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Mechanical Strength of 10 kW Wind Turbine Blade Utilize Glass Fiber Reinforced Plastic

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Abstract

Wind turbine blade usually are molded by composite material. In this research, glass fiber reinforced plastic (GFRP) is utilized. GFRP has larger ratio of strengh to weight and easily molded that can contributes high efficiency in converting wind energy to electrical energy. Unfortunately, the strength of GFRP is greatly influenced by the skill of the operator during the construction. The aim of this work to investigate mechanical strength of wind turbine blade through the calculation and measurement. Tensile strength of wind turbine blade is found as 3.790 N/cm^2 for the calculation and 3.690 N/cm^2 for the measurement.

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Keywords: wind turbine; blade; glass fiber; mechanical strength; composite

1. Introduction

Wind turbine blade that own a unique geometry usually are molded with composite material [1]. In this research, glass fiber reinforced plastic (GFRP) is utilized to construct Horizontal Axis Wind Turbines (HAWTs) as the most popular wind turbine [2]. GFRP has larger ratio of strength to weight and easily molded that can contributes high efficiency for wind turbine implementation. A composite, in the present context, is a multiphase material that is artificially made, as opposed to one that occurs or forms naturally. In addition, the constituent phases must be

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chemically dissimilar and separated by a distinct interface [3]. Commonly, composite materials are consisted of two phases i.e. matrix and fiber. Matrix is the material which is continuous and surrounds the other phase. Then the term of matrix is also called as dispersed phase**.** Fiber is the material that functioned to enhance the strength of the composites. The properties of their constituent phases, relative weight and geometry of dispersed phases are affected by the properties of the composites structure [3]. The shape of particle or fiber, their size, particle distribution and orientation are meaned as dispersed phase geometry.

Generally, composite material is distinguished of three classification, i.e. : particle-reinforced; fiber-reinforced and structural [3]. Among them, fiber reinforced is subjected as the material that suit to utilize as wind turbine blade. Fiber direction that could be set as well as load direction which give an advantages of the strength of the structure in accordance to blade load. Technologically, the most important composites are those in which the dispersed phase is in the form of a fiber. Design goals of fiber-reinforced composites often include high strength and stiffness on a weight basis. These characteristics are expressed in terms of specific strength, which correspond to the ratios of tensile strength to specific gravity [4].

The arrangement or orientation of the fibers relative to one another, the fiber concentration, and the distribution all have a significant influence on the strength and other properties of fiber-reinforced composites. With respect to orientation, two extremes are possible i.e. a parallel alignment of the longitudinal axis of the fibers in a single direction and a totally random alignment.

In this research the arrangement of each layer was set in longitudinal direction and random direction. The layer consisted of : (i). Dept Oz to smooth the surface, (ii). Woven roving to increase the strength, (iii). Met 425 to fulfill the space between woven roving. Because of the using many layers of difference glass fiber in one turbine blade, therefore the identification of mechanical strength of turbin blade becomes not so simple. It should be done through the appropriate methods to find a perfect results. This research aimed to investigate the mechanical strength of wind turbine blade through the calculation and measurement.

2. Methods

2.1. Research Design

In this research, mechanical strength of wind turbine blade was investigated as the calculation and measurement. The calculation is conducted based on applied theory and the previous research otherwise the measurement is conducted by tensile stress testing. The testing is preceded by specimen preparation. The specimen was made in room pressure and the layer as same as the layer of blade root.

Maximum load of wind turbine blade is simulated by maximum wind velocity that has been defined as 35 m/s. The simulation resulted the prediction of bending force that will be converted to the tensile strength. Tensile strength of the blade as the calculation and measurement will be compared to the tensile stress of the simulation.

2.2. Specimen Preparation

The specimen was made by glass fiber with the matrix was epoxy resin Yukalac BQTN 157. The layer of the specimen deliberately constructed as same as root layer of turbine blade that depicted in Figure 1a. The layer consisted of Dept Oz (DO); Chopped Strand Mat 425 (CSM 425) and Woven Roving 400 (WR 400). Structure of the layer were DO-WR800-CSM425-WR800-CSM 425-WR 800-CSM425-WR 800-CSM425-WR800.

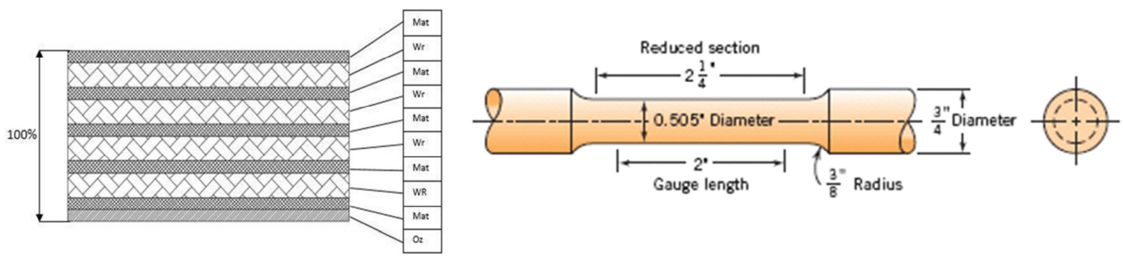

Fig. 1. Glass fiber layer and dimension and size of the specimen

The specimen has the dimension and size as shown in Fig. 1(b). which was constructed as the rule of ASTM E8. The finishing of the surface was done by sand paper CW-300 which simultaneously checking for the dimension. The specimen was prepared as much as 10 sample in regard avoiding the bias of the sample as they were hand made.

2.3. Tensile Test

Tensile test was conducted through MW-W1A Universal Testing Machine. Testing was done in 10 times for the same sample. Mean of tensile strength of all sample was then calculated and will be the basic in analyzing blade strength. The results of tensile test (measurement) also be compared by the result of tensile strength of calculation to check the truth of the experiment. After test was operated in MW-W1A Universal Testing Machine, mean value of tensile strength was found as 3,690 N/cm^2.

3. Results and discussions

3.1. Load calculation

The investigation of mechanical strength of wind turbine blade is conducted in the critical area which occurs in the blade root. The section is depicted in Fig. 2. in which maximum load is undergo in this cross section area. In this section, glass fiber composition is arranged as well to strengthen the blade as the area is called as critical area.

Load at this section is calculated as the simulation when turbine blade run at wind velocity 35 m/s as the maximum wind velocity of the design. The calculation is conducted as equation 3 as follow [5-6]:

$$P = (0.5 \times \rho \times A \times V^3)/B \tag{1}$$

$$P = (0.5 \times 1.174 \times 78.5 \times 35^3)/3$$

$$P = 658{,}552 \text{ Watt}$$

Here, P is power that converted of every blade; ρ is air density; B is number of blade; A is blade area of 10 m diameter and V is wind velocity. It has been calculated that blade displacement in wind velocity 35 m/s (in center gravity of turbine blade) is 39.2 m/s. Now, lift force could be calculated and found as F = 14,830 N. If mass of every blade is 420 N and added to the load, blade load will be F = 15,250 N, that will be the maximum load of turbine blade.

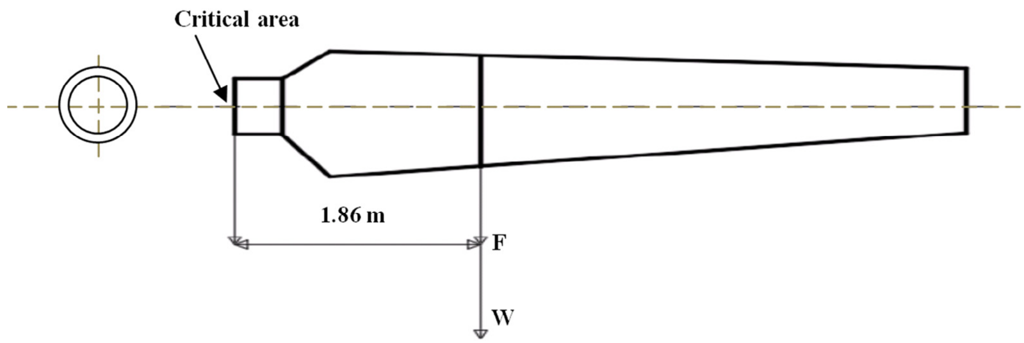

Fig. 2. Load of blade critical area

Bending moment will be Mb = 30,502 Nm, bending resistance will be Wb = 0.00176 m^3. Furthermore bending stress found as 173.3 N/cm^2. This value as same as the tensile stress of 288.83 N/cm^2.

3.2. Tensile strength of the calculation and measurement

In this research, tensile strength was calculated based on each fraction of the layer. The strength of the layer as hand made product, may better if considered as lower quality strength. As it has been well known that composite product is categories in to three quality based on the production process [7]. If they are made by machinery process or manually, if they are made by fullskill person or not, it would affect the quality of the composite [8]. In this work, the composite is made by unfulskill person, so, the result of composite quality may remain in the lower grade. All the calculation is based on the calculation that has been done by Sjarkawi [7]. The calculation are listed in Table 1. as follow.

Table 1. Data of mechanical strength of wind turbine blade

Layer No.	Thickness (mm)	Composition of Laminate Composite Fiber (wt%)			Tensile Strength (N/cm^2)
		Dept Oz	WR800	CSM425	
1.	0.4	4			849
2.	0.8			8	270
3.	1.4		14		1,930
4.	0.8			8	270
5.	1.4		14		1,930
6.	0.8			8	270
7.	1.4		14		1,930
8.	0.8			8	270
9.	1.4		14		1,930
10.	0.8			8	270

All the data was then calculated as each fraction (wt%) and then resulted the final mechanical strength of turbine blade as much as 3.790 N/cm^2. The strength will be compared to the strength turbine blade of measurement which has been found as 3.690 N/cm^2. This mean that the strength of the calculation found in higher than the measurement. It may caused by the error of the calculation in which agree to the statement that unfullskill operator resulted lower grade of mechanical strength of composite [9-10].

3.3. Comparison between mechanical stress to mechanical strength

Comparison between mechanical stress to mechanical stregth of wind turbine blade will justify that the blade is able to use or not. The comparison is emphasized on the tensile stress of the blade. Tensile stress of maximum dynamic load has been calculated and found as 288.83 N/cm^2. The promised of tensile strength of the blade of dynamic load must be include the safety number approximately in 5. So the promised tensile strength must be 1,444.15 N/cm^2. In this work, maximum dynamic load as much as 1,444.15 N/cm^2 shows lower than tensile strength 3,790 N/cm^2 and could be justified that the blade is able to use under maximum wind velocity 35 m/s.

4. Conclusion

Mechanical strength of wind turbine blade has been examined through the calculation and the measurement. Maximum load of wind turbine blade was simulated for wind velocity 35 m/s. The result shows that the tensile stress has been found as 288.83 N/cm^2 and tensile strength as 3,790 N/cm^2 which could be concluded that the blade is able to operate. The only little difference between tensile strength of the calculation and the measurement i.e. 3,790 N/cm^2 for the calculation and 3,690 N/cm^2 for the measurement may be generated by the mistake of the calculation.

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