DEVELOPMENT OF BAMBOO COMPOSITES FOR WIND TURBINE BLADE APPLICATIONS

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Abstract. Wind turbine is one of the electricity generation devices that utilizes wind energy as the driving force, typically through its wind turbine blades. Currently wind turbine blades often use composite materials made from synthetic materials, which can be relatively expensive. The objective of this research is to transform synthetic composite materials into natural fiber composites that are relatively inexpensive and environmentally friendly. This is achieved by conducting testing on black bamboo fiber composites to determine their strength values using different resin ratios. This testing utilizes tensile testing with ASTM D3039 and ASTM D638 standards. The manufacturing of wind turbine blades is carried out by creating a mold, followed by forming them according to the SG6042 standard. Subsequently, a coating process is applied to ensure the evenness of the blade's surface using epoxy resin. The tensile testing results show that the highest tensile strength was achieved with the 3:9 ratio, both using ASTM D3039 and ASTM D638 standards. The tensile strength values were 7.50 MPa with a 3.2% increase for ASTM D3039 and 10.76 MPa with a 4.92% increase for ASTM D638. This research shows that wind turbine blades can be made from bamboo fiber composite.

***Keywords**: black bamboo, resin, composite, tensile test, wind turbine blades.*

I. INTRODUCTION

The rapid growth of the population has led to an increase in fuel consumption. In contrast, it is inversely proportional to the diminishing availability of crude oil due to its continuous usage. Current oil production relies on non-renewable energy sources such as fossil fuels, coal, and petroleum. The energy resources have a very long replacement time once they have been used. Therefore, to meet the demands of this fuel energy, a transition from non-renewable energy to environmentally friendly renewable energy sources that can be used sustainably is necessary.

Wind energy is an abundant renewable energy source in nature. Wind does not produce carbon dioxide therefore, it does not contribute to air pollution. With the presence of wind as an environmentally friendly energy generation medium to maximize the available energy, wind turbines meeting appropriate standards will be a specific consideration.

The turbine blades are a component of the windmill that serves to convert kinetic energy into electrical energy by utilizing the shaft of the generator. The blowing wind causes the turbine to move [1]. Wind turbine blades nowadays often utilize composites made from synthetic reinforcement materials, which come with a relatively high price range. This issue can be addressed by altering the composite mixture from synthetic composites to natural composites. Natural composites involve combining materials that use natural fibers as reinforcement. This issue can be overcome by changing the composition of synthetic composites into natural composite mixtures. Natural composites are a combination of materials that utilize natural fibers as reinforcements. The advantages of natural composites are their relatively low cost, environmental friendliness, and adaptability to the desired materials for application.

Bamboo is a potential substitute raw material with the greatest potential, as this plant grows the fastest and is widely found in tropical and subtropical regions [2]. Due to its relatively easy cultivation and maintenance processes, bamboo fibers are widely used for housing construction, textiles, paper pulp, and composites [3]. Indonesia has various types of bamboo spread across different regions, both in the wild and cultivated through plantations. Two types of bamboo that are widely grown in Indonesia are "bambu betung" (Dendrocalamus asper) and "bambu hitam" (Gigantochloa atroviolacea).

In a previous study conducted by Kosjoko [4], research was carried out using a bamboo immersion method with NaOH, which had an impact on tensile strength. Tensile testing using ASTM D3039 standards resulted in a highest tensile strength value of 42 MPa and a lowest value of 32 MPa. The use of NaOH during the bamboo immersion process has an impact on the test results.

Abdul Kadir and his colleagues, as mentioned in [5], conducted an analysis of the influence of weaving patterns in bamboo composite materials through tensile testing. Tensile testing using ASTM D638 standards resulted in a highest tensile strength value of 20.23 MPa and a lowest value of 3.45 MPa. The tensile testing results are greatly influenced by the weaving pattern of bamboo fibers.

Febri Anggih Setiawan [6] conducted ASTM D3039 tensile testing and the process involved the addition of montmorillonite, which led to an improvement in the mechanical strength of bamboo composites. Tensile testing using ASTM D3039 standards resulted in the highest tensile strength of 25.85 MPa and the lowest of 5.77 MPa.

Sofyan Djamil and his colleagues, as mentioned in [7], conducted an analysis of the bamboo immersion process using NaOH, which was then formed into twill and plain weaves. Subsequently, they performed tensile tests using ASTM D3039 standards, resulting in a highest tensile strength of 35.15 MPa and a lowest of 25.53 MPa. The formation of bamboo fibers into twill and plain weaves resulted in differences in the test results during tensile testing.

Yulianto [8] conducted an analysis of the influence of mesh size on the mechanical properties of bamboo fiber composites through tensile testing using ASTM D638 standards. The highest strength value was obtained with mesh 40, which was 17.4 MPa, while the lowest was with mesh 20, which was 9.71 MPa. In the process of bamboo composite manufacturing, the use of mesh size significantly influences the mechanical properties obtained from tensile testing.

Mochamad Fauzan and his colleagues, as mentioned in [9], conducted an analysis of the characteristics of HDPE (High Density Polyethylene) composite reinforced with bamboo fibers through tensile testing using ASTM D3039 standards. The highest tensile strength value obtained was 9.70 MPa, while the lowest was 4.85 MPa. The use of a composite mixture of HDPE with bamboo fibers in multiple layers does affect the tensile strength values.

Based on the background, composites made from black bamboo have advantages such as dimensional stability, longevity, low maintenance, and environmental friendliness [10]. Therefore, this research attempts to utilize black bamboo fiber material as reinforcement in natural composites to create wind turbine blades. Subsequently, the bamboo composite will undergo testing through tensile strength tests following ASTM D3039 and ASTM D638 standards to obtain its strength values.

In the application process of creating black bamboo composite for wind turbine blades, the SG6042 blade standard will be employed. Using the composite mold manufacturing process, the composite is then shaped according to the SG6042 wind turbine blade standard. The SG6042 wind turbine blade has a maximum thickness of 10% at chord 33.5% and a maximum camber of 3.3% at chord 51.5% [11]. The selection of horizontally shaped blades is due to their favorable safety and structural strength factors for the maximum wind speeds present in Indonesia. The advantage of this blade type is its ability to capture wind energy more effectively due to its elevated position, enabling it to extract a greater amount of wind energy. This results in higher efficiency [12].

II. MATERIAL AND METHOD

A composite is a combination of two or more constituent materials that are merged into one, resulting in material characteristics distinct from its component materials. The characteristic properties of composite materials have advantages over the properties possessed by their original materials [13]. This is because the amount of the mixing component is relatively small (<5%), as composite materials typically consist of two parts: the matrix, which bears the forces in the material, and the fiber reinforcement.

Fibers are a type of material consisting of individual pieces with a lightweight and elongated shape that retains its form as is [14]. The primary requirement of fibers is that they need to be strong, rigid, and brittle to withstand external forces; hence, fibers must possess strength and rigidity. Strength in fibers lies in their small size, which allows them to eliminate crystal defects and imperfections found in larger solids. This makes fibers resemble defect-free single crystals but with high strength. Based on the classification of fiber sources for reinforcement in natural fiber composites, they are grouped into three categories: animal fibers, plant fibers, and mineral fibers [15].

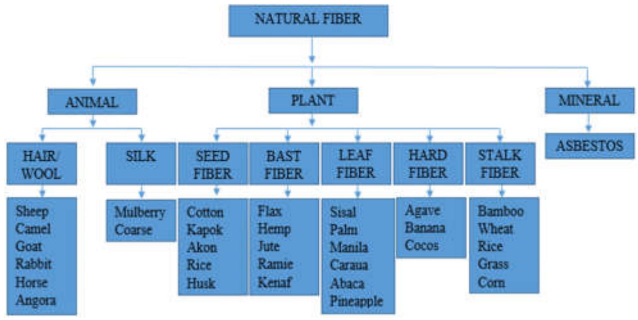

Fig. 1 Classification of Natural Fiber Sources [15].

SHCP (Singapore Highpolymer Chemical Product) resin is one type of polyester resin characterized by its non-thixotropic nature and clear appearance. SHCP 2668 exhibits good fiber wetting during mixing and a strong transparency effect in the final product. The characteristics of SHCP 2668 include a clear appearance, viscosity at 30°C for 6 to 9 seconds, an accelerator (6% cobalt) of 0.5%, gel time of 8 to 12 minutes, curing time of 20 to 40 minutes, and an exothermic peak of 130 to 140°C [16].

The utilization of bamboo fibers reinforced with Fiber Reinforced Composite (FRC) yields substantial strength and stiffness, which significantly impact their performance during application. Unlike other types of natural fibers, bamboo exhibits a higher specific strength and lower density, resulting in increased strength and stiffness [17]. Bamboo possesses distinct and varying mechanical properties across its different types. Black bamboo or wulung bamboo is one of them. Wulung bamboo (Gigantochloa atroviolacea) has a green hue when mature but as it dries its stem changes to a dark black color. The utilization of bamboo as a reinforcement material in composite materials requires a preliminary process, namely the extraction method.

The Hand lay-up method is one of the techniques for composite fabrication. This method involves pouring resin into woven fiber, then applying pressure and smoothing it with a roller [18]. The desired thickness is achieved by repeating the procedure multiple times. The advantage of using this method is that it is not difficult to execute, both for large components and small volumes.

In the process of manufacturing these composite test specimens, there are various testing standards for the dimensions of tensile test specimens, using the ASTM D3039 and ASTM D638 test standards. In the fabrication of ASTM D3039 tensile test specimens, the requirements are as follows [19] :

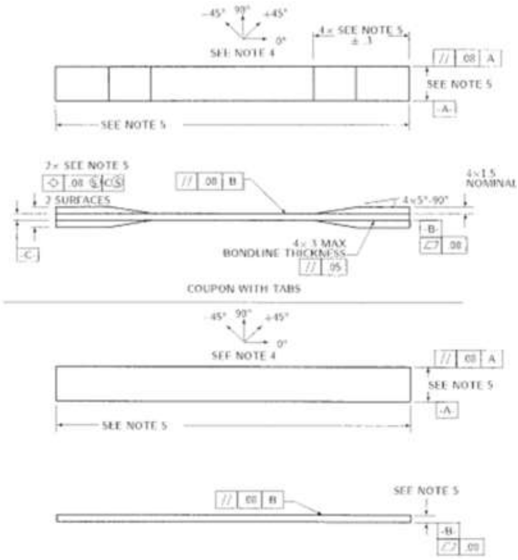

Fig. 2. ASTM D3039 Tensile Test Specimen Dimensions [19].

This testing method is used to measure the tensile properties in the plane of polymer matrix composite materials reinforced with high-modulus fibers. This method can only be applied to composites reinforced by continuous or discontinuous fibers with balanced and symmetric lamination. In the fabrication of ASTM D638 tensile test specimens, the requirements are as follows [20] :

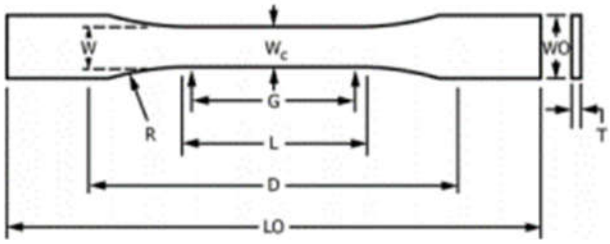

Fig. 3. ASTM D638 Tensile Test Specimen Dimensions [20].

This testing method involves conducting tension tests on both reinforced and unreinforced plastic specimens using standard dumbbell-shaped specimens. The specimens are tested under pretreatment conditions, temperature, humidity, and testing machine speed. In the tensile strength testing for this composite, a Tensilon RTF 2410 UTM machine was used and the testing was conducted in the laboratory of PT Biro Klasifikasi Indonesia (BKI). In the process of manufacturing wind turbine blades, they are shaped according to the SG6042 wind turbine blade standard. The following are the dimensions of the sg6042 wind turbine blade shape :

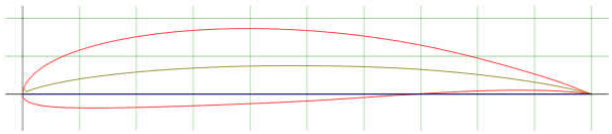

Fig. 4. Wind Turbine Blades SG6042 [11].

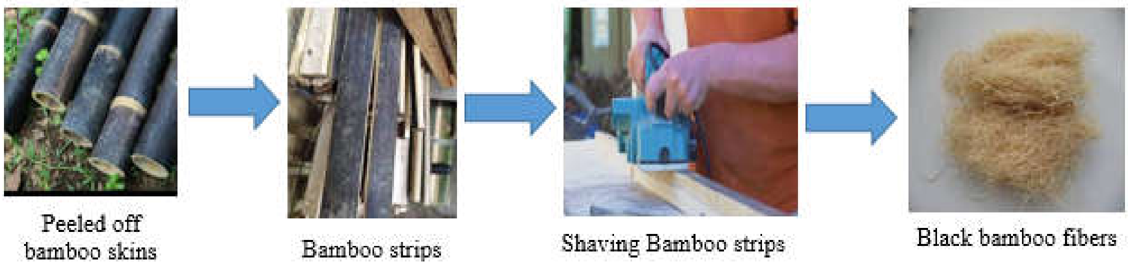

Fig. 5. Bamboo Fibers Preparation Process.

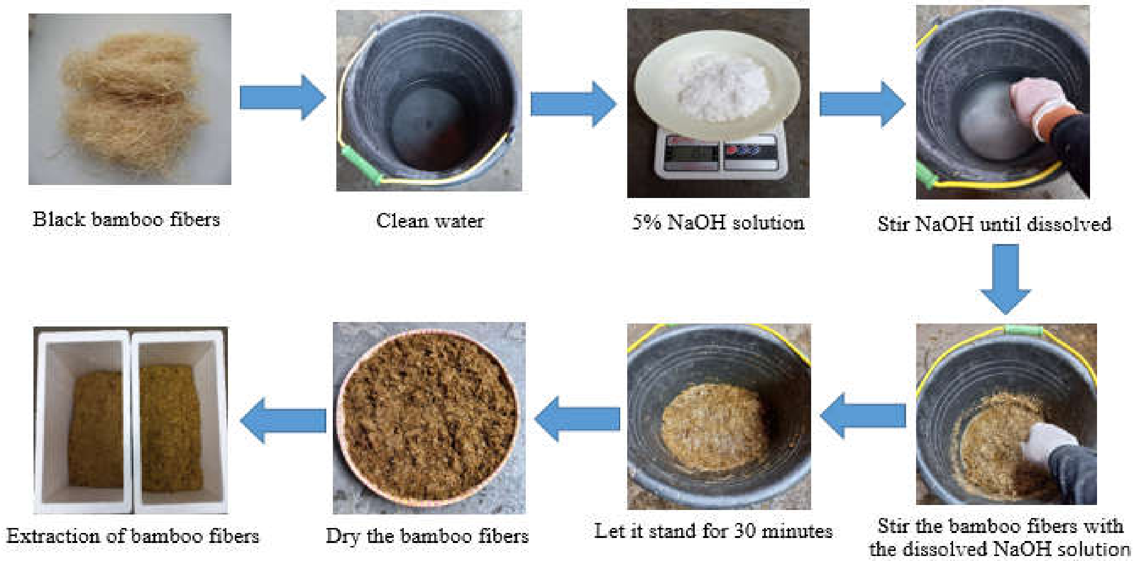

Fig. 6. Black Bamboo Fiber Extraction Process.

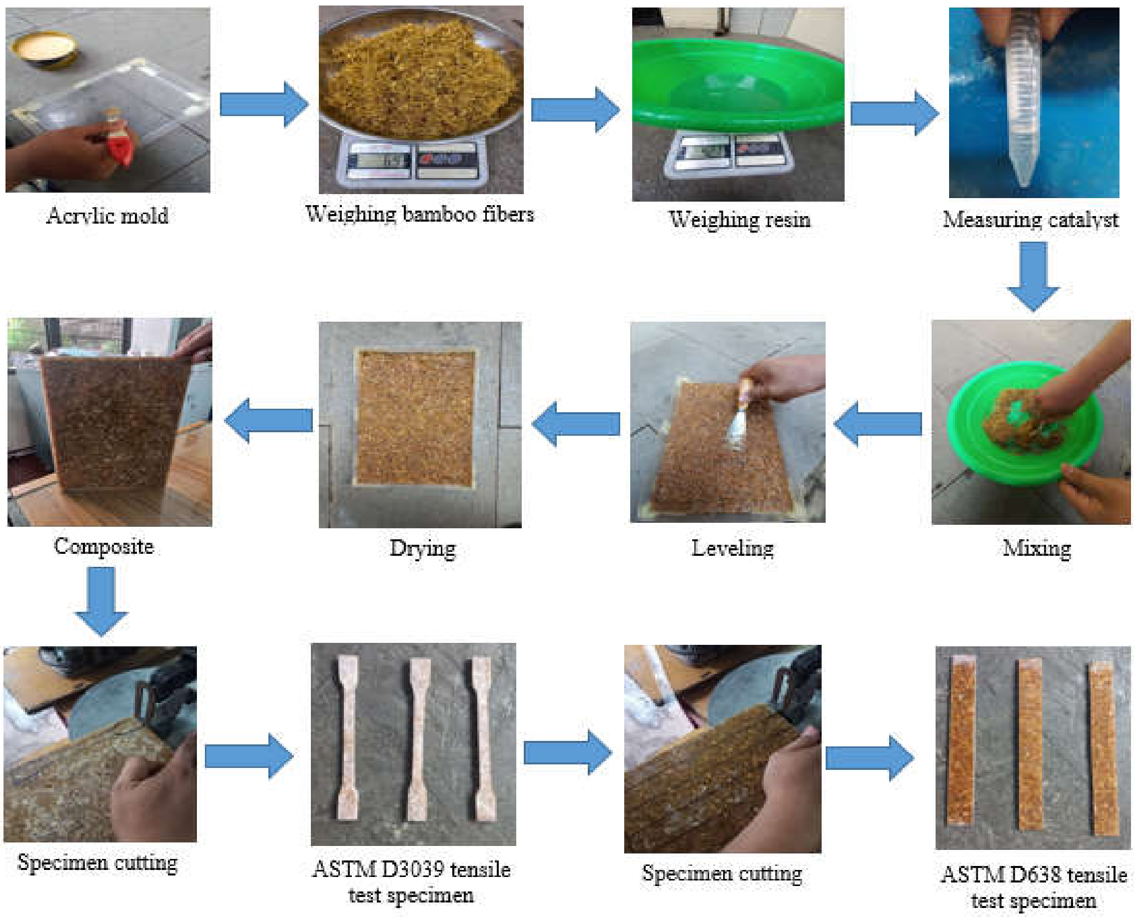

Fig. 7. Composite test specimen manufacturing process.

Fig. 8. Wind turbine blade manufacturing process.

After going through the machining process, the next step is the coating process on the formed wind turbine blade composite layer. This is achieved by applying epoxy resin evenly onto the surface of the pre-formed SG6042 wind turbine blade. Subsequently, after the coating is applied, it is left to dry completely on the surface of the SG6042 wind turbine blade for a period of 6 hours.

III. RESULT AND DISSCUSION

From the tensile testing results conducted on all samples for each specimen using ASTM D3039 and ASTM D638 standards, In the tensile testing results using the ASTM D3039 standard for the 3:9 ratio, an average maximum load of 558.30 N, a tensile strength of 7.50 MPa, and an elastic modulus of 1995.3 MPa were obtained. For the 3:12 ratio, the average maximum load was 534.48 N, the tensile strength was 7.26 MPa, and the elastic modulus was 2029.4 MPa. In the tensile testing results using the ASTM D638 standard for the 3:9 ratio, an average maximum load of 757.11 N, a tensile strength of 10.76 MPa, and an elastic modulus of 2713.3 MPa were obtained. For the 3:12 ratio, the average maximum load was 842.58 N, the tensile strength was 10.23 MPa, and the elastic modulus was 3045.2 MPa.

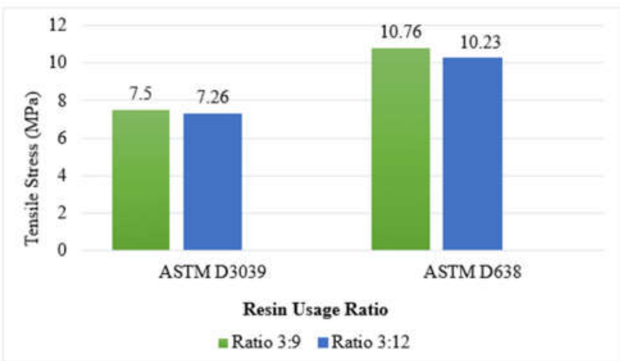

Fig. 9. Graph of Tensile Stress From the Average Results of Tensile Testing

The grahpic above explains that the highest tensile testing results were obtained from the 3:9 ratio, both when using the ASTM D3039 standard for composite material testing and the ASTM D638 standard for plastic material testing.

Below are the results of the SG6042 wind turbine blade composite, which is made from bamboo fiber composite material, following the specimen fabrication process involving mold creation and blade formation through machining. The outcomes of two wind turbine blade ratios, 3:9 and 3:12, are obtained, as shown in the image below.

Fig. 10. Black Bamboo Composite SG6042 Wind Turbine Blade

With the manufacturing process using black bamboo fibers and resin in the 3:9 ratio, a weight of 392 grams is achieved, while the 3:12 ratio results in a weight of 418 grams for the application of bamboo composite in wind turbine blades.

IV. CONCLUSION

Based on the tensile testing results using ASTM D3039 and ASTM D638 standards. The testing process using ASTM D3039 standard yielded a tensile strength of 7.50 MPa for the 3:9 ratio and 7.26 MPa for the 3:12 ratio. According to ASTM D638 standard, the tensile strength obtained is 10.76 MPa for the 3:9 ratio and 10.23 MPa for the 3:12 ratio. It can be concluded that the tensile strength for the 3:9 ratio is higher than the 3:12 ratio by 3.2% for ASTM D3039 standard and 4.92% for ASTM D638 standard. Based on the results of bamboo composite manufacturing, it can be concluded that wind turbine blades can be made from bamboo fiber composite material, weighing 392 grams for the 3:9 ratio and 418 grams for the 3:12 ratio.

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