Selecting and testing of wind turbine blades of the local-wood growing fastly on local wind characteristics

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Abstract. The total potential of wind energy in Indonesia reaches 144 GW. This wind energy potential is dominated by small wind speeds ranging from 4-6 m/s and about 113 GW. This is the reason why the development of small-scale wind powerplant is more feasible to be developed in Indonesia. The characteristics of local wind and geographical conditions of Indonesia which has the best physical and mechanical properties of wood, and is tested computationally on certain airfoils and shows a uniform distribution of stress. The types of wood are tested in this study were Sengon (Albizia chinensis), Jabon (Antocephalus cadamba), and Balsa (Ochroma Rowlee grandiflorum). The test covers the basic properties of the wood, physical and mechanical properties. The test results showed that Jabon have density 0.34 was the best compared to Sengon (0.24) and balsa (0.18). The best dimensional stability (T/R Ratios) are Jabon (1.97), sengon (2.19) and balsa (2.84), respectively. With the highest density result and the lowest dimensional stability value, mechanical testing of Jabon wood shows the best mechanical properties. The simulation result using Q-Blade software was obtained airfoil NACA 4415 most suitable for local wind characteristics, and got the low value of stress and distribution color uniformly on each wood.

1. Introduction
The development of wind power generations as part of renewable energy utilization has been implemented over the past few years, but the use of technology is not the same for every place, such as Indonesia which is a tropical area with wind energy potential of 113 GW dominated by wind speed 4-6 m/s. Therefore, the development of small-scale wind power generation is more feasible to be developed in tropical regions such as Indonesia, as lack of access to electricity can have a significant impact on education, economics, health, and gender equality [1-3]. The potential distribution of wind speed and geographical condition of Indonesia which is an archipelago country must be accompanied by the utilization of local materials as raw material for wind turbine blade manufacture.

F. Mahmuddin [4] performs computational computations based on the theory of blade element momentum (BEM) to find the performance of blade rotor [4], which is BEM theory based on momentum theory and blade element [5]. The comparison of the lift coefficient values of airfoils was tested using Q-Blade software [6], this is done to improve the performance of the blade rotor. Agung and Warits in
their essay conduct wind turbine evaluation using Q-Blade to seen similarity between blade characteristics and make blade design improvement with wind characteristic in Indonesia costal area [7, 8]. Blade is the key of wind power plants that convert wind kinetic energy into electrical energy in generator [9]. the optimal chord dimension can be made based on several parameters tailored to the design, such as wind speed, number of blade, tip speed ratio, and angle of attack, and if operated at low wind speeds it is possible to perform aerodynamic optimization of the rotor blades which are the most important part of the wind turbine. [10-12].

This study aims to get local fast growing wood wind turbines blades in Indonesia, which has the best physical and mechanical properties of wood, and is tested computationally on certain airfoils and shows a uniform distribution of stress. The types of wood are tested in this study were Sengon (Albizia chinensis), Jabon (Antocephalus cadamba), and Balsa (Ochroma Rowlee grandiflorum), which is a kind of fast growing wood in indonesia. The test covers the basic properties of the wood, physical and mechanical properties.

2. Methodology
2.1. Wood Properties Testing Set Up
A testing of physical properties, and set up of mechanical testing which are discussed in this paper is shown in figure 1 and figure 2.

![Figure 1. Physical Testing of Wood Properties](image1)

![Figure 2. Mechanical Experimental Set Up](image2)

Testing of physical and mechanical properties of wood was carried out with ASTM 2359-69, ASTM D 143-52, and British Standard testing method (BS 373-1957) [13], to obtain values of wood density and modulus elasticity.
2.2. Wind Data Record
Local wind data record on the roof top of Lipi Pusinov’s Building is shown in figure 3.

![Probability of Wind Speed at Pusinov Building](image)

**Figure 3.** Wind Speed Probability Chart

2.3. Computational Fluid Dynamic Analysis
The computational simulation conducted to obtain the blade design and performance by using Q-Blade software. In this paper several theories on wind power plants used as a calculation, in order to get the performance of rotor blade in accordance with the characteristics of local wind.

The generated wind power can be calculated by [14]:

\[
P_w = \frac{1}{2} A_r \rho V^3
\]

Which \(A_r\) is a rotor diameter, \(\rho\) is the air density and \(V\) is the wind speed, this is done in consideration in designing the blade later. We can determine the of lift and drag coefficient of the airfoil by the formula [15]:

\[
C_L(\alpha) = \frac{L}{\frac{1}{2} \rho w^2 l}
\]

\[
C_D(\alpha) = \frac{D}{\frac{1}{2} \rho w^2 l}
\]

with \(w\) as the relative speed of the wind and \(l\) is the chord width, the lift and drag coefficients are functions of angle of attack (\(\alpha\)).

The Reynold number is determined by the equation below by taking into account the local characteristic of wind which is dominated by wind speeds range about 4 to 6 m/s.

\[
Re = \frac{wl}{v}
\]

With \(v\) kinematic viscosity (1.5111E-5 \(m^2/s\)) dan \(l\) chord width, Reynold number will be used as parameter calculation of coefficient lift and drag.

3. Test Result
3.1. Result of Physical and Mechanical Test
The physical testing result of wood properties was carried out with ASTM 2359-69, ASTM D 143-52, and British Standard testing method (BS 373-1957) [13], to obtain values of wood density and modulus elasticity. The result of the physical testing is shown in table 1.
Table 1. Density values Jabon, Sengon, dan Balsa

| No. | Wood Type | Density Value | Unit   |
|-----|-----------|---------------|--------|
| 1   | Sengon    | 0.24          | g/cm³  |
| 2   | Jabon     | 0.34          | g/cm³  |
| 3   | Balsa     | 0.18          | g/cm³  |

From table 1, Jabon wood has better density value among another local wood with value 0.34. The greater the wood density value the more stable the wood when used as a blade.

The result of this mechanical testing shows that Jabon wood has the highest elasticity value, as shown in Table 2.

Table 2. Elasticity Value Jabon, Sengon, dan Balsa

| No. | Wood Type | MOE       | Unit |
|-----|-----------|-----------|------|
| 1   | Sengon    | 4331.8915 | mPa  |
| 2   | Jabon     | 4615.5684 | mPa  |
| 3   | Balsa     | 2107.9982 | mPa  |

3.2. Result of Computer Fluid Dynamic Simulation

3.2.1. Blade Performance Simulation. From the Figure 3, is determined blade that works at low wind speeds. In this paper, a computational simulation is performed for airfoil NACA 4415 and SG 6042. By using equation (4) and with the chord width 97.1953 mm, it can be obtained the Reynold Number Re 22515, as shown table 3.

Table 3. Computation Input data

| Parameters       | Unit        | Parameters       | Unit        |
|------------------|-------------|------------------|-------------|
| Airfoil (a)      | NACA 4415   | Chord            | 97.1953     |
| Airfoil (b)      | SG 6042     | Rotational Speed | 216.68 rpm  |
| Radius           | 925.5 mm    | Wind Speed       | 3.5 m/s     |
| Reynold Number   | 22515       |                  |             |

All of data is simulated using Q-Blade software to obtain the Coefficient Lift (Cl) and the TSR and CP ratio of airfoil NACA 4415 and SG 6042, as shown in the figure 4.

![Figure 4](image)

Figure 4. Comparison of Coefficient Lift

In figure 4, the curve changes of Coefficient Lift vs Alpha on NACA 4415 has more constant increase compared to SG 6042, it is mean that the stability of lift values of blade can be maintained on the variation of the existing angle of attack.
a. NACA 4415  

b. SG 6042

**Figure 5.** Comparison chart of CP and TSR values

The change in TSR (tip speed ratio) values occurring in NACA 4415 is more stable than SG 6042, as shown in Figure 5, which can be concluded that NACA 4415 has a better TSR stability than SG 6042.

3.2.2. **Blade Stress Distribution Simulation.** The stress distribution simulation as part of computational simulation was conducted of three types of wood using airfoil which has the best performance that is NACA 4415. The Figure 6 shows that the stress distribution in each type of wood is different, Balsa has a better stress distribution value than Jabon and Sengon, this happens because Balsa has a lowest density value. The strongest of stress distribution of each wood can be indicated with the red colour on blade surface. The smaller the red color on the blade surface area the better the pressure distribution on the blade surface.

![Stress Distribution Simulation](image)

**Figure 6.** Stress Distribution Appearance of each wood

The maximum stress of each wood can be seen in Table 4, where the stress distribution in each type of wood is different, Balsa has a better stress distribution value than Jabon and Sengon, that is 0.29 mPa. This result happens because Balsa has a lowest density value.
Table 4. Maximum Stress on each wood

| No. | Wood Type | Max Stress | Unit |
|-----|-----------|------------|------|
| 1   | Sengon    | 0.29       | mPa  |
| 2   | Jabon     | 0.30       | mPa  |
| 3   | Balsa     | 0.33       | mPa  |

4. Conclusion
From the test results of physical and mechanical properties can be concluded that Jabon wood is better as a local wood material for wind turbine blades by considering the stability dimensions and mechanical strength when compared with Sengon and Balsa wood. Similarly, the type of airfoil used can be concluded that the airfoil NACA 4415 has a better lift and drag coefficient curve than SG 6042 at local wind speed, and for the graphical TSR and CP of NACA 4415 also has better stability form SG 6042.

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