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Analysis of Variation in Fiber Volume Fraction on Torsional Strength of Epoxy and Polyester Matrix Coconut Fiber Composites

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Abstract--*Natural fibers can be employed to enhance the strength and rigidity of composite structures. These fibers can be combined with matrix materials to create composite materials. One specific example of a natural fiber is coconut fiber. Unfortunately, coconut fiber is currently underutilized, leading to organic waste. However, coconut fiber offers several advantages as a substitute for automotive product composites despite facing specific technical challenges. Hence, it is important to understand the potential of coconut fiber composites with epoxy and polyester matrices. This study aimed to assess the capabilities of coconut fiber composites with epoxy and polyester matrices through a torsion test. The study involved conducting torsion tests on composites with varying volume fractions, precisely 25:75, 30:70, 35:65, and 40:60 (coconut fiber fraction to polyester/epoxy fraction). The research entailed creating torsion test specimens and performing the torsion tests. Subsequently, an analysis of the torsion test results was conducted. This research indicates that coconut fiber with an epoxy matrix demonstrated a maximum stress value of 31.27 MPa and a maximum shear strain value of 1.022 rad at a 30% volume fraction. Similarly, coconut fiber composite with a polyester matrix exhibited a maximum stress value of 27.83 MPa and a maximum shear strain value of 0.91 at a 30% volume fraction. Based on these outcomes, it can be concluded that the optimal volume fraction of coconut fiber for producing satisfactory specimens is 30%, regardless of whether the composites have epoxy or polyester matrices.*

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1. INTRODUCTION

Composite materials can be made with natural or synthetic fibers [1]. Natural and synthetic fibers are two types of fibers that differ in their sources, physical properties, and applications [2]. Natural fibers are fibers from natural sources, such as plants or animals. Examples of natural fibers include cotton fiber, hemp fiber, jute fiber, sisal fiber, and coconut fiber. Natural fibers have properties such as good strength, are lightweight, biodegradable, and are easy to decompose, so they are often used in products that require environmentally friendly materials.
Meanwhile, synthetic fibers are fibers made through manufactured manufacturing processes. Synthetic fibers include polyester fiber, nylon fiber, rayon fiber, and olefin fiber. Synthetic fibers are durable, strong, resistant to moisture and resistant to corrosion, so they are often used in products that require high resilience and durability, such as textiles, packaging materials, automotive products, and industrial products.

Natural fibers can be used as composite materials to increase the strength and stiffness of composite structures [3]. Natural fibers have good mechanical properties and are lightweight, so natural fibers are often used in the automotive, aerospace, and construction industries [4]. Natural fibers often used as composite materials include jute fiber, jute fiber, sisal fiber, and coconut fiber. These natural fibers can be mixed with matrix materials such as polymer resin or clay to form composite materials [5]. This research will use coconut fiber mixed with epoxy and polyester to form an environmentally friendly composite material.

One of the tests that can be used to determine the capability of the composite is the torsion test [6]. From the torsion test results, several important parameters about the material's mechanical properties will be obtained, such as torsional elastic modulus, torsional strength, deformation angle, and coefficient of friction [7]. Torsion tests will be conducted on composite specimens molded with a cylinder-like structure [8]. Tests will be conducted on three different composite volume fractions. It aims to determine the most optimal volume fraction of composite mixture to use [9]. Marpaung et al. [10], in their research on the analysis of mechanical properties of coconut fiber composites, obtained results showing that the best mechanical properties were obtained in composites consisting of 30% fiber and 70% polyester resin. Based on this information, the research for this torsion test will be carried out on composites with three volume fractions contained in the range, including 0:100, 25:75, 30:70, 35:65, 40:60 (coconut fiber fraction: polyester fraction and coconut fiber fraction: epoxy fraction).

2. METHODOLOGY

2.1 Research Flow Chart

The research flow chart shows the research steps carried out from the beginning to the end of the research. The research flow chart can be seen in Figure 1.

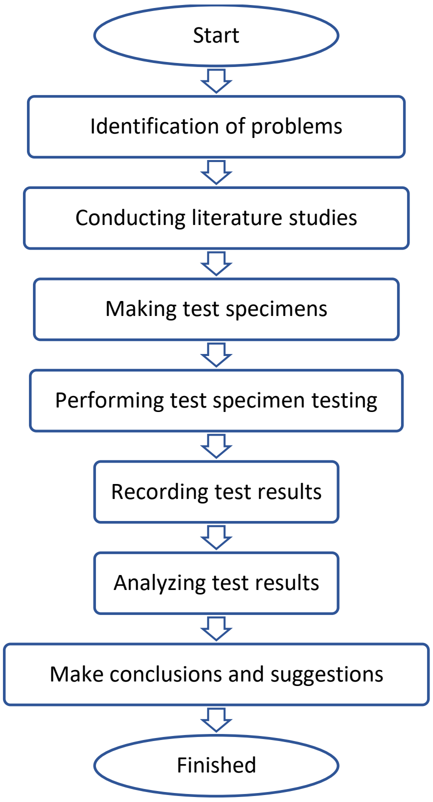

Figure 1. Research Flow Chart

2.2 Tools and Materials

The tools used in this research are:

1. Digital scales
2. Torsion test equipment
3. Specimen mold
4. Sandpaper
5. Scissors
6. Measuring cup
7. Comb
8. Vernier Caliper

The materials used in this study are:

1. Coconut fiber

2. Hardener
3. Polyester
4. Epoxy

2.3 Volume Fraction Variation

This study will use five variations of fiber volume fraction for each composite, including fiber volume fraction of 0%, 25%, 30%, 35%, and 40%. The volume fraction can be seen in Table 1.

Table 1. Volume Fraction Variation

Fiber: Matrix
0: 100
25: 75
30: 70
35: 65
40: 60

2.4 Specimen Making Flow Chart

The specimen manufacturing flow chart in Figure 2 shows the steps of making specimens, from preparing raw materials to producing them.

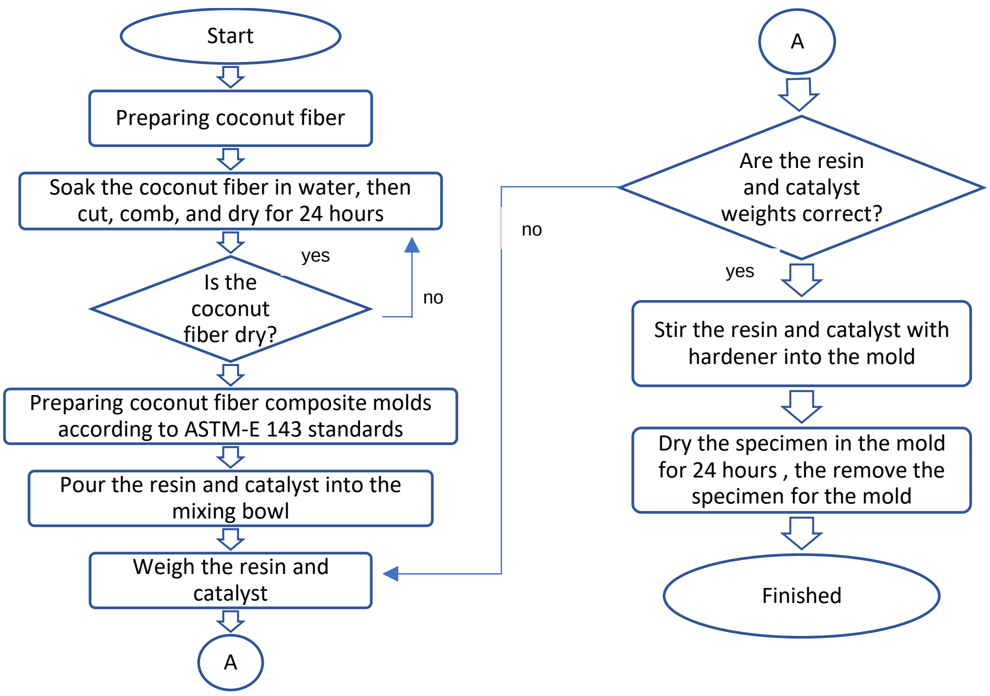

Figure 2. Specimen Making Flowchart

2.4 Specimen Testing Flow Chart

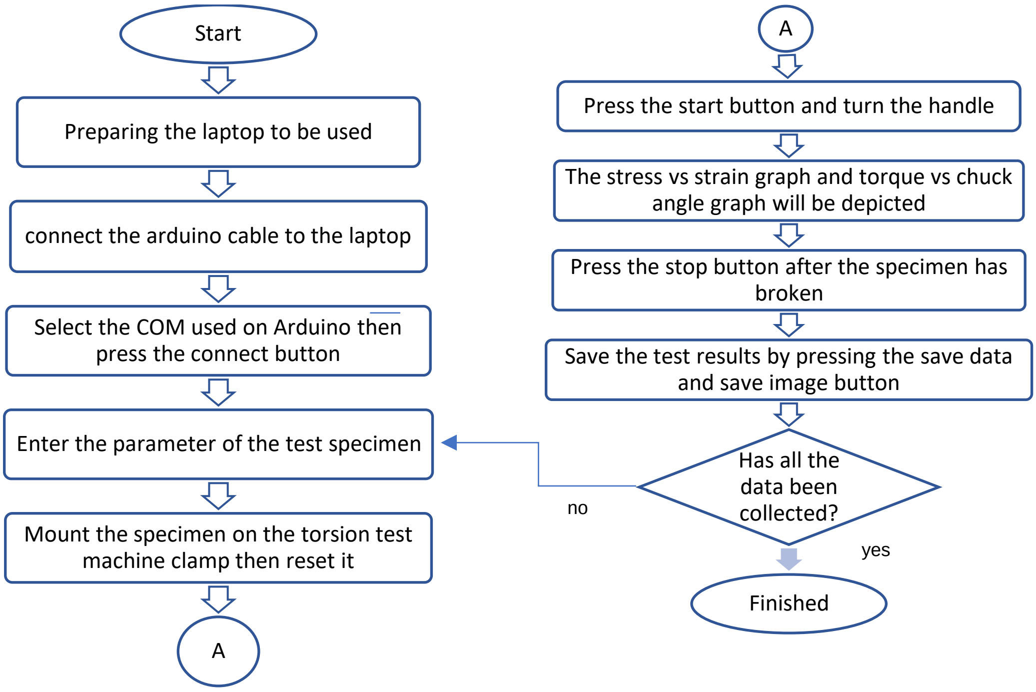

Figure 3. Specimen Testing Flow Chart

3. RESULT AND DISCUSSION

3.1. Maximum Shear Stress and Maximum Shear Strain of Coconut Fiber Composites with Epoxy Matrix

Table 2 shows the maximum stress and maximum strain obtained from coconut fiber composites with epoxy matrix at five different volume fractions.

Table 2. Maximum Shear Stress and Maximum Shear Strain of Composites

Fiber Content Percentage (%)	Maximum Shear Stress (MPa)	Maximum Shear Strain
0	4.15	0.14
25	28.14	0.92
30	31.27	1.02
35	30.12	0.98
40	26.68	0.87

3.2. Maximum Stress and Maximum Strain of Coconut Fiber Composite with Polyester Matrix

Table 3 shows the maximum shear stress and maximum shear strain obtained from coconut fiber composites with polyester matrix at five different volume fractions.

Table 3. Maximum Shear Stress and Maximum Shear Strain of Composites

Fiber Content Percentage (%)	Maximum Shear Stress (MPa)	Maximum Shear Strain
0	2.35	0.08
25	24.38	0.80
30	27.83	0.91
35	26.17	0.86
40	22.33	0.73

3.3. Regression Equation of Coconut Fiber Volume Fraction Relationship to Maximum Stress of Epoxy Matrix

The regression equation for the relationship of coconut fiber volume fraction to maximum stress for the epoxy matrix is $y = -0.0011x^3 + 0.0474x^2 + 0.4988x + 4.1434$. The highest maximum shear stress was obtained at a 30% volume fraction. The lowest maximum stress was obtained at 0% volume fraction. The value of $R^2 = 0.9992$ indicates that the volume fraction significantly impacts the maximum stress of the composite with epoxy matrix. The regression graph can be seen in Figure 4 below.

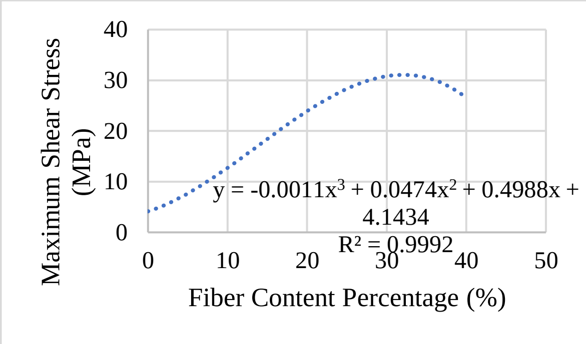

Figure 4. Regression of the Relation of Percentage of Coconut Fiber Content to Maximum Shear Stress of Epoxy Matrix

3.4. Regression Equation of Coconut Fiber Volume Fraction Relationship to Maximum Stress of Polyester Matrix

The regression equation for the relationship between coconut fiber volume fraction and maximum stress for the polyester matrix is $y =—0.0014x^3 + 0.063x^2 + 0.176x + 2.3421$. The highest maximum stress was obtained at 30% volume fraction, and the lowest was obtained at 0% volume fraction. The value of $R^2 = 0.9982$ indicates that the volume fraction greatly impacts the maximum stress of the composite with polyester matrix. The regression graph can be seen in Figure 5 below.

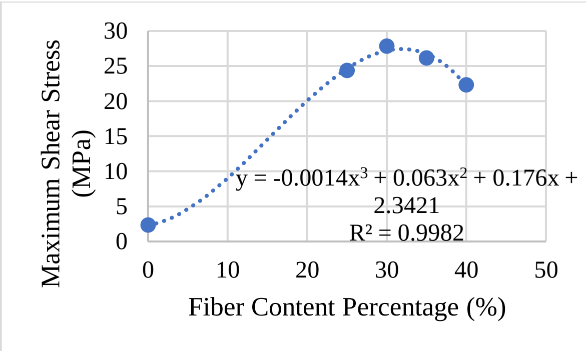

Figure 5. Regression Relationship of Coconut Fiber Volume Fraction to Maximum Shear Stress of Polyester Matrix

3.5. Regression Equation of Coconut Fiber Volume Fraction Relationship to Maximum Shear Strain of Epoxy Matrix

The regression equation of the relationship between coconut fiber volume fraction and maximum shear strain for the epoxy matrix is $y = -0.00004+ 0.0016x^2 + 0.0163x + 0.1355$. The highest maximum shear strain was obtained at a 30% volume fraction. The lowest maximum shear strain was obtained at 0% volume fraction. The value of $R^2 = 0.9992$ indicates that the volume fraction significantly impacts the maximum shear strain of the composite with epoxy matrix. The regression graph can be seen in Figure 6 below.
x^3

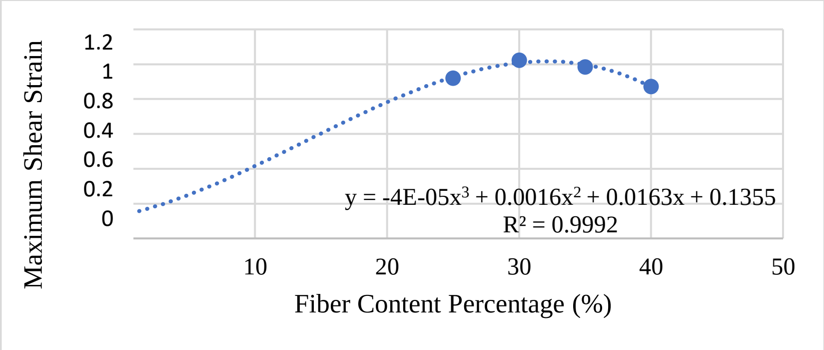

Figure 6: Regression of Coconut Fiber Volume Fraction Relationship to Maximum Shear Strain of Epoxy Matrix

3.6. Regression Equation of Coconut Fiber Volume Fraction Relationship to Maximum Shear Strain of Polyester Matrix

The regression equation of the relationship between coconut fiber volume fraction and maximum shear strain for the polyester matrix is $y = -0.00004x^3 + 0.0021x^2 + 0.0058x + 0.0766$. The highest maximum shear strain was obtained at a 30% volume fraction. The lowest maximum shear strain was obtained at 0% volume fraction. The value of $R^2 = 0.9982$ indicates that the volume fraction significantly impacts the maximum shear strain of the composite with polyester matrix. The regression graph can be seen in Figure 7 below.

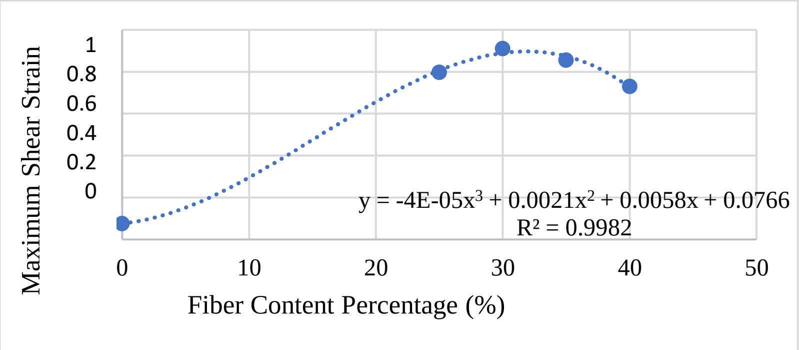

Figure 7. Regression Relationship of Coconut Fiber Volume Fraction on Maximum Shear Strain of Polyester Matrix

4. SUMMARY

The variation of coconut fiber volume fraction significantly affects the torsional strength of epoxy and polyester matrix coconut fiber composites. The coconut fiber composite with epoxy matrix produced a maximum stress value of 31.27 MPa and a maximum shear strain value of 1.022 rad at a volume fraction of 30%. Both values also get an R square value of 0.9992, which indicates that the volume fraction has a strong effect on the maximum stress value of the composite. The coconut fiber composite with polyester matrix produced a maximum stress value of 27.83 MPa and a maximum shear strain value of 0.91 at a volume fraction of 30%. Both values also get an R square value of 0.9982, indicating that the volume fraction strongly affects the maximum stress value of the composite. From the above results, it can be concluded that the optimal coconut fiber volume fraction to use to produce good specimens is 30%, both for composites with epoxy or polyester matrices. In the future, it is necessary to conduct further research for composite torsion tests with different coconut fiber volume fractions from this study to determine the most optimal volume fraction to make strong composites.

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