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FINITE ELEMENT ANALYSIS OF THE WHISPER H80 WIND TURBINE'S TOWER

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Abstract: The stresses and the displacements which are appearing in the wind turbines towers are influencing the systems behavior. Due to these, the wind turbines rotor can have a non-linear rotational motion (vibrations can appear in the system). The finite element analysis purpose is to find out the stresses and displacements which are appearing due to the external loads (the wind) and to find the eigen values of the tower, which should avoid the resonance. The study is made for a 1 kW Whisper H80 type wind turbine.

1. Introduction

The external loads which are acting on the wind turbines towers are depending on the wind speed, on the rotors frequency and on the weight of the wind turbines nacelles; all these loads are producing stresses and displacements in the towers body and, due to that, they can influence the behavior of the rotor (vibrations can appear). On the other hand, the eigen values of the tower should avoid the resonance of it (the eigen values should be different than the vibrations produced by the rotor's frequency.

The aim of the finite element analysis is to find out the stresses and the displacements fields in the tower, in the case of extreme functioning conditions (high wind speeds); a second analysis will find out the eigen values of the tower.

The paper presents the finite element analysis of the tower for a 1 kW Whisper H80 type wind turbine (figure 1).

Figure 1: The tower

2. The analysis model

The column type tower is made from three parts of 3 m length each of them (figure 2) [6]. The inner diameter of the tubular tower is 90 mm and the thickness 3.5 mm [6]. The flanges of the three parts are connected through M12 screws [6]. The tower is anchored by 4 wires which are fixing the top element of the tower to the ground.

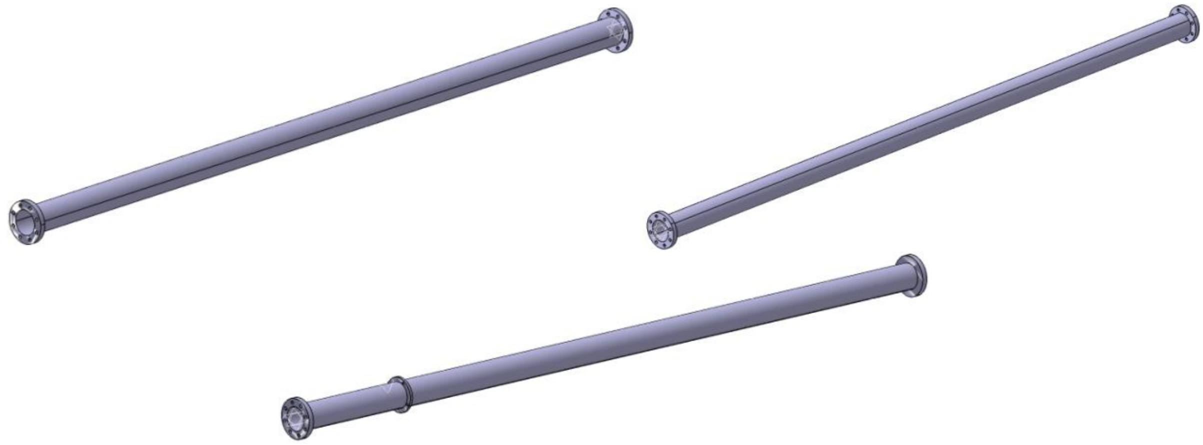

Figure 2: The components of the tower

The calculus model of the tower (the cantilever beam) is presented in the figure 3. The loads which are acting on the tower are represented by:

- F_y is the thrust which is generated by the wind;
- F_z is the mass force of the rotor and the nacelle;
- M_x represents the bending moment created by the wind;
- M_y represents the moment along the rotor's axis;
- M_z is the torsion moment.

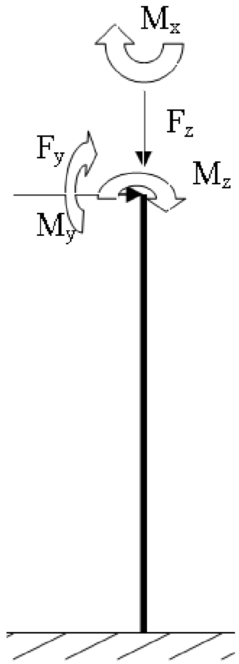

Figure 3: The calculus model of the tower

The maximum acting loads are calculated by using some assumptions [1, 4, 5].

The thrust load [1, 4, 5]

$$F_y = 300A, \qquad (1)$$

where A represents the swept area of the rotor. For the 1 kW Whisper H80 type wind turbine, the rotor's diameter is 3.1 m; it is obtained that F_y=2120 N.

The mass force [1, 4, 5]

$$F_z = (m_{rotor} + m_{nacelle})g, \qquad (2)$$

where: m_{rotor}=45 kg is the rotor's mass; $m_{nacelle}$=42 kg is the nacelle's mass [6]; g=9.81 m/s^2 is the gravity. It results F_z=870 N.

The bending moment [1, 4, 5]

$$M_x = \frac{R}{6} F_y \ , \tag{3}$$

where R=1.55 m is the radius of the rotor; it is obtained M_x= 548 Nm.

The moment along the rotor's axis is [1, 4, 5]

$$M_y = 1.3 \frac{P}{2\pi n R} \eta , \tag{4}$$

where: P=1 kW is the nominal power of thr wind turbine; n=400 rpm is the rotational speed of the rotor; R=1.55 m represents the rotor's radius; η=80% … 90% is the nominal efficiency. Finally it is obtained M_y=0.28 Nm.

The torsion moment is [1, 4, 5]

$$M_z = M_x = \frac{R}{6} F_y \ . \tag{5}$$

The finite elements model of the tower is presented in the figure 4. The loads which are acting on is are represented by F_y, F_z, M_x, M_y, M_z and the gravity g [2, 3].

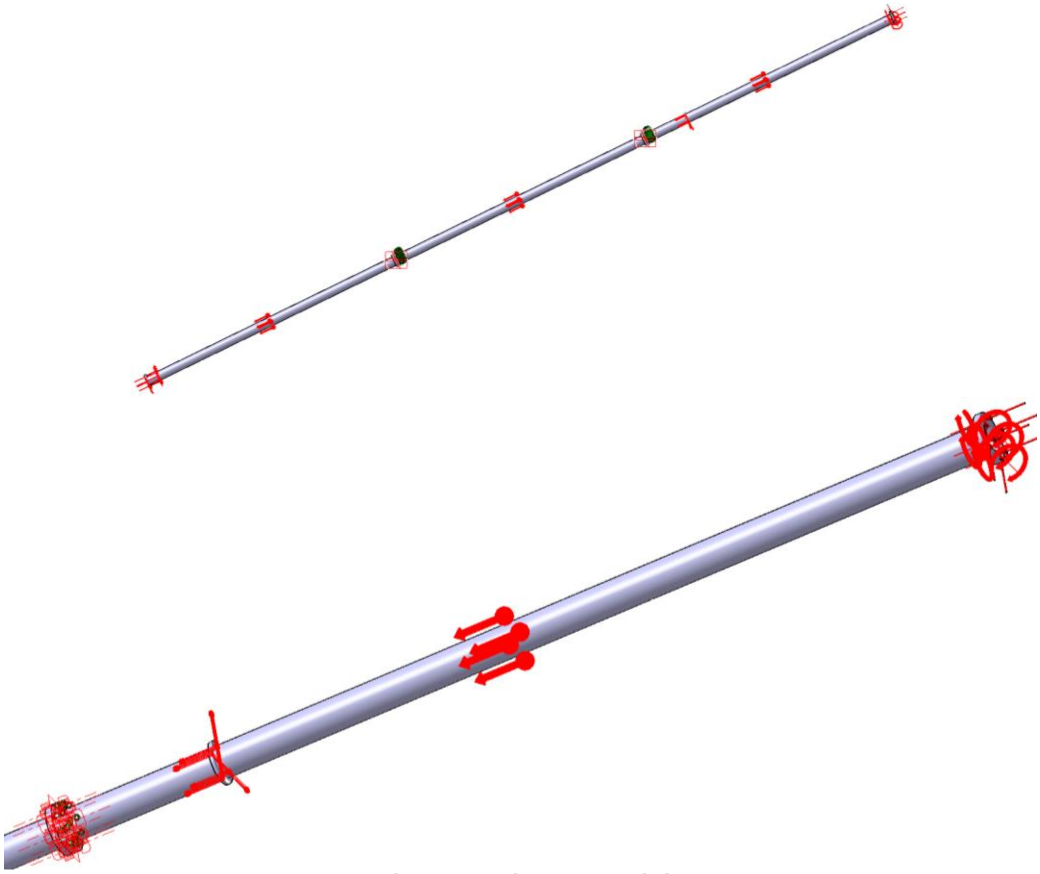

Figure 4: The FE model

3. The analysis results

The analysis results are presented in the figure 5. The maximum, values of the von Mises stresses is 554 MPa and there are obtained in the area where the tower is anchored by the 4 wires.

The frequency analysis results (the frequency shapes) are presented in the figure 6.

The frequency values are presented in the figure 7.

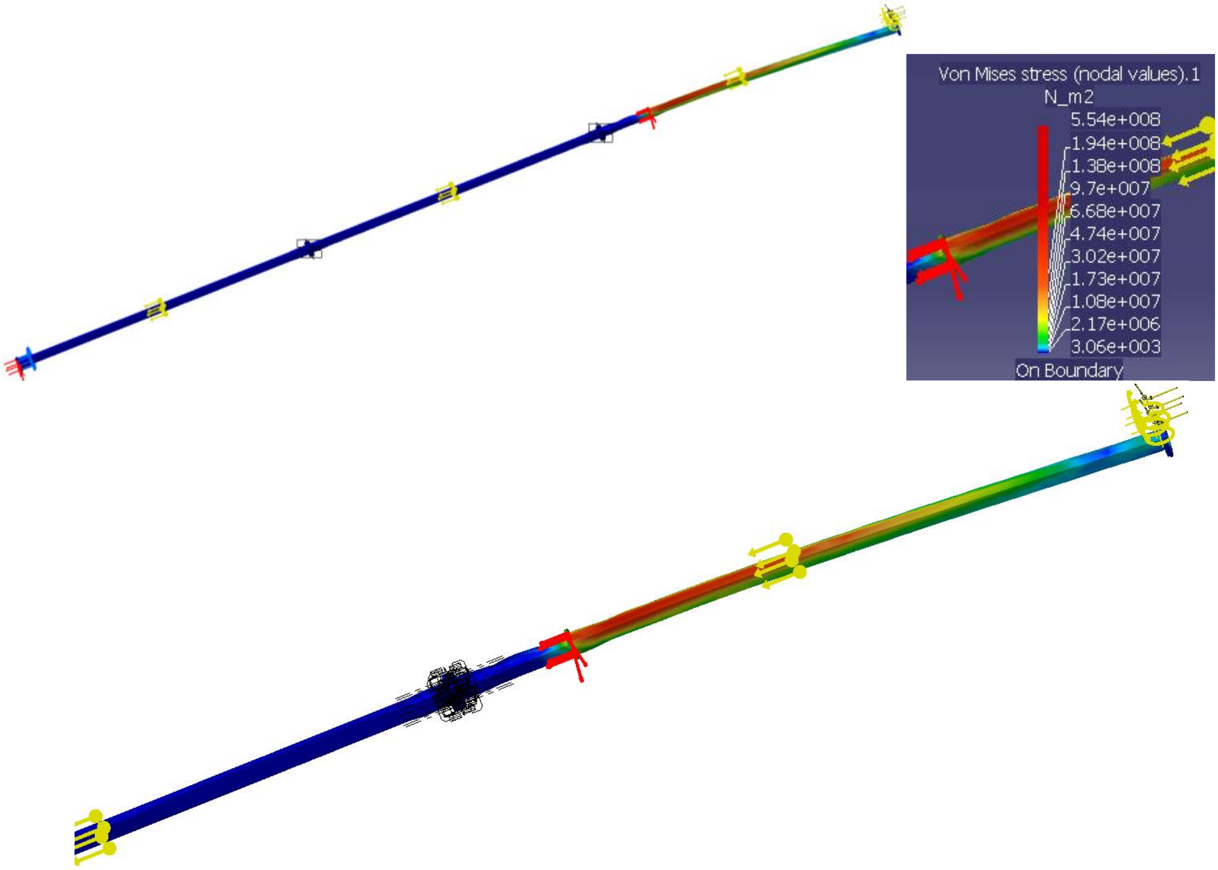

Figure 5: The von Mises

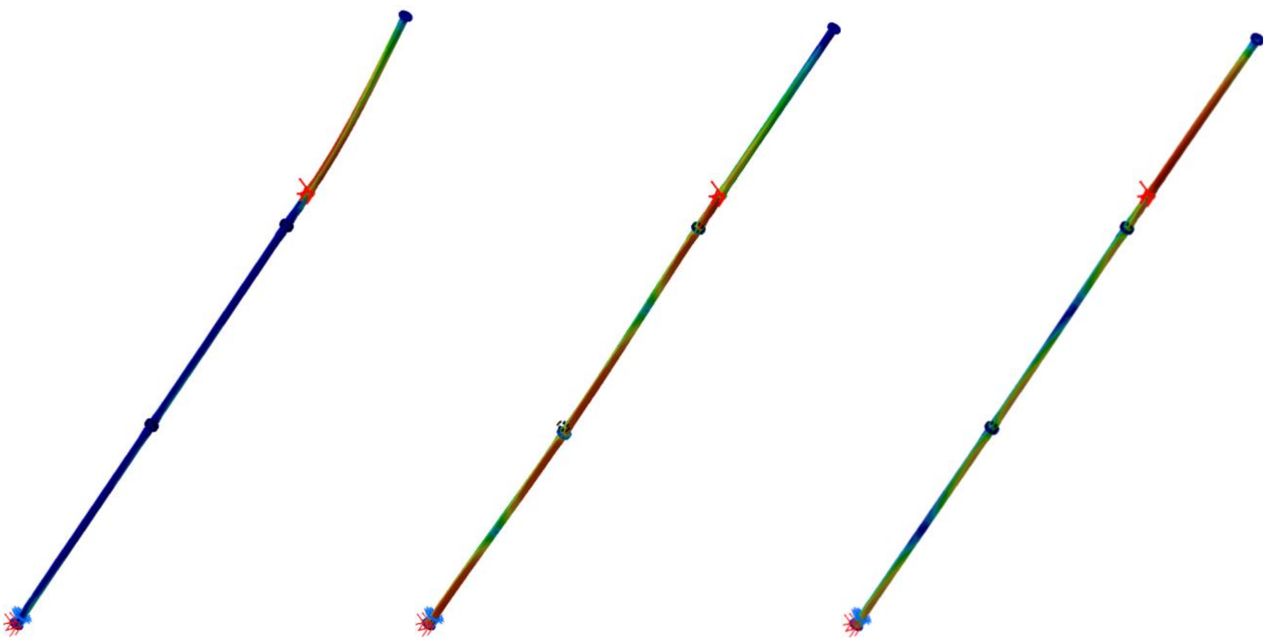

Figure 6: The frequency shapes

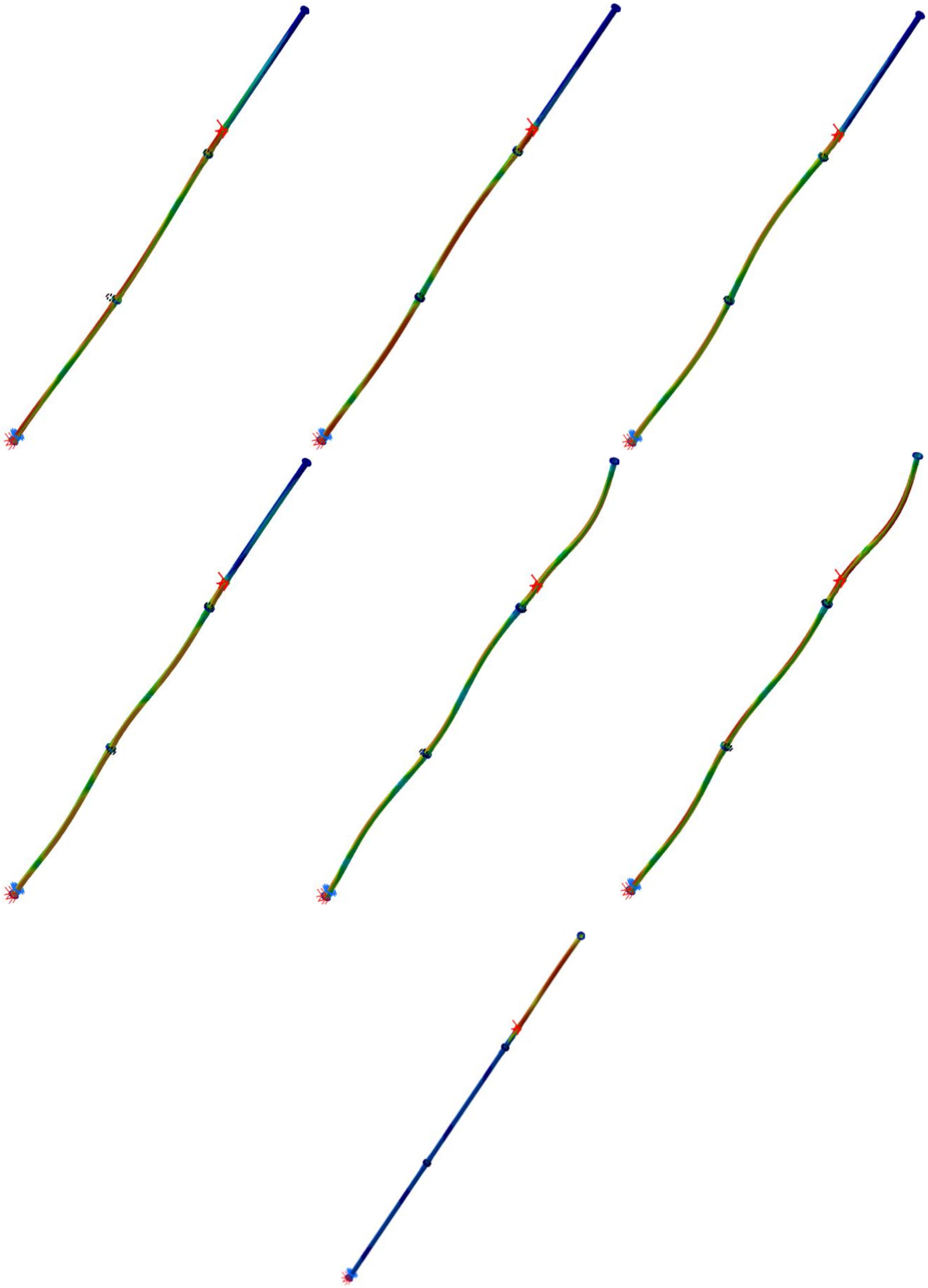

Figure 6: The frequency shapes

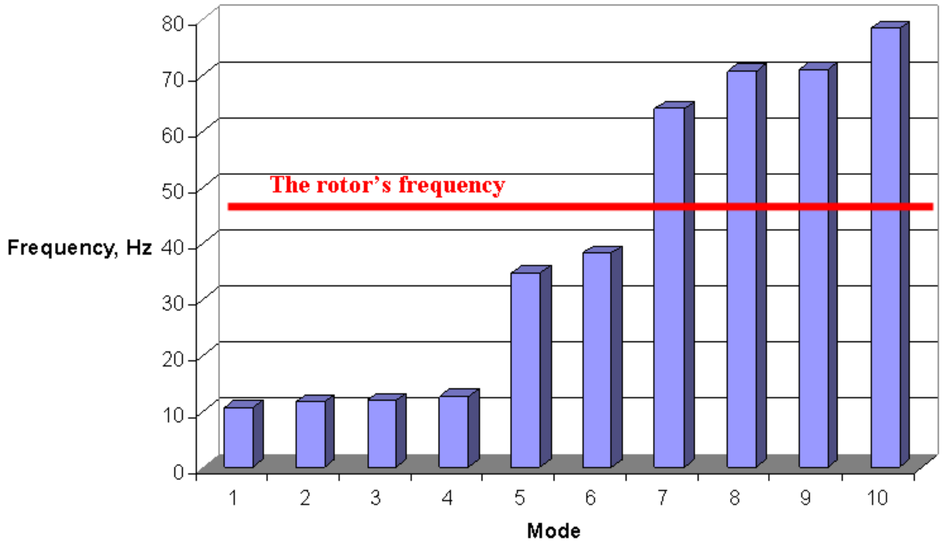

Figure 7: The frequency values

4. Conclusions

The finite elements analysis of the wind turbines towers is important to find out the distribution of the stresses, the frequency shapes and values. The maximum values of the stresses are obtained in the area where the tower is anchored by the 4 wires.

The frequency shapes and their values are influencing the tower's behavior in the case of earthquakes and there are useful to find these values in order to avoid the resonance.

It can be observed that the frequency values are different than the rotor's frequency (41.88 Hz [6]), so, according to that point of view, the resonance is avoided.

References

[1] I. Bostan a.o. Sisteme de Conversie a Energiilor Regenerabile. Editura Tehnica-Info, Chisinau, Republica Moldova, (2007).
[2] M. T. Lates. Metoda Elementelor Finite. Aplicatii. Editura Universităţii Transilvania din Braşov, (2008).
[3] G. L. Mogan, S. L. Butnariu. Metoda Elementelor Finite. Editura Universităţii Transilvania din Braşov, (2007).
[4] B. Sorensen, Renewable Energy, Second Edition, Academic Press, Roskilde – Denmark (1997).
[5] ***, Guidelines for Design of Wind Turbines, Second Edition, Det Norske Veritas and Risø National Laboratory – Denmark (2002).
[6] ***, Whisper H80 type wind turbine, Technical Manual.