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PROBLEMS SPECIFIC TO BLADE JUNCTION TO HUBS FOR WIND TURBINES

T.E. Bolfa[1], C. S. Bit[2]
[1] Transilvania University of Brasov, Brasov, ROMANIA, t.bolfa@unitbv.ro, cbit@unitbv.ro

Abstract: *The paper is a theoretical and experimental study concerning the dynamic stress of the junctions of curved blades' ends to hubs in the case of wind turbines. The outcomes of resistance study are presented, regarding the behavior of the extruded curved blade's material towards dynamic stresses.*
Keywords: *wind turbines, blades, hubs*

1. INTRODUCTION: WIND TURBINE STRESS ANALYSIS IN BLADE

Stress analysis in the blade has been made under the circumstances:
a) stress under its own weight;
b) stress under wind pressure and its own weight;
c) stress under wind pressure, centrifugal force and weight.

2. THEORETICAL AND EXPERIMENTAL ASPECTS

Stress under its own weight

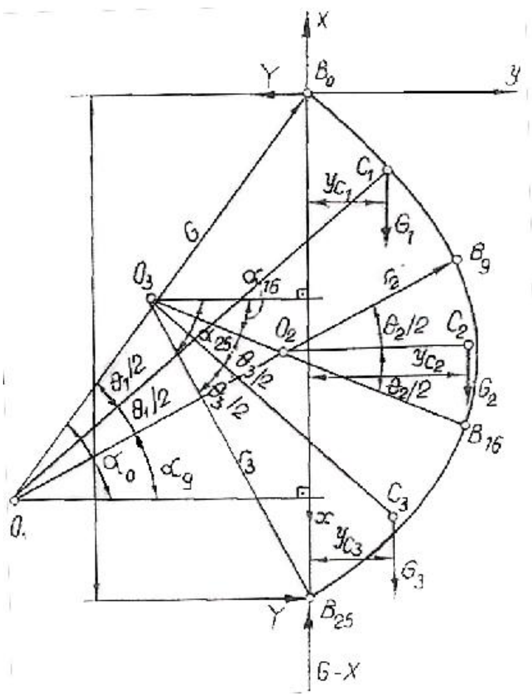

Figure 1

Considering the weight of blade's unit length p= 0,15 MPa, the own weight of the three sections from Fig.1, can be determined with the following relations:

$G_1 = p \cdot r_1 \cdot \theta_1 = 1398{,}4$ N; for $r_1 = 20{,}825$ m and $\theta_1 = 25°{,}650$ (1)

$G_2 = p \cdot r_2 \cdot \theta_2$; for $r_2 = 8{,}224$ m and $\theta_2 = 50°{,}430$ (2)

$G_3 = p \cdot r_3 \cdot \theta_3$; for $r_3 = 13{,}939$ m and $\theta_3 = 39°{,}710$ (3)

The total weight of the blade is:

$G = G_1 + G_2 + G_3 = 3933{,}45$ N (4)

The horizontal reactions from B_0 and B_{25} will have the value Y = 814,55 N.

Regarding the vertical reaction X from the joint B_0 , its value depends on the conditions of making the blade assembly (the temperature of the environment and the real value of the opening 1), the bar being statically indeterminate.

To eliminate the indeterminacy, deformation conditions are imposed additionally. The value of reaction X can be established in advanced conviniently so that can be obtained bending moments as low as possible during the combined action given by its own weight, wind aerodynamic force and centrifugal force. During the calculations, X varies between 1000 and 3000 N.

Stress under wind pressure and its own weight

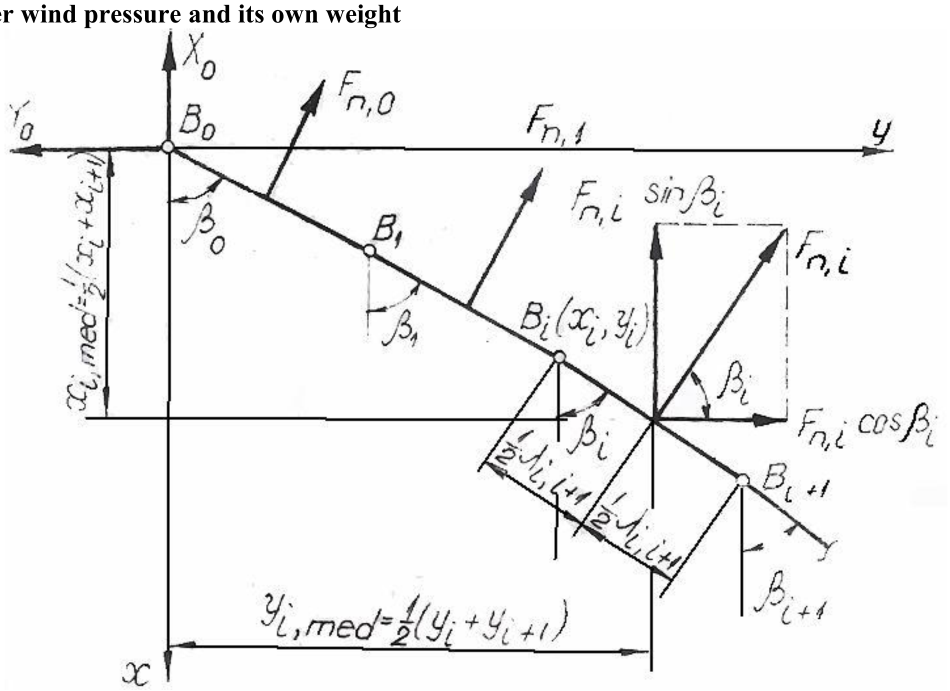

Figure 2

To determine the aerodynamic force, the longitudinal axis of the blade is aproximated with a polygonal line, as shown in Figure 2.

The maximum wind pressure corresponds to the speed S = 40 m/s, when the blade is not moving. It is admitted that the wind blows horizontally, attacking the concave side of the blade, the maximum aerodynamic coefficient c_n = 2,08 corresponding to an incidence angle φ ~ 90°.

The aerodynamic wind force, normal on the side B_i $B_{i+\square}$, applied in its middle can be calculated with the formulas from paper [1].

The horizontal reactions X_{25} and Y_0 result from the equilibrium equations.

According to the calculations from paper [2], the reactions value is obtained Y_{25} = 13992,29 N and Y_0 = 14019,78 N.

To determine the vertical reactions X_0 (indeterminate static unknown factor), the theorem of Menabrea will be applied, canceling the partial differential of deformation energy in relation to X_0. From the condition $\partial U/\partial X_0 = 0$ is obtained the value of the indeterminate static reaction under the effect of maximum aerodynamic pressure X_0 = 9044,63 N.

Stress under wind pressure, centrifugal force and own weight

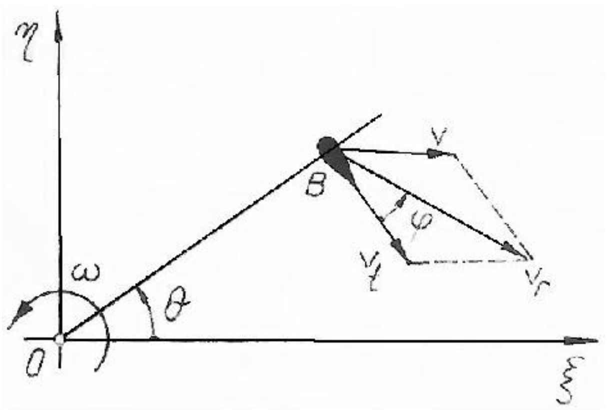

Figure 3

According to the data provided by the beneficiar, the blade rotates with the maximum angular velocity $\omega = 2\pi$ rad/s, and the wind speed of S = 25 m/s.
The normal aerodynamic force on the side $B_i\,B_{i+\square}$ will be as it follows:

$$
\begin{aligned}
&i = 0,1 \dots 8 \dots F_{n,i} = 0{,}059282\; c_{n,i} \cdot v_r'^2 \\
&i = 9 \dots 15 \dots F_{n,i} = 0{,}059151\; c_{n,i} \cdot v_r'^2 \\
&i = 16 \dots 24 \dots F_{n,i} = 0{,}061417\; c_{n,i} \cdot v_r'^2
\end{aligned} \qquad (5)
$$

where $c_{n,i}$ is the aerodynamic coefficient , the relative velocity is given in m/s.
The centrifugal force H_i belonging to the segment $B_i\,B_{i+\square}$, Fig.2, is considered to be applied in its middle, its value could be determined, resulting [1]:

$$
\begin{aligned}
&i = 0,1 \dots 8 \dots H_i = 62{,}5256\; y_{i,med} \\
&i = 9 \dots 15 \dots H_i = 62{,}3868\; y_{i,med} \\
&i = 16 \dots 24 \dots H_i = 64{,}7772\; y_{i,med}\,.
\end{aligned} \qquad (6)
$$

In comparison with the numerical values given in paper [2], the aerodynamic maximum pressure on the concave side of the blade corresponds to the approximate position $\theta = 52°$ (fig.3), adding the centrigual force in position $\theta = 52°$, leading to the highest stress:
$Y_{25} = 56129{,}76$ N; $Y_0 = 53129{,}64$ N.
From the condition $\partial U/\partial X_0 = 0$, results $X_0 = 46393{,}2$ N.

3. CONCLUSIONS

Taking into account the numerical data obtained, can be concluded that the maximum force (the generated tensions) can be taken by the blade (made from A1 6064 material) even in the most detrimental positions.

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