Filament winding is a widely used method for producing tubes and pressure vessels from composite materials. However, overlapping of fibers during the winding process can lead to rough surface and increased voids in the finished product. To improve the quality of CFRP materials produced through filament winding, the structure is cured either at room temperature or in an oven with a controlled heat profile, depending on the type of resin used. Various finishing techniques, including shrink tape, compression molding, and vacuum compression molding, have been attempted to improve the quality of the specimen. Among these techniques, vacuum compression molding has been found to deliver the best results in terms of surface roughness, with average roughness (Ra) values of 0.35 µm in the fiber direction and 0.61 µm in the transverse direction. This level of roughness is comparable to that achieved through milling machine manufacturing. Moreover, this technique ensures uniformity in fiber composition and volume fraction, achieving a homogeneous density of 1364.49 kg/m^3 *and the highest fiber volume fraction of 63 %. As a result, remarkable mechanical attributes, such as a tensile strength of 926.07 MPa and a stiffness of 21.35 GPa, can be obtained. In addition, by utilizing various finishing techniques, the tensile strength of these properties can be increased by up to 80 %. CFRP is a versatile material with unique characteristics, and selecting appropriate finishing techniques such as vacuum compression molding can significantly enhance its overall quality and mechanical properties. However, one drawback of the filament winding method is the poor outer surface finish which can be improved by vacuum compression molding*

Keywords: filament winding, CFRP, surface roughness, fabrication, fiber fraction, Void, Tensile strength

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THE FILAMENT WINDING METHOD'S FINISHING PROCESS IMPACT ON HIGH-FIDELITY SPECIMENS: HOMOGENITY OF DENSITY, FIBER VOLUME FRACTION, OUTER SURFACE ROUGHNESS AND TENSILE STRENGTH

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1. Introduction

In modern engineering, composites like CFRP are crucial due to their exceptional strength-to-weight ratios and unique mechanical properties [1–3]. They play a critical role in industries such as aerospace, automotive, and construction. Compared to metals, composites are significantly lighter, which is important for reducing weight and improving fuel efficiency in transportation and aircraft [4–6]. Additionally, composites are ideal for harsh environments or chemical exposure due to their inherent corrosion resistance. Their ability to be shaped into intricate forms allows engineers to tailor designs for precise performance needs. Composites also require less maintenance than traditional materials, leading to long-term cost savings. They can be customized to meet specific mechanical and thermal needs, resulting in enhanced performance for diverse applications [7].

Composite manufacturing process has a great impact on the final product performance. Filament winding is a popular manufacturing method for composites especially for axisymmetric products. However, engineers and manufacturers must consider the limitations of the process. During this process, fiber overlap can cause surface roughness, requiring additional finishing techniques for desired smoothness. Void formation can also occur and negatively impact the structural integrity of the composite structure. Therefore, special attention and quality control measures are necessary to minimize void content.

Additional processes can be done to minimize surface roughness and void formation in the filament wound product. Compression molding was well known as a process that can produce the best surface for polymer composite material. On the other hand, the vacuum bagging process was recognized to reduce the void in polymer composite material. The combination of these two processes is expected to solve the problems with filament wound products.

Composite manufacturing, including techniques like filament winding, is crucial in various industries due to the unique properties of composite materials. However, it's important to be aware of the limitations of the filament winding process, such as surface roughness, void formation, and constraints on complex geometries, to make informed decisions when selecting manufacturing methods for specific applications. Compression molding and vacuum processes were known to have a positive impact on polymer composite material products. The effect of these processes as a finishing method for filament wound products has not been known. Therefore, research on the use of finishing processes to improve filament wound product quality is relevant.

2. Literature review and problem statement

Filament winding is a commonly used method in the manufacturing of continuous fiber reinforced resin composites, especially for pressure vessels and pipes [8, 9]. Carbon Fiber Reinforced Polymers (CFRP) are cost-effective and efficiently produced through this preferred method. Achieving a perfect manufacturing process is crucial, particularly in addressing surface roughness and void-related issues. Filament winding has several advantages including its suitability for high fiber volume fractions. It is also applicable to components with high internal pressure such as pressure vessels and propulsion nozzles [1]. Due to its efficiency and cost-effectiveness, it is a popular choice in many engineering fields [10, 11].

Although the filament winding process is effective, it has limitations that need to be addressed. One of these limitations is the unsatisfactory external surface finish that impacts the final product's aesthetics and functionality [12]. Composite components produced via filament winding are often plagued by voids, which can result from problems like fiber overlap and variations between layers. Additionally, uneven and bumpy areas may develop, and resin bubbles in the resin bath may also contribute to the formation of voids. Proper resin impregnation is crucial in reducing voids in filament winding [13].

Controlling void content is crucial in aerospace composite production. Primary structures may require less than 2 % void content [14]. The absence of material within a structure can greatly affect its overall characteristics and may result in structural problems. [15]. The porosity of composite materials depends on curing cycle temperature and pressure. Autoclave curing is effective but has drawbacks like long cycle times and high costs [16]. Out-of-autoclave (OoA) processes apply vacuum, pressure, and heat outside an autoclave to reduce costs and energy consumption [17, 18].

In order to fully understand composites, it is crucial to have access to both geometric and topological data regarding their constituent phases. This requires knowledge of the average fiber and void fractions, as well as the distinct properties of each component. Collecting this crucial information can significantly enhance modelling capabilities, resulting in better alignment with the production process and ultimately leading to more accurate and efficient outcomes [19]. Finishing using shrink tape and compression molding is expected to produce specimens with high perfection and that can reduce production costs.

According to research, the filament winding method's drawback is a poor outer surface [12, 20]. Several other studies have analyzing deformations between layers and the outside surface of a multilayer filament-wound composite pipe [21], and surface roughness on the cutting surface [22, 23]. Based on our analysis, it is possible to conclude that it would be worthwhile to conduct a study on how to enhance the quality of filament winding products. Specifically, it is necessary to focus on improving the homogeneity of the product, reducing the roughness of the outer surface, and enhancing the strength of CFRP products through the filament winding method.

3. The aim and objectives of the study

The aim of this study is to identifying the influence of finishing process affects on manufacturing of filament winding. This will make it possible to enhance the consistency of the manufacturing results, attain an optimal fiber volume fraction, and decrease the roughness of the outer surface of the filament winding.

To achieve this aim, the following objectives will be accomplished:

– determine the density uniformity;
– determine the fiber fraction;
– determine the surface roughness;
– determine the tensile strength.

4. Material and methods

4. 1. Object and hypothesis of the study

The Filament Winding manufacturing method, along with its added finishing processes of various types, has been utilized in this research. The filament winding machine undergoes the same stages for material and setting, but the finishing process after the wet winding process varies.

The finishing process that will be carried out after the curing or wet winding process. This process aims to improve the outer surface roughness caused by pose winding deficiencies. This process is expected to improve density uniformity and enhance tensile strength.

Curing treatment is typically performed at room temperature or using an oven. By incorporating the finishing process with the curing process, it is expected to result in products with improved surface smoothness. In addition, the compression process applied in these three variations of the finishing process can remove excess matrix, resulting in the optimal fraction volume for achieving the desired density of the product. By compressing the material and using a vacuum process, voids are expected to be reduced.

The finishing process is carried out in an autoclave system that uses heat, vacuum, and pressure during the curing process. The finishing process is expected to reduce production costs compared to autoclave processes while maintaining high product quality.

4. 2. Material and specimen

In this particular research endeavor, let's employ a carbon fiber tow Tansone® H 2550 with a density specification of 1800 kg/m^3. The matrix was Epoxy Huntsman Araldite® 5052, combined with the Huntsman Araldur® 5052 hardener at a ratio of 100:28, resulting in a final density of 940 kg/m^3. To finish the project, the overhead shrink method, which involved the use of 20 % fiberglass shrink tape. The efficacy of the shrinkage process was largely influenced by the temperature employed during the curing process of CFRP.

A composite plate is made using raw materials of carbon fiber and epoxy resin. The design of the plate measures 300 mm in length, 280 mm in width, and 2 mm in thickness. From the manufacturing of these plates, they will be divided into multiple ASTM D 3039 test specimens and some others will be used for testing density, fiber fraction, and surface roughness measurements.

4. 3. Filament winding process

The production of CFRP plates is executed with precision and expertise, utilizing the filament winding process with plate-shaped molding. The finishing process is meticulously carried out to ensure the creation of a flawless specimen. The wet winding process illustrated in Fig. 1 optimizes molding speed to 15 RPM, allowing sufficient time for resin and fiber to fully impregnate in the resin bath, thereby minimizing voids. The carriage winding speed is set to 0.51 mm/second to ensure even coverage over the molding surface and reduce the possibility of porosity.

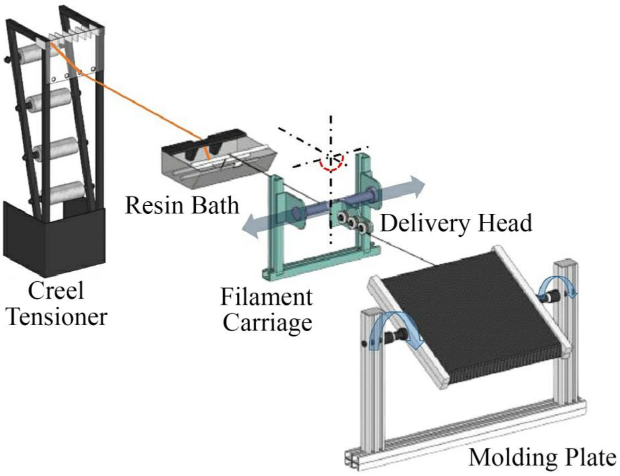


Fig. 1. Filament winding process

There are five main components of the filament winding process with different functions. First, the creel tensioner functioned as a filament holder equipped with some pulleys that give additional tension to fiber filament. Then, the resin bath acted as a matrix container which passed by the filament to be wetted by the resin. Furthermore, the filament carriage delivered the wetted filament that can be moved parallel to the molding plate. The delivery head functioned to point the filament to the mold. Lastly, the molding plate served as a support system for the rotating mold where the filament will be placed.

The process after wet winding uses 3 different processes. First, the process uses shrink tape to reduce porosity. However, it can cause fiber buckling in low fiber content conditions [24]. In this process, the fiber content will be maintained at normal conditions by regulating the impregnation process in the resin bath. Secondly, the process uses compression molding after wet winding to improve surface and reduce excess matrix composition. Finally, the integration of vacuum into the compression molding process is anticipated to diminish voids by as much as 2 %.

4. 4. Finishing fabrication

The finishing process occurs after the wet winding process and involves three layers of hoop winding. There are different variations of the finishing process.

4. 4. 1. Shrink tape

The shrink tape process is performed by wrapping shrink film around the wound plate after the wet winding process with hoop winding. The plate is then heated in an 80-degree Celsius oven. Using Shrink Tape enables the creation of mechanical pressure without relying on vacuum technology. This specialized polyester compaction film is expertly applied to laminates, where it creates pressure during the curing process. In Fig. 2 are the properties of shrink tape used in this study where temperature greatly affects the shrinkage of shrink tape.

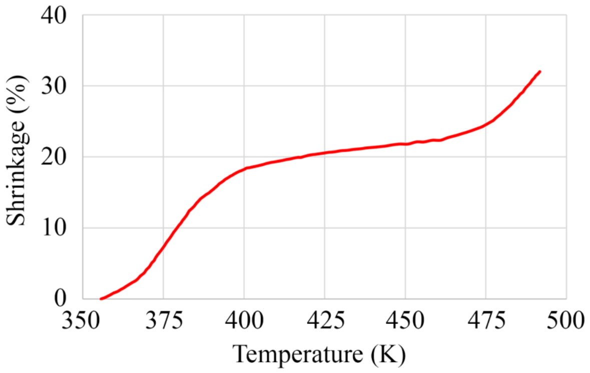


Fig. 2. Shrink tape properties

Shrink Tape is a method that uses heat to generate pressure instead of traditional vacuum bagging methods. When heated, it shrinks up to 20 %, which compresses the composite material and eliminates excess resin and air. Temperature strongly affects the shrinkage, but it must be considered because the properties of the resin, which cure faster at high temperatures, can affect the specimen's results.

4. 4. 2. Compression molding

This equipment compresses the mandrel between two plates using 1 ton of pressure and heat treatment at 353.15 K, matching the shrink tape process. The mandrel is compressed by this equipment with 1 ton of pressure and undergoes heat treatment at 353.15 K, which is an effective method similar to the shrink tape process.

4. 4. 3. Vacuum compression molding

The vacuum process added to compression molding is expected to reduce voids while maintaining the same curing temperature, resulting in equal plate thickness for comparison studies.

4. 5. Characterization

The quality of composite specimens is evaluated by analyzing various aspects of their microstructure, including fiber volume fraction, uniformity of fiber and matrix distribution, specimen density, and surface roughness.

4. 5. 1. Density measurement

This test accurately quantifies the density discrepancy of composite structures that arise from the fabrication process. The test specimens are precisely crafted to detect density variations within the same volume, Density data collection using precise 180 A densitometer. In order to ensure consistent manufacturing outcomes, a thorough assessment is conducted by collecting 20 random samples from various production sites. These samples are then cut into 10×10 mm sizes and compared to the calculated fraction volume and mass fraction to obtain precise data.

4. 5. 2. Surface roughness measurement

The SEF800-G Kosaka Roughness and Contour Tester is a highly effective tool that is utilized to measure the surface roughness of fabricated materials. This instrument can measure up to 40 points on both the upper and lower sides of the specimen, including fibers and transverse areas with a maximum length of 10 mm per point. The test standard that is employed for this measurement is JIS B 0601:2001. The results are presented as average roughness values (Ra) and are classified into 12 levels (N1-N12) based on the ISO 1302 standard. Surface observations were made using the Dino-Lite AF 4915ZT microscope at 64,4 X magnification to detect defects on the specimen's outer surface.

4. 5. 3. Scanning electron microscopy

Observe the microstructure of composite materials using a Scanning Electron Microscope (Phenom PRO X) to analyze voids, fiber and matrix homogeneity. Analyze SEM data using Image J software to determine the Fiber Volume fraction of each specimen at a magnification of 750x.

4. 5. 4. Volume fraction and mass fraction

The definitions of fiber volume fraction V_f and matrix volume fraction V_m are as follows [1, 2]:

$$V_f = \frac{v_f}{v_c},$$

$$V_m = \frac{v_m}{v_c},$$

$$v_f + v_m = v_c,$$

where v_c is volume of composites, v_m is volume of matrix, and v_f is volume of fiber. The matrix mass fraction is W_m, and fiber mass fraction is W_f can also be calculated before the volume fraction computation begins:

$$W_f = \frac{w_f}{w_c},$$

$$W_m = \frac{w_m}{w_c},$$

$$w_f + w_m = w_c,$$

where w_f is fibre mass, w_m is matrix mass, and w_c is composite mass. By entering the density, the mass fraction and volume fraction are related:

$$V_f = \frac{w_f}{\rho_f},$$

$$V_m = \frac{w_f}{\rho_m} = \frac{w_c - w_f}{\rho_m},$$

where ρ_f is fibre density, and ρ_m is matrix density.

4. 6. Mechanical testing

To determine the effect of the finish process on the strength of the CFRP structure, a feeding tensile test will be carried out. The tensile strength and elongation at break were measured using the Shimadzu AG-X plus 50 kN equipment and following ASTM D 3039. Three specimens were tested, with a gauge length of 100 mm and a crosshead speed of 2 mm/min, and the average values were obtained.

5. Result the perfection of a specimen is influenced by the results of the finishing process.

5. 1. Determining the quality of a specimen based on the density

To ensure precise evaluation of specimen density, a total of 20 samples are extracted from different spots across the manufacturing plate. It is expected that a comprehensive picture of the density uniformity produced by the three finishing variations will be obtained. The density measurement results are clearly presented in Table 1. Through thorough testing, it has been determined that the vacuum compression molding process produces the highest level of consistency in density, with a standard deviation of only 4.927 and the average density reaches 1364.49 kg/m^3. During the shrink tape process, overlapping can occur, resulting in variations in thickness, fiber content, and ultimately, inconsistent density.

Table 1

CFRP Density with Combination finishing process

Specimen number	Shrink tape (kg/m^3)	Compression molding (kg/m^3)	Vacuum compression molding (kg/m^3)
1	1270.00	1365.75	1364.49
2	1262.27	1369.88	1368.42
3	1262.85	1361.85	1366.12
4	1283.29	1357.12	1355.88
5	1267.35	1367.81	1353.35
6	1221.11	1340.96	1364.38
7	1244.27	1362.07	1362.15
8	1278.76	1357.26	1369.82
9	1287.56	1361.43	1359.23
10	1243.24	1371.98	1361.73
11	1317.85	1365.26	1375.24
12	1252.97	1358.93	1369.21
13	1263.58	1353.92	1361.48
14	1264.22	1362.71	1364.68
15	1278.82	1369.23	1366.52
16	1249.53	1362.76	1365.23
17	1258.89	1370.14	1364.82
18	1267.59	1361.09	1367.95
19	1279.43	1389.17	1360.26
20	1253.78	1363.93	1368.79
Average	1265.36	1363.66	1364.49
Standard Dev	19.559	8.920	4.927

Based on the Table 1, it is evident that vacuum compression molding produces the lowest standard deviation during the finishing process. This indicates that manufacturing with this method results in the most consistent and uniform output compared to other finishing techniques.

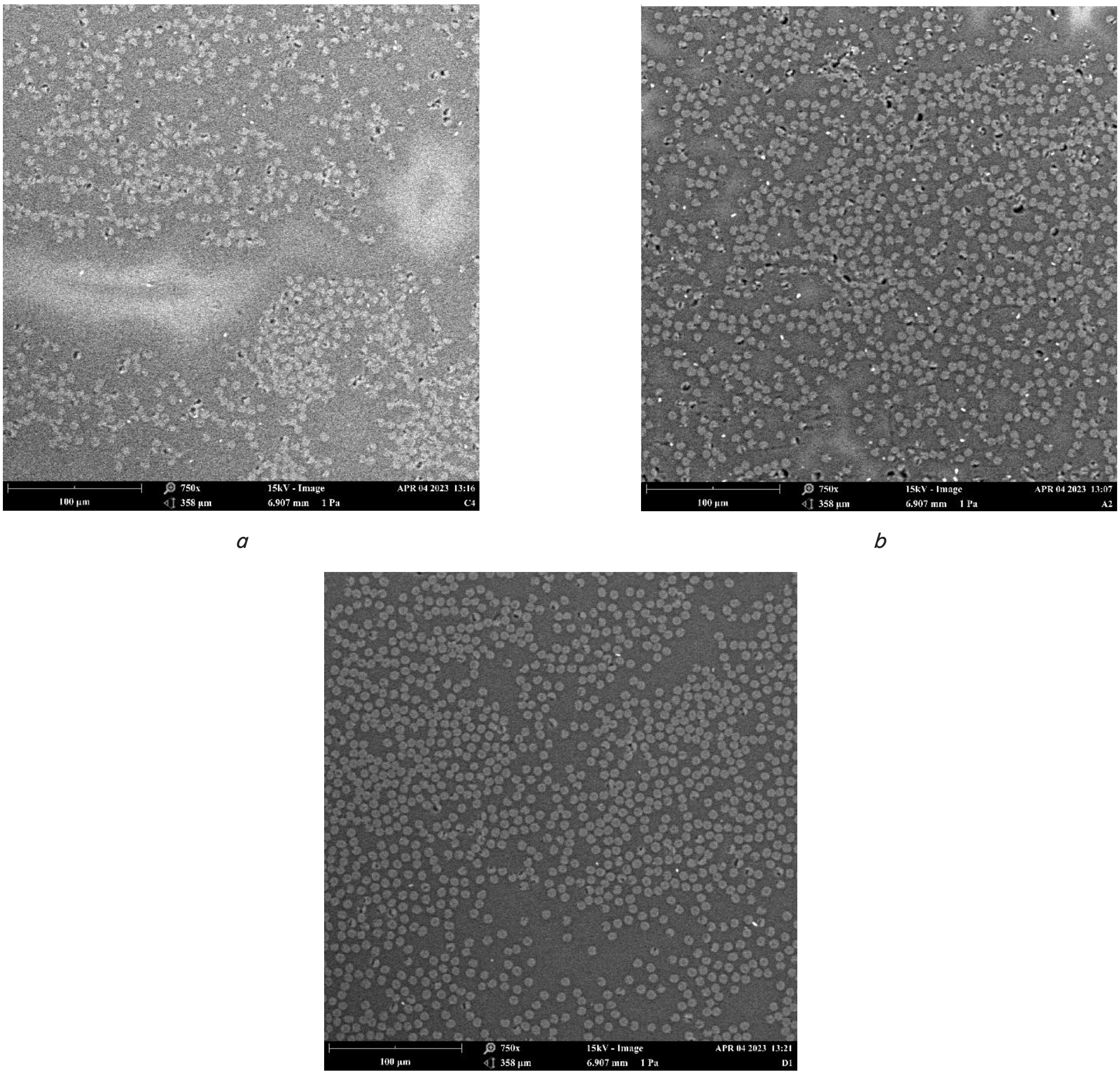
5. 2. Determining the quality of a specimen based on fiber fraction

The SEM images presented in Fig. 3 illustrate the successful achievement of high fiber-matrix composition through vacuum compression molding, with a maximum fiber content of 63 %. This study found that consistent fiber composition and matrix lead to uniform sample density. Additionally, vacuum during the finishing process reduced voids. Although shrink tape can achieve optimal results at 200 °C, the curing process only uses 353.150 K, resulting in poor outcomes. Additionally, this contrasts with the specifications of epoxy resin, which has a gel time of 2 minutes at a temperature of 393.150 K. The full shrink process takes 15 to 20 minutes. The temperature of 353.150 K, is chosen because the epoxy resin has a gel time of 14 to 17 minutes at this temperature. Temperatures below 353.150 K are not used because the Shrink Initiation Temperature is at 353.150 K. It is possible that the shrink tape process may work better with certain types of epoxy resins.

SEM result in Fig. 3 shows the density difference between shrink tape and compression molding, with the latter having more voids than vacuum compression molding.

5. 3. Determining the quality of a specimen based on its surface roughness

Surface roughness measurements are taken on each sample surface using 20 lines, with 10 in the direction of the fiber and 10 crossing it along 10 mm each sampling line. The result of the measurement is expressed as Ra, which represents the arithmetic average of the absolute values of deviations in profile height from the centerline. The molding process produces surfaces with almost equal flatness on both sides, whether in contact with the molding or the mandrel. For both vacuum compression molding and compression molding, the fiber roughness value of Ra is 0.35 µm and 0.37 µm, respectively. The transverse direction, both get the same result, which is 0.61 µm. When using shrink tape, the outer surface becomes relatively rough with Ra 0.58 µm in the fiber direction and 4.57 µm in the transverse fiber direction. In the cross direction of fiber. There is an upward trend every 3–4 mm, this is due to overlap that occurs in the winding process where overlap occurs every 4 mm. The roughness comparison of the three finishing processes can be viewed in Fig. 4 along the fiber direction and Fig. 5 across the fiber direction.

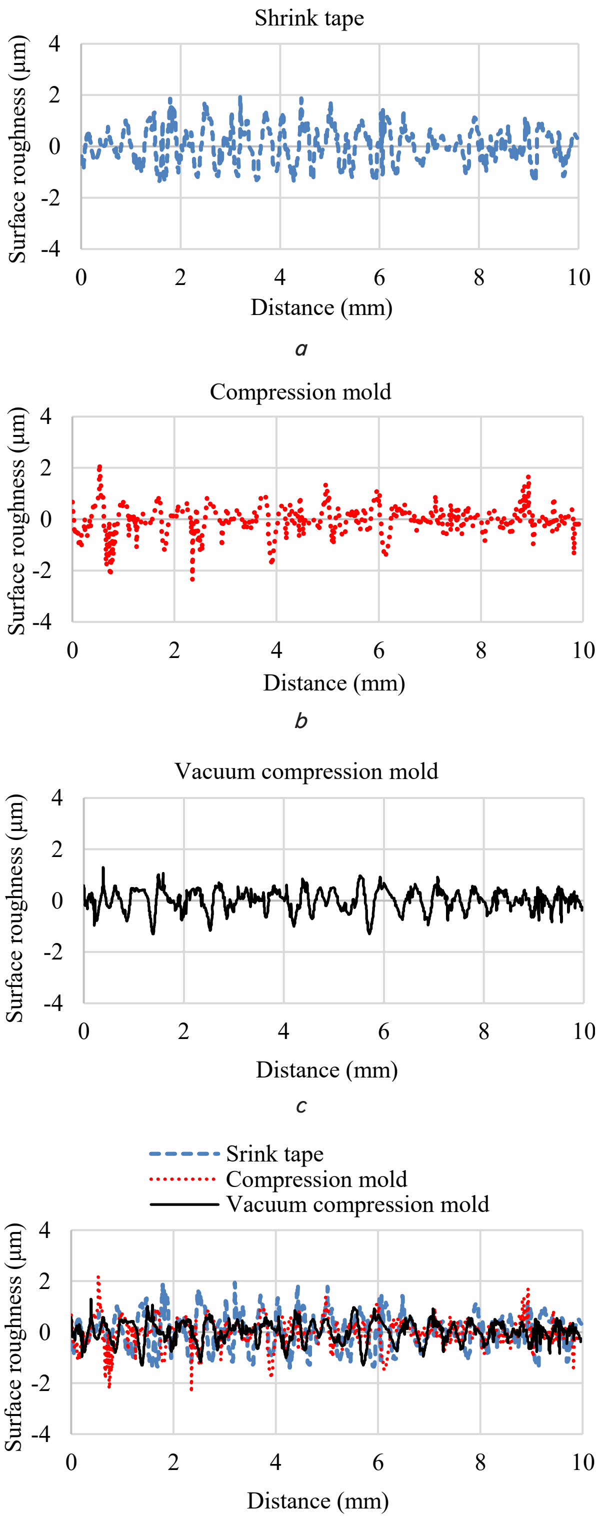


a

b

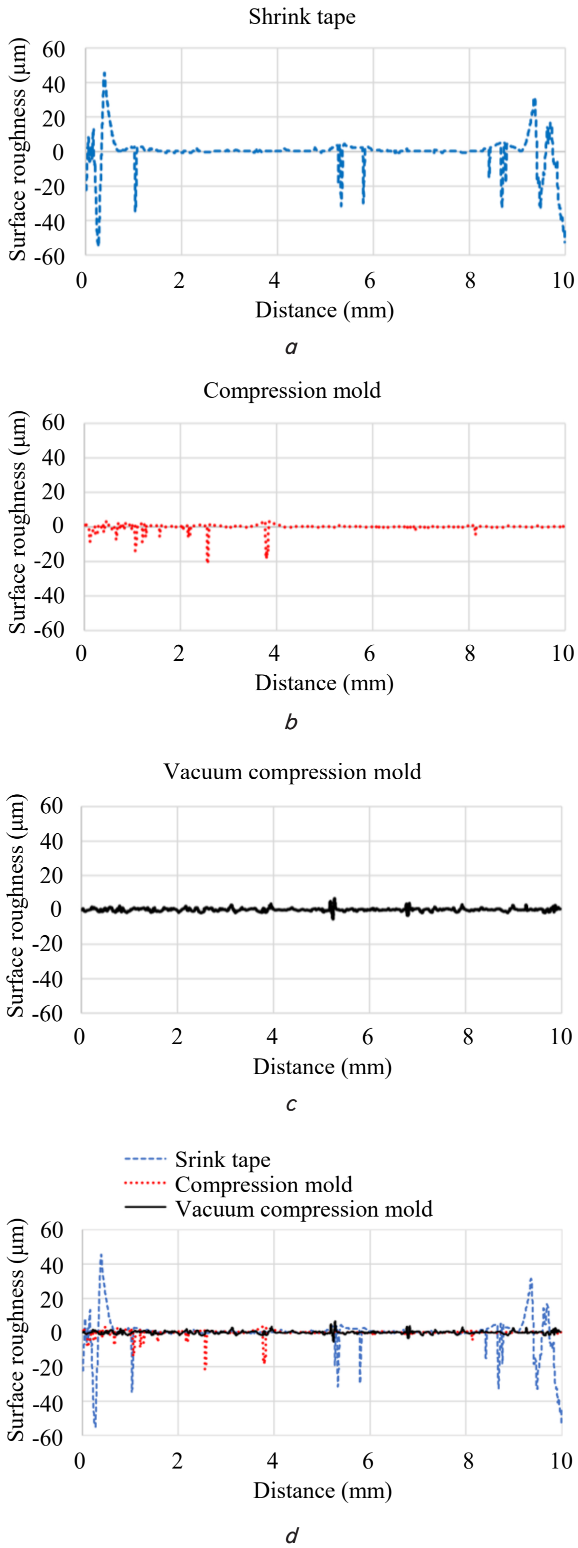
c

Fig. 3. Scanning Electron Microscopy Images of all specimens at magnification 750 X: *a* – shrink tape; *b* – compression mold; *c* – vacuum compression mold



a, *b*, *c*, *d*

Fig. 4. Roughness in fiber direction of variation finishing process: *a* – shrink tape; *b* – compression mold; *c* – vacuum compression mold; *d* – combination

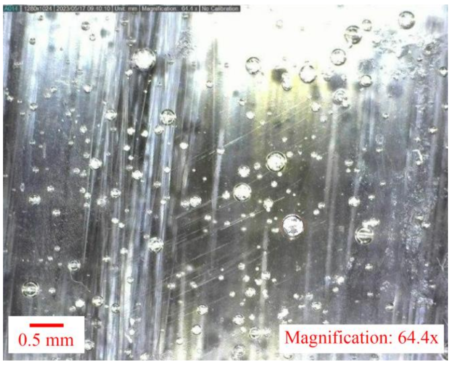


a, *b*, *c*, *d*

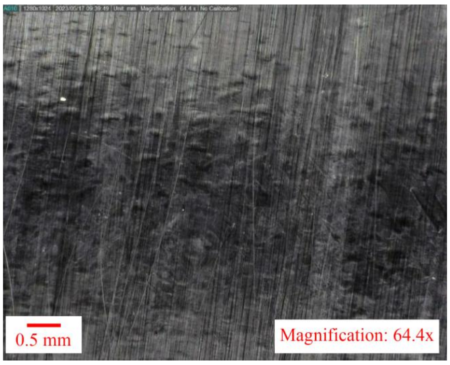
Fig. 5. Roughness in cross fiber direction of variation finishing process: *a* – shrink tape; *b* – compression mold; *c* – vacuum compression mold; *d* – combination

In order to ensure the quality of the final product, let's not only use the Kosaka Roughness and Contour Tester to measure roughness but also examine the outer surface of the specimen for any defects using a digital microscope. Fig. 6 shows some of the defects that can occur during the finishing process when using shrink tape.

Based on the observations, it has been determined that there are still defects in the form of bubbles on the surface, this can be seen in Fig. 6. It seems that the shrink tape finishing method has the worst surface roughness compared to other finishing methods, particularly on the outer surface.



a



b

Fig. 6. Outer surface magnification 64.4 X with Dino lite: *a* — shrink tape; *b* — vacuum compression moulding

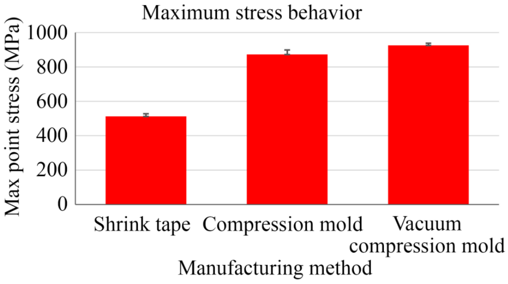
5. 4. Determine the perfection level of specimens in terms of tensile strength of carbon fiber reinforced polymers

Tensile strength testing is conducted after observing the specimen and measuring density, surface roughness, uniformity, and fiber fraction. The goal is to determine how to increase tensile strength by improving the quality of microstructure specimens. Tensile test as shown in Fig. 7 using the ASTM D3039.

Fig. 7. Perform a tensile test following ASTM D 3039 procedures

From testing all variations of the finishing process, the vacuum compression molding finishing process produced the greatest tensile strength, averaging 926.07 MPa and an elastic modulus of 21.35 GPa. On the other hand, using shrink tape only produced a tensile strength of 512.88 MPa and an elastic modulus of 12.61 GPa. The tensile specimens all had an acceptable failure mode, with the failure code being SAV, indicating long splitting, multiple areas, and various locations.

In Fig. 8, *a* significant comparison is shown between the finishing process of shrink tape and Vacuum Compression molding with respect to maximum stress and elastic modulus behavior.



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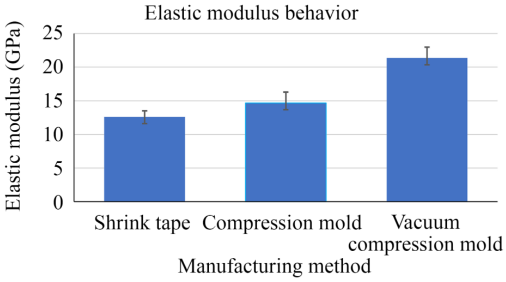

b

Fig. 8. Result of tensile test ASTM D3039: *a* — maximum stress; *b* — elastic modulus

The maximum stress in Fig. 8 may vary significantly due to surface flaws in the form of voids observed in Fig. 6, *a*. This is influenced by the low fiber fraction and the different methods used such as shrinking tape, compression molding, and vacuum compression mold. Furthermore, the use of vacuum also impacts the outcome, with only a 53.13 MPa difference observed between compression molding with and without vacuum. The results prove that the perfection of microstructural specimens has a significant impact on the strength of the material. This study also demonstrates that improving the finishing process after the wet winding process can lead to better perfection and improved mechanical properties of the specimen.

. Discussion of result of the study the finishing process impact on the quality of the specimen

The study discovered that the microstructure of CFRP composites can be affected by the finishing process carried out after the wet winding process. Table 1 shows that the Vacuum compression molding finishing process obtained the highest density value of 1364.49 kg/m^3 with the lowest standard deviation of 4,927, indicating that the material obtained using this finishing method is more uniform than the other two methods. The winding process is generally, at the end of the winding process, the structure is cured at room temperature or in an oven with a controlled heat profile depending on the type of resin used [25]. The resulting fiber fraction is evident in Fig. 3 where the results of fiber fraction with the shrink tape method get a value of 51 % fiber, Compression molding gets a result of 54 % Fiber and the process of Vacuum Compression molding reaches 63 %, calculated using ImageJ software. This is better than the filament winding process alone, achieving 52–55 % fiber volume [26].

The characteristics of surface roughness indicate the same thing as observations of microstructure. In Fig. 4, 5, *d*, the comparison of flatness levels can be seen, where the Vacuum Compression molding process has the best surface roughness level. This is also supported by Fig. 6, where the surface produced by the shrink tape method still has many defects in the form of bubbles with a radius of 0.144 mm, with a surface layer rich in matrix, in contrast to the vacuum finishing process method, which has a better surface. The level of surface roughness reaches N5 or is equivalent to CNC milling machines. This method can overcome the problem of obtaining surface roughness by machining, which can cause special surface damage [27]. Additionally, it proves that the weakness of the filament winding method, which is a bad external surface [12, 20], can be overcome by changing the finishing process after the wet winding process.

To determine the mechanical properties by reducing voids and uniformity of fiber composition with the matrix will certainly increase mechanical properties in this case tensile strength. This is clearly seen in Fig. 8 where the maximum stress achieved by Vacuum compression molding is higher reaching 926.07 MPa, very significant compared to the shrink tape method which only reaches 512.88 MPa. The distribution of stress on the fiber surface is also influenced by surface roughness [28] so this greatly affects the mechanical properties of CFRP.

This study had limitations as it only used a plate form with unidirectional fiber direction or hoop winding in the filament winding process. The overlap of fibers and the pattern of the expected object may be affected by fiber direction factors. Additionally, the study did not discuss the compatibility between the matrix and shrink tape used. Fig. 2 shows the properties of the shrink tape, which may result in poor outcomes if the specifications do not match the epoxy resin used. When the resin viscosity reaches 14–17 mPa s at 80 °C, it becomes challenging to flow, and the mechanical pressure from the shrink tape does not work correctly, leading to surface defects on the bubble tile. Compression molding produces a better surface finish. To fully understand the impact of the finishing process on the microstructure and mechanical properties of filament-wound composites, multiaxial and multifacial testing, along with environmental conditioning, should be conducted. Additionally, a reliable observation technique is necessary to determine the overall proportion of voids in the final specimen.

7. Conclusions

1. The vacuum compression molding finishing process produces the highest density and best homogeneity compared to other processes. On average, it produces a density of 1364.49 kg/m^3 with a standard deviation of 4.927.

2. The process of vacuum compression molding has resulted in a fiber volume fraction of 63 %, which is the highest compared to other finishing processes. This result is consistent with the density uniformity measurements. The density of the material is directly proportional to the fiber composition, with higher fiber composition resulting in higher density closer to 1800 kg/m^3, which is higher than the matrix density of 940 kg/m^3.

3. The vacuum compression molding finishing process can produce a surface roughness that is similar to milling, with a roughness level of N 5 or a roughness value of Ra of 0.35 μm. This finishing process is a solution to the issue of poor outer surface roughness that is often produced by the filament winding process. Although the finishing process using shrink tape produces a Ra value of 4.57 μm. This is because this process will also cause overlap between shrink tape which results in surface roughness in the gap produced by the overlap.

4. The method of finishing the manufacturing process through filament winding has a significant impact on tensile strength. In the case of the finishing process that uses shrink tape, the maximum stress obtained is 512.88 MPa. On the other hand, the process of vacuum compression molding yields a maximum stress of 926.07 MPa. This variation in stress levels can be attributed to factors such as the uniformity of the specimen, the fiber volume fraction, and the stress concentration resulting from differences in surface roughness.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has associated data in a data repository.

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Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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