Analysis of The Number of Layers and Types of Carbon Fiber Against Tensile Strength, Compressing Strength and Shock Load of Bicycle Frame

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Abstract. The need for bicycle transportation with strength and aesthetics as well as light weight is increasing, so it is necessary to innovate material technology to overcome these needs. The main components of a bicycle are the frame, wheels, handlebar, and pedals. In addition to the safety factor, what needs to be considered is the weight of the bicycle. Bicycle frame materials are generally made of steel and aluminium. To reduce the weight of the bicycle, the frame material is replaced by using carbon fibre material so that the bicycle becomes lighter and makes the rider less tired. The purpose of the study was to determine the number of layers, fibre direction and the type of carbon and Hybrid (carbon and hemp) used as bicycle frames. Using carbon fibre with plain (P), twill (T), and jacquard (J) types, with the number of layers every three layers and five layers (P3, P5, PH3, PH5, T3, T5, TH3, TH5, J3, J5, JH3, JH5), the tensile test was carried out using the BSEN 10002 standard, the compression test with the ASTM D695 standard and the impact test with the Charpy method using the ASTM E23 standard. Compression and tensile testing using a Taernogroki machine. The test results show that there is an effect of the type of carbon fibre and coating on the stress obtained from the tensile, compressive and impact tests, which show that Twill type carbon fibre is the strongest with stress of 540.60 kg/mm2, 525 kg/mm2 and 0.0157 N/ mm2, while the strongest layer type is pure carbon fibre layer type, and for the number of layers the strongest is five layers.

Keywords: number of layers, fibre type, carbon, hemp, shock load, compressive strength, tensile strength, bicycle frame

1 Introduction

The need for transportation is also increasing, one of which is bicycle transportation. Bicycles have been around since the 19th century until now. At first, the bicycle had a simple form, and its use was limited. Since the 19th century until now, bicycles have undergone a transformation in terms of design, materials, and accessories, which are adapted to human needs. A bicycle is a vehicle that does not require power from a

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fueled engine, so to move a bicycle using mechanical power generated by humans, namely by pedalling a bicycle. In addition, bicycles are also environmentally friendly because bicycles do not produce pollution in the form of gases, especially CO2 and NOx compounds that are harmful to the environment. At this time, the manufacture of bicycles was mostly made of metal. The majority of bicycles are made of stainless steel, alloy, and Chromoly. Apart from metal, currently, bicycles have been developed made with carbon fibre materials. Bicycles made of carbon fibre have a lighter weight than bicycles made of metal. Bicycles made of carbon fibre can be formed in various shapes that can be adjusted according to the needs of bicycle users.

The main components of a bicycle are the frame, wheels, handlebar, and pedals. The frame is the main part where the wheels, pedals, handlebars and other accessories are attached. The frame also functions as a support for the load of the rider, so when designing, the safety factor must be considered. In addition to the safety factor, what needs to be considered is the weight of the bicycle. Bicycle frame materials are generally made of steel and aluminium. To reduce the weight of the bicycle, the frame material is replaced by using carbon fibre material so that the bicycle becomes lighter and makes the rider less tired. So carbon fibre is often used for projects with high pressure. Therefore the number of layers affects the strength of the components made of carbon fibre.

Previously, many studies related to bicycle frames had been carried out, [1], [2] carried out design optimization for an Aluminum Bike Frame. The research was conducted to optimize frame materials, heat treatment, and geometries with the aim of increasing fatigue life. [3], [4] conducted on fibre direction and stacking sequence design for bicycle frames made of carbon/epoxy composite laminate. The research conducted was to compare variations in fibre direction and arrangement of carbon layers on bicycle frames using ANSYS software. The tests used are torsional loading, frontal loading, and vertical loading. Data from the results of the tests carried out were analyzed using the theory of maximum stress. The material used is carbon fibre type T300, which has a tensile modulus of 230 GPa, and the number of layers making up eight symmetrical layers with variations in the combination of fibre directions 0o,45o,90o, and -45o. The conclusions obtained from the research are better design and bad design.

Therefore, it is necessary to conduct experimental research on the number of layers, fibre direction and type of carbon twill, plain, and jacquard with variations of Hybrid fibre (a combination of carbon and hemp), which is used as a bicycle frame.

2 Literature Review

[5] investigated the effect of laminated composite laminate with e-glass fibre and carbon fibre reinforcement on tensile strength with a polyester matrix. The problem discussed in this research is to determine the properties of the laminated composite material reinforced with e-glass fibre and carbon fibre with a polyester matrix. In this study, there were four variations, namely three layers of a random type of e-glass

fibre, three layers of e-glass fibre with Woven Roving (WR) type, three layers of carbon fibre, and three layers of Hybrid. The results of research conducted by the tensile test can be concluded that the carbon fibre layer has the highest strength with a value of 256.99 MPa, then followed by e-glass fibre with WR type with a value of 198.25 MPa, Hybrid layer 196.30 MPa, while the random type of e-glass fibre is the weakest among the other test materials with a value of 115.01 MPa.

[6], [7] analyzed the Analysis of Road Bike Strength with Variations in Fiber Direction, Number of Layers and Types of Material in testing the bicycle frame design with static loading, namely torsional loading, frontal loading, and vertical loading. The type of carbon fibre used in AS4 and T800 with the number of layers of 6 and 8 layers, the variation being done is with the direction of the carbon fibre, namely 0 o, 45 o, 90 o, and -45 o. The results obtained from this study are that the best carbon fibre direction is on AS4 with a number of layers of 8 layers with an angle of 0/90/90/0. While the best bicycle frame design on T800 carbon fibre with a combination of 0/45/-45 direction.

CARBON FIBER

Carbon fibre was introduced in 1960, which is made from organic fibres that are made from acrylic, rayom, or made from residual petroleum. Carbon fibre is the strongest reinforcement for most polymer composites after glass fibre. Carbon fibre is very expensive and can cause galvanic corrosion when in contact with metals [8].

[9], [10] conducted research to optimize frame material, heat treatment, and geometry with the aim of increasing fatigue life. For frame strength analysis, the author uses two types of analysis, namely physical analysis and analysis using software based on the finite element method (FEA). The test standard used is ASTM F2711-08 for horizontal loading. Fatigue test data using FEA on an initial design bicycle with aluminium 6061-T6 material is 490,000 cycles, and on a physical test, 449,000 cycles, so the difference between the FEA method and the physical test is 8.4%. The data generated from physical analysis and using FEA for fatigue analysis are almost the same.

Based on the data obtained from the test results, researchers want a longer cycle life. It is necessary to optimize geometry, heat treatment, and change materials. Because the difference between physical test data and FEA is not too far away, the researcher optimizes using FEA the reason is that it can change the geometry easily and save more costs and time. The material used to replace the previous material is aluminium 6013-T6.

[11] conducted research on Fiber direction and stacking sequence design for bicycle frames made of carbon/epoxy composite laminate. The research conducted is to discuss the direction of the fibre and the arrangement of layers on a bicycle frame using carbon/epoxy composite materials according to the theory of maximum stress. The test method used for testing the bicycle frame is torsional, frontal, and vertical loading. From the analysis using the FEA method, the results of the good composite layer design are [0/90/90/0]s and [0/90/45/-45]s, while the poor composite layer arrangement is [0/0/0 /0]s, [90/90/90/90]s, [45/45/45/45]s and [-45/-45/- 45/-45]s. Areas that are prone to failure are located in the fillets and joints due to stress concentrations. A layer of carbon fibre with fibre directions 0o and 90o which is placed on the inner and outer, can effectively inhibit the high stress that occurs in that area.

2.1 Hemp Fiber

Hemp fibre is a natural fibre that comes from the hemp plant. The hemp plant is an annual plant shaped like grass. This plant is easy to grow in the tropics, especially in Indonesia. This plant is also resistant to diseases and pests. This plant has advantages over other fibres. Flax fibre is stronger in a pull, water absorption, humidity, heat resistance, and resistance to bacteria. Hemp fibre has a tensile strength of 938Mpa and a Young modulus of 128Gpa [12].

3 Material and Method

Using carbon fibre with plain (P), twill (T), and jacquard (J) types, with three layers and five layers, respectively. In the tensile test, compressive test and impact test, there are two types to be tested, first the carbon layer only and the hybrid layer (H) between carbon and hemp fibre, with research variations (P3, P5, PH3, PH5, T3, T5, TH3, TH5, J3, J5, JH3, JH5). The compression and tensile tests were carried out using a Taernogroki machine with the ASTM D695 compression test standard, with standard dimensions (see Fig. 1). For the tensile test using standard BSEN 10002, with the size of the specimen (see Fig. 2), the impact test is carried out using a hammer test with the Charpy method using the ASTM E23 standard, as shown in Fig. 3.

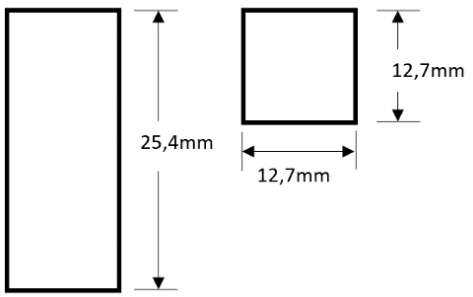

Fig. 1. Compressive test specimen with Standard ASTM D695[13]

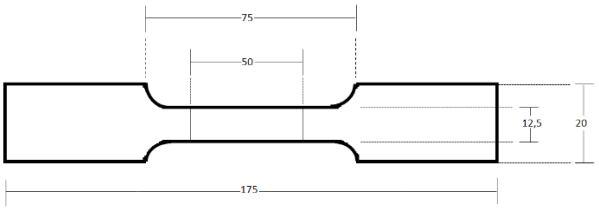

Fig. 2. Tensile test specimen with Standard BS EN 10002[14]

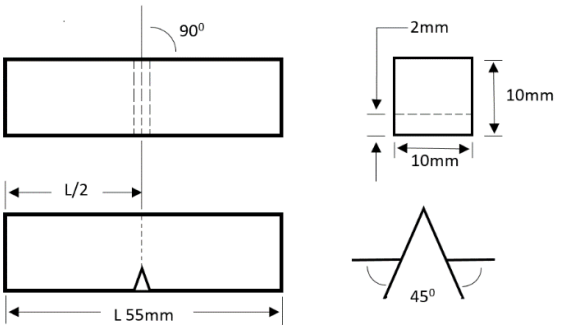

Fig. 3. Impact test specimen with Standard ASTM E23.[15]

4 Results and Discussion

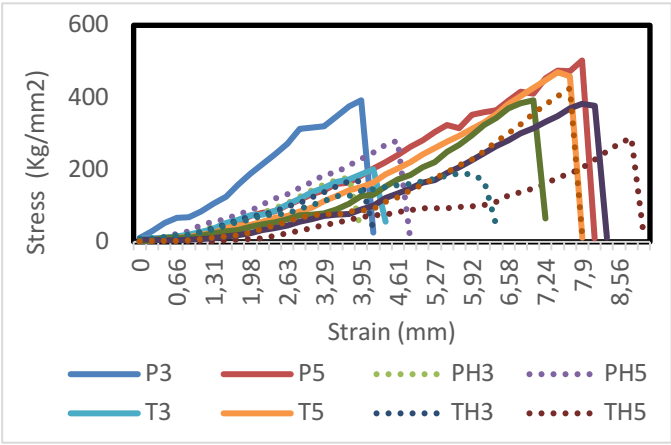

Fig. 4. Tensile test results on variations in the number of layers and types of carbon fibre.

Fig. 4 shows that the strongest carbon fibre is Twill fibre, while the strongest layer type is pure carbon fibre, and the number of layers of the strongest is five layers. The relationship between carbon fibre and coating type shows that twill carbon fibre in pure carbon coating type is stronger than others. In contrast, the relationship between the type of carbon fibre and the number of layers shows that the carbon fibre twill with the number of layers of 5 layers is the strongest among the others. And the relationship between the type of layer and the number of layers shows that the type of pure layer with five layers is the strongest among the others. The type of hybrid layer with the number of layers of three layers shows that the combination is the weakest. In contrast, the type of pure carbon layer with five layers shows that the alloy is the strongest.

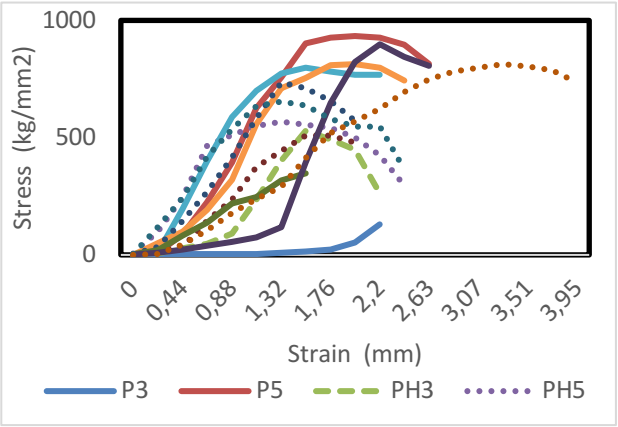

Fig. 5. Compressive test results on variations in the number of layers and types of carbon fibre.

Fig. 5 shows that the strongest carbon fibre is Twill fibre, while the strongest layer type is pure carbon fibre, and the number of layers of the strongest is five layers. This shows that the relationship between carbon fibre and coating type indicates that the twill carbon fibre in the pure carbon layer type is stronger than the others. In contrast, the relationship between the type of carbon fibre and the number of layers shows that the jacquard carbon fibre with the number of layers of 5 layers is the strongest among the others. And the relationship between the type of layer and the number of layers showed that the pure layer type with five layers was the strongest among the others. Composites with a hybrid layer type with three layers showed that the combination was the weakest. In contrast, the type of pure carbon layer with five layers shows that the alloy is the strongest.

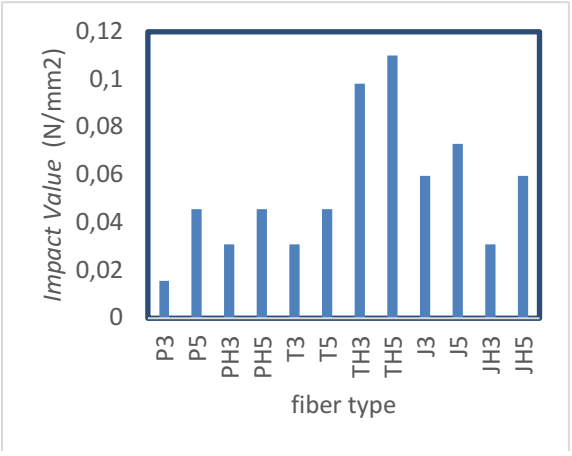

Fig. 6. Impact test results on variations in the number of layers and types of carbon fibre.

Fig. 6 shows that the strongest carbon fibre is Twill fibre, while the strongest layer type is hybrid carbon fibre, and the number of layers of the strongest is five layers. This shows that the relationship between carbon fibre and coating type indicates that the twill carbon fibre in the pure carbon layer type is stronger than the others. In contrast, the relationship between the type of carbon fibre and the number of layers shows that the jacquard carbon fibre with the number of layers of 5 layers is the strongest among the others. While the relationship between the type of layer and the number of layers shows that the pure layer type with five layers is the strongest among the others. Based on the results of the study, it was shown that the type of hybrid layer with the number of layers of three layers showed the combination was the weakest. In contrast, the type of hybrid layer with five layers shows that the combination is the strongest.

5 Conclusion

Based on the results of the study, it can be concluded as follows.

1. The effect of the type of carbon fibre and coating on the stress got from the tensile test shows that the Twill type carbon fibre is the strongest with a tension of 540.60 kg/mm2, while the strongest layer type is the pure carbon fibre layer type, and for the amount of The strongest layer is five layers.
2. The effect of the type of carbon fibre and coating on the stress got from the compression test shows that the Twill type carbon fibre is the strongest with a tension of 525 kg/mm2, while the strongest layer type is the pure carbon fibre layer type, and for the number of layers the strongest is five layers.
3. The effect of the type of carbon fibre and coating on the stress obtained from the impact test shows that the Twill type carbon fibre is the strongest with a tension of 0.0157 N/mm2, while the strongest layer type is the hybrid layer type with a combination of carbon fibre and hemp fibre, and for the number of layers the strongest is five layers.

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