World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Exploitation of the elastic behavior of Borassus in the development of wind blades

Komlan LOLO [1,*] and Seydou OUEDRAOGO [2]

[1] *Department of Mechanic Engineering, Laboratory of Structure and Mechanics of Materials (LaS2M), University of Lome,01 BP 1515 Lome 01 – TOGO*
[2] *Laboratoire de Recherche en Sciences de l'Ingénieur (LARSI), Département de Génie Électrique, Institut Universitaire de Technologie, Université Nazi BONI, 01 BP 1091 Bobo-Dioulasso 01, Bobo-Dioulasso.*

World Journal of Advanced Research and Reviews, 2023, 20(02), 1371–1376

Publication history: Received on 18 October 2023; revised on 25 November 2023; accepted on 27 November 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.20.2.2428

Abstract

Wind turbines have existed since ancient times and helped man accomplish various tasks. The essential organ is the blade allowing the energy of the wind to be transformed into desired energy. According to its role, the choice of material for its manufacture was the subject of several researches because of the expected weight and the multiple demands. Although wood in general was refuted because of its degradation, borassus remains tenacious in the face of bad weather and various stresses. Several material resistance tests carried out on borassus specimens showed its elasticity, proof of its usability in the production of wind turbine blades. The absence of knots and the fact that borassus cannot be attacked give reason to the choice of borassus in wind turbines. The object of this work is to present the borassus, little known but having more values, in the three-way bending solicitation where the linear zone is exploited.

Keywords: Wind; Wind Turbine; Blades; Elasticity of Borassus

1. Introduction

The search for clean energy is a challenge for the scientific and industrial world. Humanity today lives in pollution leading to climate degradation. This degradation is the result of the release of carbon dioxide into the atmosphere. Multiple researches have led to the finding of new sources of clean energy to reduce the danger that undermines the entire planet. Among these new sources comes the exploitation of energy from wind.

Energy from the wind, which is called wind energy, has long been used in navigation to propel boats, and in ancient Egypt to grind cereals. It remains a clean, non-polluting energy. This energy is free in nature. From a system, this free energy is transformed into electrical energy thanks to a system composed of blades and an electromechanical group. This is the case for wind generators or wind turbines. Three main parts can be distinguished: the mast, the nacelle and the blades.

The blades remain the essential part of the system. They must be light, flexible but mechanically resistant. Several materials have been used in the design of blades including metals, plastic, wood and nowadays composite materials. The latter are supposed to have attractive advantages residing mainly in the good mechanical characteristics in terms of specific rigidity and resistance. Wood will very quickly be abandoned. But in reality the wood is light, easy to work, resists fatigue well but remains sensitive to erosion. Wood often has gray areas for its elasticity: erosion, knots and holes or galleries of xylophages in the wood. The nodes constituting stress concentration zones. In these areas, the constraints vary, so the loads also vary. In addition to knots, wood can be attacked by wood-eating insects. The presence of holes weakens the wood in the area of the hole. No study has presented borassus as a wood with advantages beyond its worrying density.

* Corresponding author: Komlan LOLO.

Among the elastic woods, borassus is a famous hardwood for construction, which has no knots and cannot be attacked by xylophages. It is as elastic as bamboo. Borassus is ideally suited to be used for making wind turbine blades in order to resist deformation under certain forms of stress. Under the action of the wind, the blades are subject to bending. Examining the effect of this load is of concern in order to choose the essential and useful material in the manufacture of the blades.

The aim of this work is to present the value of borassus in the manufacture of wind blades. Borassus presents, by its constitution, enough advantages for its choice in the manufacture of wind blades. Its limits remain difficult machinability and high density (sometimes greater than 1).

2. Materials and Methods

The working material is Borassus wood taken in its hard part, the construction part. The Borassus is tested under simple bending stress. The material is continuous, without the presence of knots or holes. All elements of borassus are identical. Borassus is a wood with anisotropic properties. The approach adopted consists of considering the maximum value of the stress as the elastic limit. The elastic domain is exploited throughout the test. The analysis is done on a single request. Samples considered as blade models are subjected to bending. The load is the force of the wind. It is evenly distributed on the blade.

The test carried out is three-point bending which is not exactly an illustration of the stress on the blades. The bending test measures the breaking strength of a material. In this exercise, this measurement is expressed as displacement, a deformation called the deflection. Deflection is a term used to describe the deformation of a beam under a given load. Calculating the deflection (f) of a beam depends on several factors, such as the length of the beam (l), the applied load (F) and the mechanical properties of the beam material (E,I).

The samples are placed on two (02) supports as shown in the modeling in Figure 2. A force directly opposite to the result of the reactions to the supports is exerted in the middle of the sample. The test is carried out until the specimen breaks.

Figure 1 Evidence of MDR Testing

These are the specimens subjected to the three (03) point bending test (fig. 1.a) and the tensile test (fig. 1.b) the results of which made it possible to find the modulus of elasticity. The bending test is taken into account in the rest of the work. The pressing force is the shear force. This exercise is more advanced than the loading of the wind blade. The deflection for a three (03) support bending is given by relation (1).

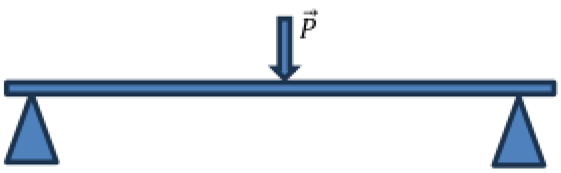


Figure 2 Modeling of a beam subjected to simple bending

$$f_s = \frac{P.l^3}{48.E.I} \quad (1)$$

The borassus specimens are subjected to this type of test, the results of which will be analyzed later in the article.

The wind turbine blades are mounted on the nose of the spindle by a rigid connection. They are, during operation, embedded, that is to say blocked at this end and free at the other. The action of the wind is evenly distributed on the blade. This action of the wind is represented in the figure by small arrows. It constitutes the external force acting on the blade. Figure 3 shows the modeling of the wind exercise on the blade.

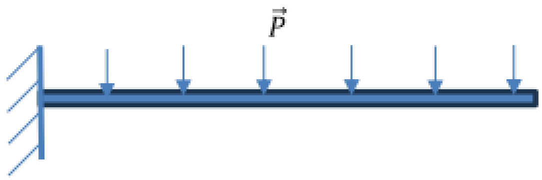


Figure 3 Modeling of a blade subjected to the action of the wind

The blade bends under the action of the force of the wind, producing a maximum deflection given by formula (2).

$$f_e = \frac{P.l^4}{8.E.I} \quad (2)$$

The deflection is used to calculate the deformation of the beam underload, regardless of the type of load. The results will be extrapolated to express the elasticity of borassus. The ratio of the two stress cases, for the same given length, is given by formula 3.

$$\frac{f_s}{f_e} = \frac{\frac{P.l^3}{48.E.I}}{\frac{P.l^4}{8.E.I}} \quad (3)$$

$$\frac{f_s}{f_e} = \frac{1}{6l} \quad (4)$$

$$\boldsymbol{f_e = 6l\,.f_s} \quad (5)$$

The deflection for an embedded stress six (6) times greater than that in simple bending multiplied again by the length considered (see relation 5).

In the following, the modeling is done by considering two faces (large surface and on the profile surface) of the blade while using the borassus data for the parameterization.

3. Results and Discussions

Borassus is a wood that does not have knots. The galleries dug by insects weaken the wood. An advantage of this wood is the fact that it is not attackable by insects.

Wood, in general, has knots which constitute stress concentration corners. These concentration zones weaken in terms of elasticity. The relationships between stresses and strains are linear. The planar sections normal to the fibers before deformation remain planar and normal to the fibers during and after deformation.

The 3-point test is mainly used for elastic and ductile materials. Calculating the deflection is complex; in mechanics to obtain a precise result, it is best to consult an engineer. Nevertheless, the three-way tests carried out on three borassus specimens showed results presented as the following illustration (figure 4).

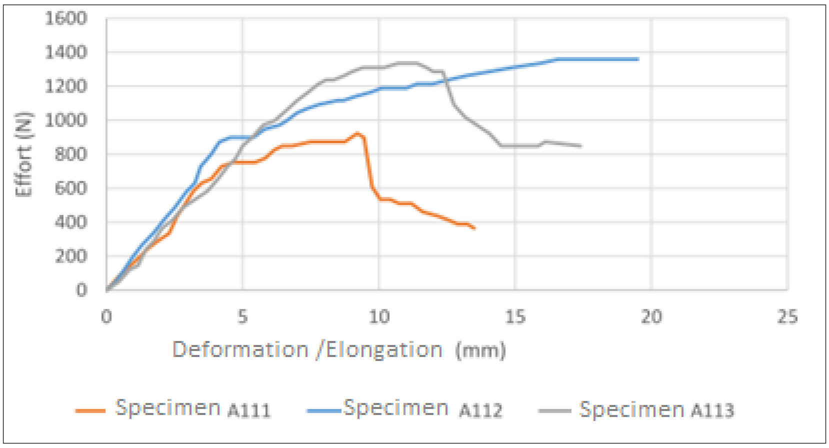
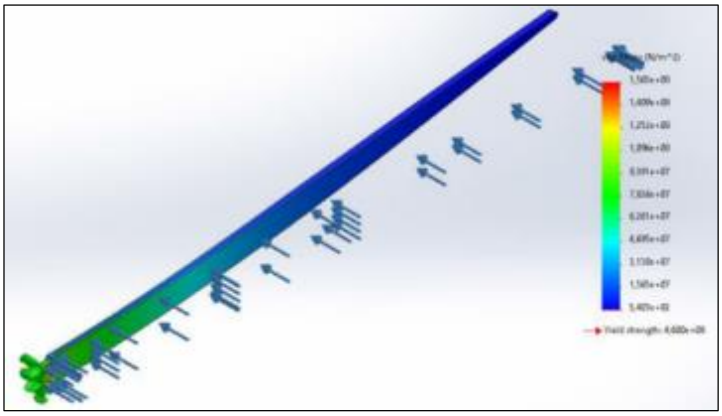


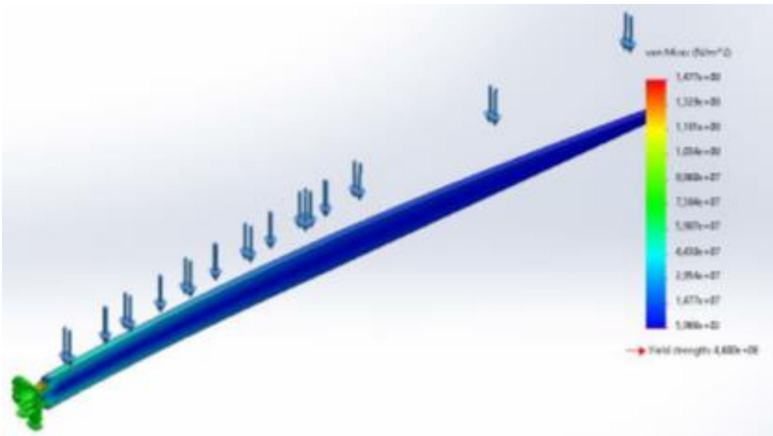
Figure 4 Curves showing the elasticity of borassus /

During the bending test, these different curves are drawn very closely resembling the traction curves. At the start of the curves, the shapes and appearances are similar. The curves are linearly similar up to five (05) mm. After this increase in elasticity towards the highest point, the behavior changes for each test specimen. After the maximum point where the maximum load is reached and the maximum stress is obtained, for a brittle material, the specimen should break. This is not the case, the curve reflects the fact that the test piece is still elastic without breaking.

3.1. Analysis of stress constraints



Strength on the large surface area / Force on large surface



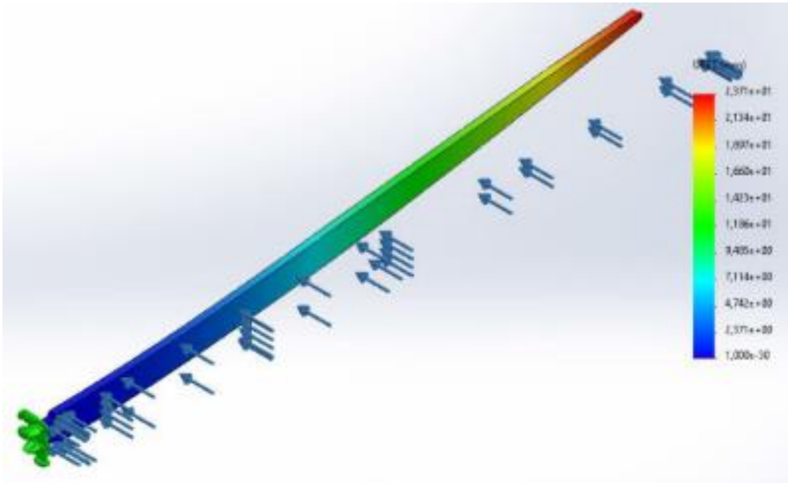
Force on blade profile / Force on the blade profile

Figure 5 Variation of Blade Stresses

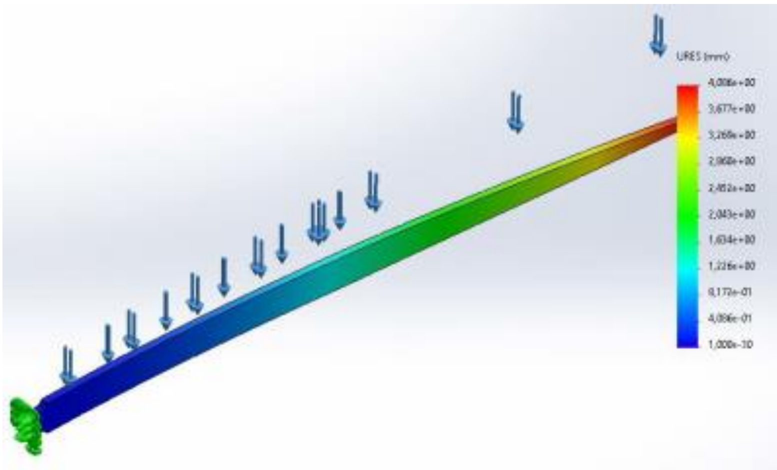
Figure 5 shows the wind force on the blade. This force is represented by the arrows in front of the blade in the two extreme positions. The figure shows the result of the constraints in simulation. The blade undergoes bending stresses whose values are between $5{,}403.10^2$ and $1{,}565.10^8$ $N.m^{-2}$ when the lift is dominant (fig.5.a). The bending stresses have values between $5{,}968.10^2$ and $1{,}477.10^8$ $N.m^{-2}$ when the lift is low (fig. 5.b).

3.2. Deformation analyzes

Figure 6 presents the result of the deformed shapes in simulation. The action of the wind causes the blade to bend. Deformations are between 10^{-3} and 23.71 when the force is exerted on the large surface of the blade (fig.6.a). This value of 23.71 of the blade corresponds to a deflection of 3.95 mm. The deformation is very large. When the force is exerted on the profile of the blade (fig. 6.b), the deformation is small ; it is between 10^{-3} and 4.086.



Deformation caused on the large surface



Deformation caused on the profile surface

Figure 6 Variation in deformations (elongations) of the blade

It appears from these two tests that the blade flexes less when the direction of the force acts on the profile of the blade. But this side is not the best even when using the large surface, the value of the corresponding deformation is not alarming. This shows that borassus is very elastic because of the presence of intertwined fibers and also the absence of knots.

4. Conclusion

This study presents the advantage of borassus subjected to the different phases of the stress on the blades of a wind turbine. In the analysis of the operation where the blade is subjected to bending compounded with torsion, the borassus offers a good advantage in its behavior.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] H. Faida, J. Saadi, M. Khaider, S. El Alami and M. Monkade, "Study and analysis of wind data in order to size a wind energy production system : The case of a site in northern Morocco," Revue des Energies Renouvelables Vol. 13 N°3, p. 477 – 483, 2010.

[2] S. Ouedraogo, K. Lolo, K. Attipou, A. S. A. Ajavon, and S. Tiem, "Assessment of Wind Potential in the Perspective of Water Pumping in Sahelian Area of Burkina Faso," International Journal of Engineering Research & Technology (IJERT), Vol. 9, No. %103, pp. 231 – 243, Vol. 9 Issue 03, March-2020.

[3] P. Jaohindy, Modelling of vertical wind systems integrated into buildings : modelling of the production/building couple, Saint-Dénis : University of La Réunion, 2012.

[4] L. Vadot, "Synoptic Study of the Different Types of Wind Turbines," La Houille Blanche, No. 12, pp. 189-212, March-April 1957.

[5] A. Zeroual and H. Louiza, "Wind Energy : Environmental Aspects and Impacts," Revue des Energies Renouvelables SMEE'10, pp. 27-36, 2007.

[6] R. A. Guettafi, Synthesis on the calculation of applied forces on a wind turbine blade, Tlemcen-Algeria : Aboubakr Belkaïd University, 2017.

[7] M. K. ,. G. M. Velliangiri, "Prediction of Number of Shells and Log Mean Temperature Difference Correction Factor of Shell and Tube Heat Exchangers," International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE), pp. 30-41, Vol 4, Issue 6, June 2019.

[8] K. Lolo, S. Tiem, and S. Banakinao, "Valorization of the Borassus Aethiopum wood behavior in tensile and bending," Research Journal of Engineering Sciences, Vol. 6, No. %111, pp. 20 – 29, 2017.