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Tensile Strength Improvement of LLBC Material for Low Speed Wind Turbine Rotor Blade by Varying Composite Matrix

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Abstract. Low-speed wind energy conversion systems generally use Carbon Fiber Reinforced Plastic (CFRP) and Glass Fiber Reinforced Plastic (GFRP) as materials for rotor blade because these materials are light weight and hard but expensive. Layer Laminated Bamboo Composite (LLBC) is a bio-composite with bamboo base material which is abundant material and has a relatively lower price. This study investigates tensile strength of LLBC-based bio-composite materials for rotor blades of low-speed wind turbine. This research uses experimental method by varying three types of polymer (Araldite AV138M-1, Araldite AW106, and standard Epoxy Resin) as an adhesive of composite laminate LLBC based on Gombong bamboo. The results show that combination of polymer and bamboo increase the tensile strength ranges from 2 to 7 times as compared to pure bamboo. Araldite AV138 produces the highest tensile strength (230.11 MPa) while Araldite AW106 produces the highest average tensile strength (222.11 MPa). We conclude that combination of bamboo and polymer is a potential material for low speed wind turbine rotor blade.

1. Introduction

In 2006, the President of Republic of Indonesia issued Presidential Decree Number 5 Year 2006 on National Energy Policy. Indonesia targets that 15% of energy resources in Indonesia for year 2025 comes from renewable energy sources such as biofuel, geothermal, biomass, micro-hydro, solar power and wind turbine.

One of the most potential and not optimally developed renewable energy sources is the Wind Turbine. Up to 9,190 MW potential that can be developed according to the Ministry of Energy and Mineral Resources, only 1.6 MW can be realized [1]. It means less than 1% of existing potential wind energy can be utilized, while more than 99% cannot be used as a renewable energy source.

The challenge in wind turbine development in Indonesia is wind speed. According to the National Aeronautics and Space Agency (LAPAN), the average wind speed in Indonesia ranges between 3 - 8 m/s [2]. The low wind speeds make the development of wind turbine in Indonesia limited to class II and III only on IEC (International Electrotechnical Commissions) standards or in low-medium wind speed category [3]. Therefore, the development of low-speed or small-scale wind turbine is very potential in Indonesia.

The relatively low wind speeds make the turbine blade in a low speed wind turbine class should be designed lighter in order to operate, but does not reduce the strength of the turbine material itself. The

most commonly used material for wind turbine blades is Glass Fiber Reinforced Polymer (GFRP) or better known as Fiberglass and Carbon Fiber Reinforced Polymer (CFRP). Fiberglass and Carbon Fiber are known as a light weight, but have a much stronger than the metal in general [4]. However, this material is very expensive, so it will increase the cost of making the turbine blades. In addition to Fiberglass and CFRP, other commonly used materials are bio-composite or a combination of natural materials such as wood with polymers as a matrix.

The alternative material that can be utilized for wind turbine blade structure is bamboo. Bamboo is a very abundant Natural-Composite in Indonesia. Bamboo has the advantage of being easy to get, have a high-strength to-cost ratio, an environmentally-friendly. Some of the bamboo species such as Bamboo Haur (phyllostachys Aurea) and Green Bamboo (dendrocalamus strictus) can become more robust than steel after heat treatment or combined as a composite material [5,6].

At present, the development of bamboo materials as composites has been very diverse. Bamboo has been combined as a reinforced (Fiber) with Polymer (Bamboo Fiber Reinforced Polymer/ BFRP) as a matrix, and has also been developed into laminated composite as Layered Laminated Bamboo Composite (LLBC). This research investigates the strength of LBCC as a candidate material for low speed wind turbine rotor blade.

2. Methods

This research uses experimental method by varying three types of polymer as an adhesive of composite laminate LLBC based on Gombong bamboo (Gigantochloa atroviolacea). The polymer used are Araldite AV 138M-1 with HV 998 Hardener, Araldite AW 106 with HV 953 U BD Hardener and standard Epoxy Resin in the market. The structure of this LLBC is combining bamboo and polymer layer together to form a lamination structure in several stages. Each type of LLBC specimen tested in universal testing machine to determine the tensile strength of materials with ASTM D3039 standard. Figure 1 provides geometry of specimen according to ASTM D3039 standard for composite structure.

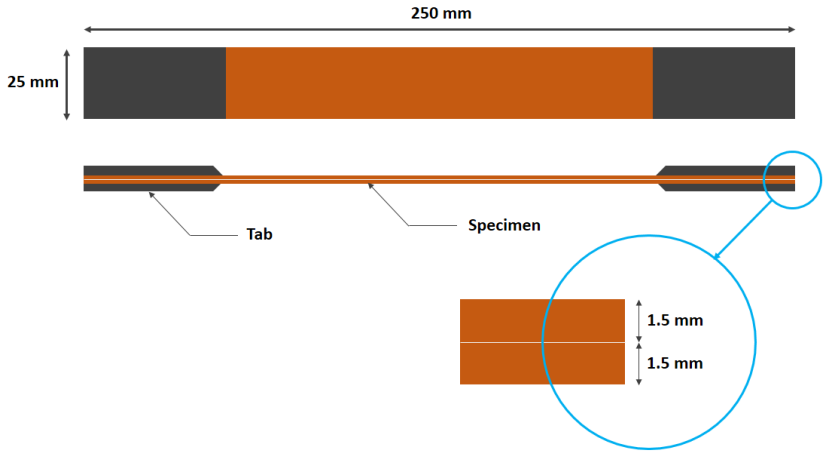

Figure 1. ASTM D3039 Standard for Bamboo Composite

Each composite sample has three specimens for test. The specimens are mounted in universal testing machine to be tested. The results of the tests give a measure of the tensile strength of each LLBC composite sample. Figure 2 shows the installation of specimen in the testing machine.

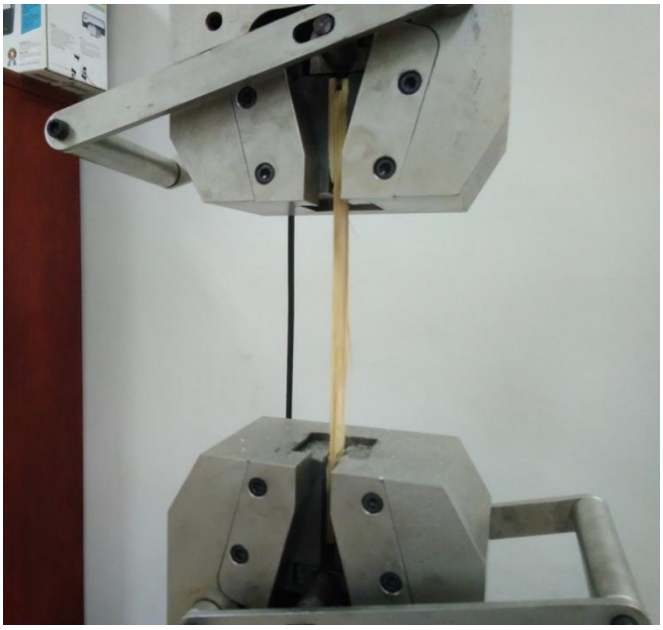

Figure 2. Installation of Specimen on Tensile Test

3. Results and discussion

Table 1 provides the result of tensile test measurement. The results show variation of tensile strength values. The maximum tensile strength obtained from the experiment is 230.11 MPa. This value is obtained when using Araldite AV 138 as polymer. Combination bamboo with Araldite AV138 polymer also gives the minimum value of 183.52 MPa. The average value of tensile strength from three types of polymer shows that combination bamboo and AW 106 has the highest value (222.11 MPa), followed by Epoxy Resin (209.23 MPa) and AV138 (209.06 MPa).

Other researcher reported that *Dendrocalamus strictus* bamboo with Araldite LY 556 Polymer has tensile strength in the range from 240 MPa to 191 MPa which means relatively similar values as obtained in this research [7]. We noted that the strength of bamboo was reported in the range from 31 MPa to 94 MPa [8]. Based on these results, combination of polymer and bamboo increase tensile strength 2 to 7 times as compared to pure bamboo. These results indicate that combination of bamboo and polymer is a potential material for rotor blade of wind turbine.

Table 1. Results of Tensile Tests

Polymer Type	Max Value (MPa)	Min Value (MPa)	Average (MPa)
AV 138	230.11	183.52	209.06
AW 106	227.65	215.95	222.11
Epoxy Resin	220.75	187.58	209.23

4. Conclusion

We have investigated tensile strength of composite laminate LLBC based on Gombong bamboo with three types of polymer as an adhesive (Araldite AV138M-1, Araldite AW106, and standard Epoxy Resin). We found that combination of polymer and bamboo increase the tensile strength ranges from 2

to 7 times as compared to pure bamboo. Araldite AV138 produces the highest tensile strength (230.11 MPa) while Araldite AW106 produces the highest average tensile strength (222.11 MPa). We conclude that combination of bamboo and polymer is a potential material for low speed wind turbine rotor blade.

Acknowledgements
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