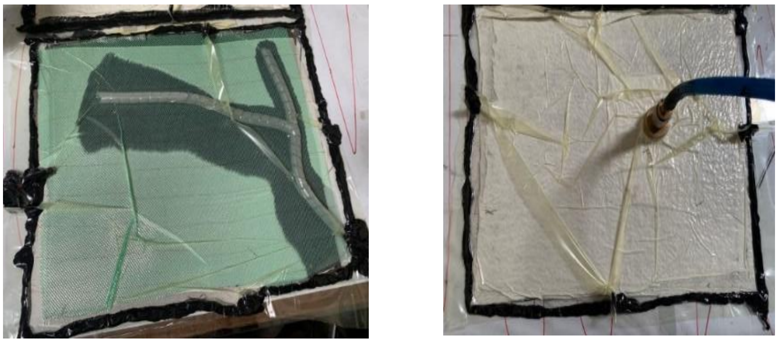
A breder cloth is placed over the carbon fibers to strengthen the composite structure. Hoses are attached to the middle part of the mold to allow air to be removed, and then the mold is covered with a plastic bag sealed with dodol adhesive to prevent air leakage into the mold. Next, the composite is left to cure for approximately 6 hours. After the curing period, the vacuum machine is turned off, and the composite is left to rest for 18 hours before removing the plastic bag and extracting the composite from the mold. Once successfully removed from the mold, the composite undergoes material forming to meet ASTM testing size requirements using milling machines and sandpaper as preparation for testing. The formed specimens are then ready to be tested in bending tests.

In the final stage, data from all tests are collected and recorded for further analysis and discussion in this research. All these stages are carried out to achieve accurate and reliable results in this composite study.

RESULTS AND DISCUSSION

A. Research Result

This section displays the data processing results of the tests carried out. The data from this study were sourced from bending tests and micro-photos using six specimens. For data analysis, it takes the average value of each variation used (Figure 2).



a) b)

Figure 2. a) Vacuum Infusion b) Vacuum Bagging Processes

The results follow after the vacuuming process for 6 hours and then left for 18 hours (Figure 3).

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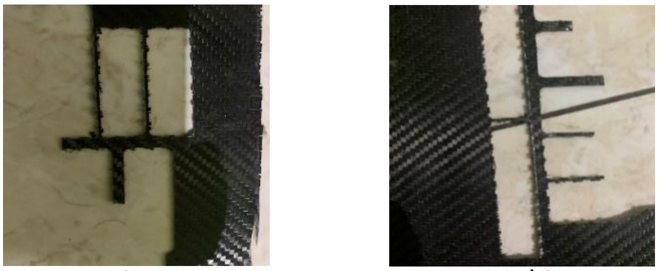
a) b)

Figure 3. The Results a) The Vacuum Infusion b) Vacuum Bagging Processes

Then, cut the specimen using a CNC router to get precise sizes according to ASTM D790 (Figure 4).

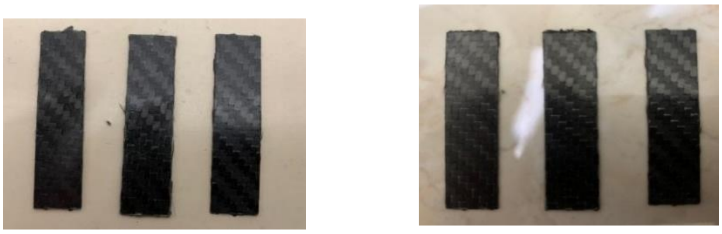


a) b)

Figure 4. Results Of Cutting Using CNC Router a). Vacuum Infusion Cutting Results b) Vacuum Bagging Cutting Results

Bending Test

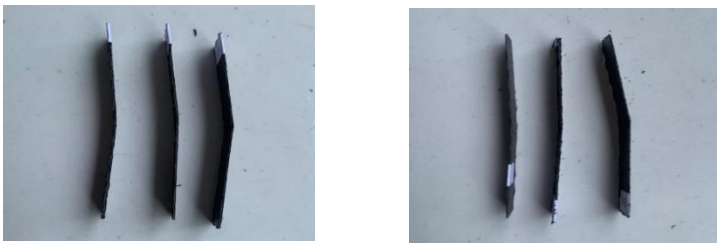
After the results of cutting composite materials using a CNC router and according to ASTM D790-17 for bending strength testing (Figure 5)



a) b)

Figure 5. Specimens of the vacuum infusion and vacuum bagging method a).specimen vacuum infusion method b) specimen vacuum bagging method

Photos of the bending test results can be seen in Figure 6.



a) b)

Figure 6. Documentation of the results of a) Vacuum infusion bending test results _b) Vacuum bagging bending test results

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P-ISSN: 2621-0215, E-ISSN: 2621-489X

Table 1. Shows the comparison of the vacuum infusion and vacuum bagging methods.

Variation	Bending Strength (MPA)	Bending Strength Average (MPA)
Vacuum Infusion method	1017,74 1182,56 1130,43	1110,25
Vacuum Bagging Methode	1079,00 1201,90 1198,37	1159,75

Table 1 shows the average carbon fiber bending test results using the vacuum infusion and bagging methods. The average bending strength results are obtained at 1110.25 MPa in carbon fiber using the vacuum infusion method. Using the vacuum bagging method, carbon fiber's average bending strength is obtained at 1159.75 MPa. In this bending test, the increase in bending strength from the vacuum infusion to the vacuum bagging method reached 0.045%.

a. Specimen Metode Vacuum Infusion

Figure 7 represents the bending test results of carbon fiber using the vacuum infusion method with three specimens. The highest bending stress was achieved at 1182.56 MPa in specimen 2, while the lowest bending stress was recorded at 1017.74 MPa in specimen 1.

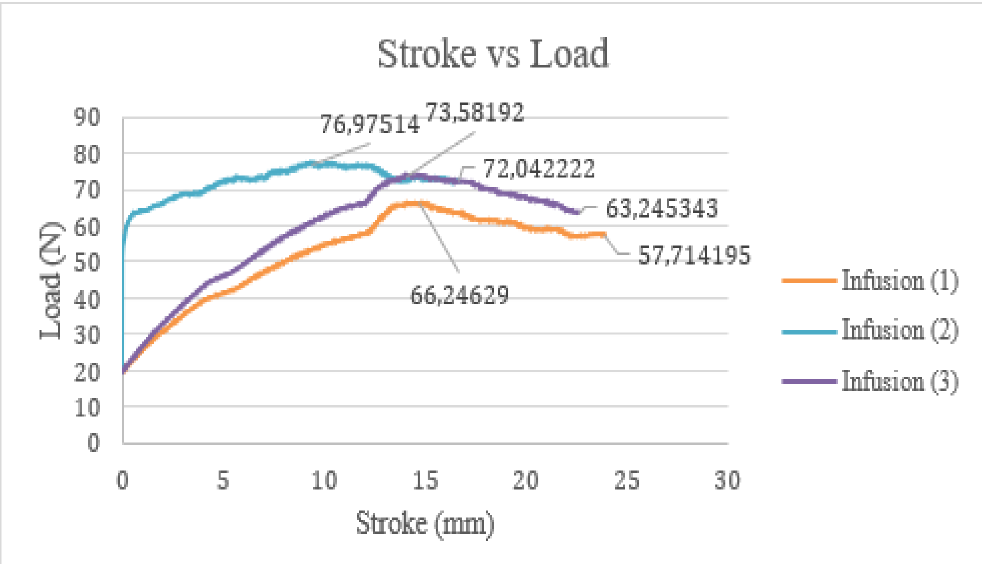


Figure 7. Load vs. stroke Chart of The Vacuum Infusion Method

b. Specimen metode vacuum bagging

Figure 8 shows the results of the bending test of carbon fiber using the vacuum bagging method with three specimens. The highest bending stress was achieved at 1201.90 MPa in specimen 2, while the lowest bending stress was recorded at 1079.00 MPa in specimen 1.

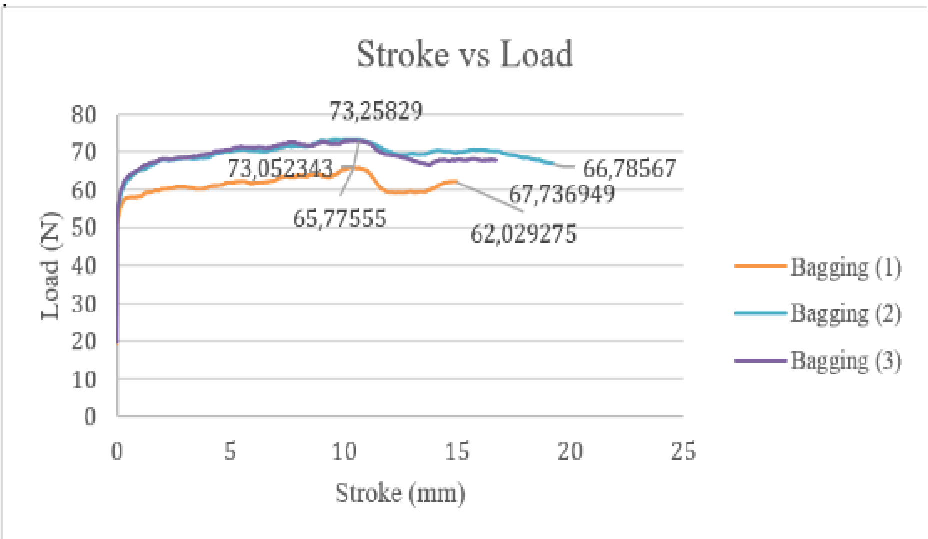
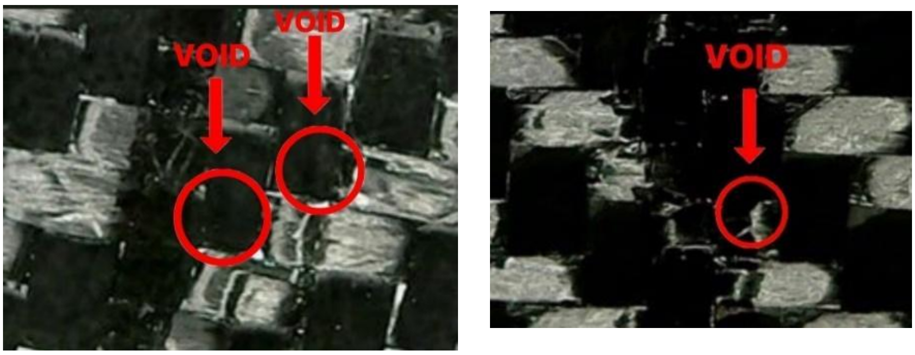


Figure 8. Load vs. Stroke Chart of the Vacuum Bagging Method

Micro Photo

The best variation was achieved using the vacuum bagging method in the bending strength testing. This is because, during the manual resin application, it was evenly distributed using a brush. On the other hand, the vacuum infusion method showed imperfect resin penetration into the fibers due to poor application, caused explicitly by uneven resin distribution through the spiral hoses, primarily positioned in the middle. The vacuum bagging method produced better results with fewer voids. This can be observed from the micrograph of the specimens at 70x magnification shown below.



a) b)

Figure 9. a). Micro vacuum infusion photo results b). Photographs of micro vacuum bagging

Figure 9 shows that the vacuum infusion method has more voids, and the vacuum bagging method has fewer voids. This is caused during the manufacturing process.

B. Discussion of results

The discussion of the results of the bending test and microphotographs shows that the best method to be used in the manufacture of composite materials for the UAV Skywalker 1900 fuselage is the vacuum bagging method because the highest results are from the results of making specimens in the form of samples and then bending tests by ASTM

D790, the best results are obtained. By vacuum bagging. The micro photo shows that the vacuum bagging method receives the best penetration between resin and fiber. The vacuum infusion process did not go well due to the uneven application of the wax, as seen in the image below.

Figure 10. Application Of Resin Vacuum Infusion

Figure 10 shows that resin application tends to flow downward so that it is not evenly distributed at the top when applying resin to the fiber. To manufacture the vacuum infusion method, place the spiral hose on the side like the letter U so that it is evenly distributed in the infusion method.

CONCLUSION

The bending strength testing results of the specimens indicate that the vacuum infusion method achieved the highest bending strength at 1182.56 MPa, while the lowest bending strength reached 1017.74 MPa. On the other hand, the bending strength testing with the vacuum bagging method had the highest bending power at 1201.90 MPa, and the lowest bending strength was recorded at 1079.00 MPa.

Based on the results and discussions, the best method for manufacturing carbon fiber composite materials for the UAV Skywalker 1900 fuselage is the vacuum bagging method. This method provides higher bending strength compared to the vacuum infusion method. The use of vacuum infusion encountered challenges in resin penetration into the fibers, mainly due to uneven resin application through spiral hoses, particularly caused by the position of the spiral hoses in the middle, resembling the letter T. Thus, the vacuum bagging method is considered more effective, producing composites with better mechanical properties for UAV fuselage applications. These results offer essential insights for improving and developing the composite material manufacturing process based on the desired needs and technical requirements.

SUGGESTION

For future researchers, it is recommended to focus on developing lighter materials that maintain high bending strength. Carbon fiber composite materials have the potential to be used in various applications, including UAV fuselages. By optimizing the weight-to-bending strength ratio, composite materials will become more efficient and deliver better performance in their applications.

Additionally, for improvements in the vacuum infusion method, the following researchers can consider placing the spiral hoses on the sides, forming a U shape. With this improved placement, resin distribution into the fibers will be even more during infusion. This will help enhance resin penetration into the fibers and reduce the possibility of structural weaknesses caused by uneven resin distribution in the previous method. Consequently, vacuum infusion can be optimized to produce better carbon fiber composite materials.

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