ANNALS of the ORADEA UNIVERSITY.

Fascicle of Management and Technological Engineering, Volume VI (XVI), 2007

STRESSES IDENTIFICATION WITH FEM IN PORTABLE VERTICAL WIND TURBINES STRUCTURES

Mihai-Tiberiu LATEŞ
"Transilvania" University of Braşov, Product Design and Robotics Department,
latesmt@unitbv.ro

Keywords: wind energy, portable vertical wind turbine, FEM, mechanical stress.

Abstract: The objectives of the paper are proceeding from the main aim: the identification of the portable vertical axis wind turbine type which assures less value of the equivalent stresses and displacements, according to the same generated output power, in the same wind conditions. According to the aim, the paper's objectives are referring on: the identification of the most used small vertical axis wind turbines; the modelling of the wind data; the vertical axis wind turbines structures mechanical modelling; the stress and displacements fields identification in the most used vertical wind turbines structures.

1. Introduction

The sustainable energy source, the wind, is technically easy to govern and as opposed to nuclear power they present no threat and there is no need of controlling their misuse. They offer an inexhaustible energy potential and are available immediately.

Wind energy will not only be able to contribute to securing European energy independence and climate goals in the future, it could also turn a serious energy supply problem into an opportunity for Europe in the forms of commercial benefits, technology research, exports and employment.

The capacity of European power systems to absorb significant amount of wind power is determined more by economics and regulatory rules than by technical or practical constraints. Already today a penetration of 20% of power from wind is feasible without posing any serious technical or practical problems [1, 2, 4, 5].

Considering the rotor's axis position, the wind turbines can be classified in horizontal axis wind turbines and vertical axis wind turbines.

The paper offers useful conclusions regarding the stress distribution in the portable vertical axis wind turbines structures and, according to this, application recommendations are generated.

2. The vertical wind turbine

For the vertical wind turbines, the axis of rotation is perpendicular to the direction of the wind; the main vertical wind turbines sollutions are based on the *Darrieus* and *Savonius* rotors (Figure 1).

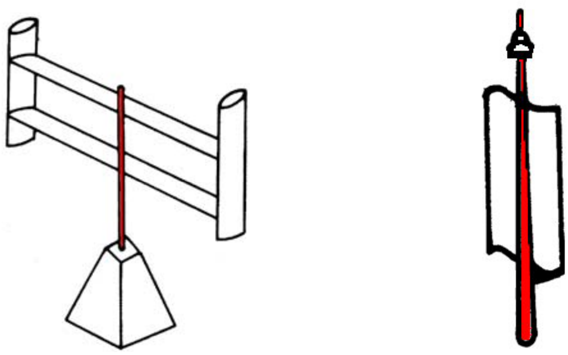

Figure 1: Darrieus and Savonius rotors

The main advantages of the vertical wind turbine are referring on [1, 2, 4, 6]:

- it accepts the wind from any direction (so, simplify the design and eliminates the problem imposed by gyroscopic forces on the rotor of conventional machines as the turbines yaw into the wind);
- permits mounting the generator and gear at the ground level;
- according to the environmental conditions, the vertical axis wind turbine has a small working space – smaller than the horizontal axis wind turbine – and it can be applied in the case of small output power values, on the houses roofs.

The disadvantages are represented by [1, 2, 4, 6]:

- requires guy wires attached to the top for support, which may limit its application, particulary for offshore sites;
- has less value for the efficiency.

The power available from the wind is a function of the cube of the wind speed [1, 3, 4, 6]

$$P = 0.5 \rho v^3 A C_p \qquad (1)$$

where: ρ represents the air density (ρ=1.2255 kg/m^3 at the see level); v – the wind velocity; A – the rotor area; C_p – the power coefficient [1, 3, 4, 6]

$$C_p = \eta_m \, \eta_e \, , \qquad (2)$$

where η represents the efficiency (electrical or mechanical) with η_e=0.97 … 0.98 and η_m=0.95 … 0.97.

The rotor area depends on the rotor type and dimensions; for the *Savonius* type

$$A = 2H\pi R \, ; \qquad (3)$$

For the *Darrieus* type

$$A = 2H\pi r \, . \qquad (4)$$

The torque at the rotor is obtained according to the relations:

$$T = 2FR \, , \qquad (5)$$

$$T = 2F(r + L), \qquad (6)$$

where R represents the *Savonius* profiles radius, r – the *Darrieus* cylinders radius; L – the distances between the *Darrieus* rotors axis and the cylinder surface.

According to the generated power, the torque at the rotor is

$$T = 9.55 \cdot 10^6 \frac{P}{n} \, , \qquad (7)$$

where n represents the rotational velocity of the rotor's shaft

$$n = \frac{60}{\pi} \frac{v}{2R} \, , \qquad (8)$$

$$n = \frac{60}{\pi} \frac{v}{L + 2r} \, , \qquad (9)$$

for *Savonius* and *Darrieus* rotor, respectively.

3. Application for a small vertical wind turbine

Portable wind turbines are characterized by small values of the generated power (less than 2 kW) and are used for small energy requirements (in domestic applications). Figure 2 shows the power requirements for a domestic application of a small vertical wind turbine (in the case of a holyday house); there are considered the main electrical devices: a fridge, a TV, a radio, a washing machine, a PC, a printer, lights and a reserve required power (totally 1.1 kW).

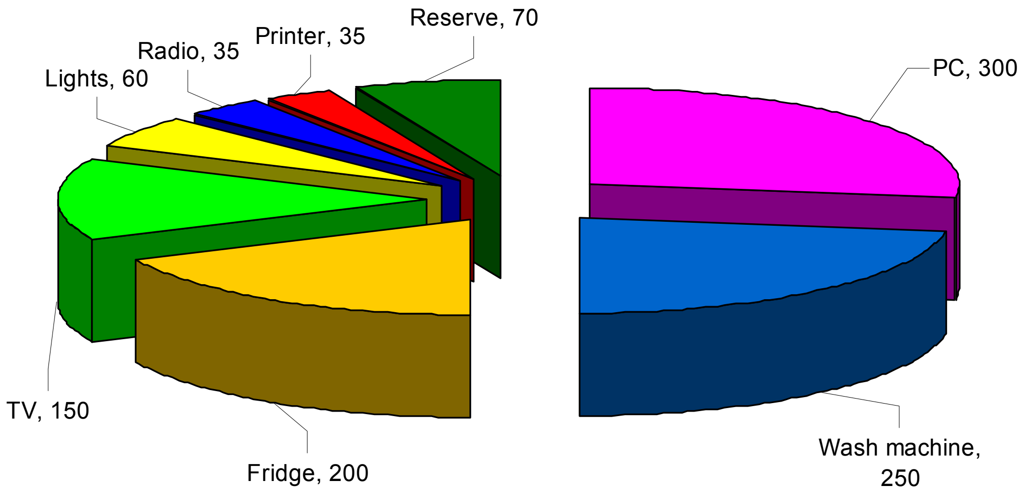

Figure 2: Required power for a hollyday house

According to the relation (1), the required swept area for a wind turbine it has a variation with the wind speed, shown in Figure 3 (for η_e=0.975, η_m=0.96 and ρ=1.2255 kg/m^3); for a rated wind speed v=15 m/s the swept area value is A=5.682766 m^2.

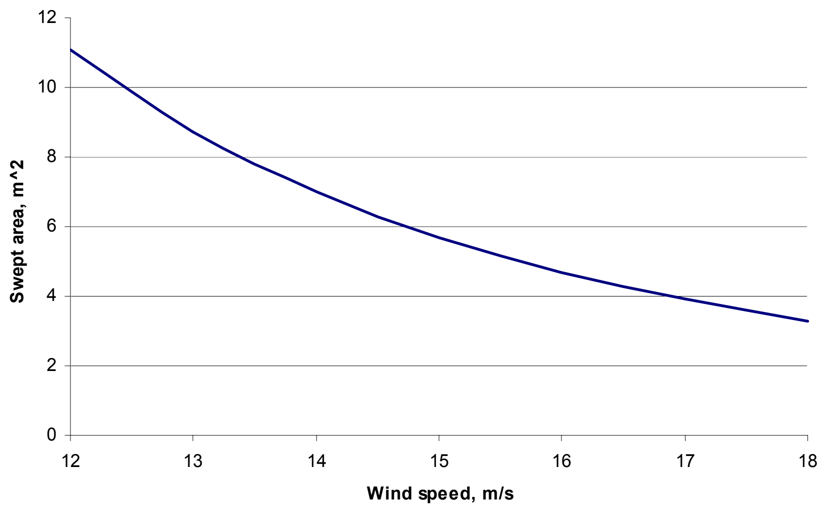

Figure 3: Required swept area variation

Considering the dependencies between the rotors height H and the radius R and r: H/R=6 for *Savonis* and H/r=20 for *Darrieus*, H= 2400 mm; R=400 mm.
The L dimension of the *Darrieus* rotor will be calculated according to the condition that the same torque T should acting on each wind turbine; it means that

$$2R = L + 2r \qquad (10)$$

so, $L = 2(R - r) = 2(400 - 210)$; it results L=380 mm.

The rotational speed of the rotor (same for the *Savonius* and the *Darrieus* rotor) is

$$n = \frac{60}{\pi}\frac{v}{2R} = \frac{60}{\pi}\frac{15000}{2\cdot 400}, \; n\text{=358.09 rot/min.} \qquad (11)$$

The same acting torque is given by

$$T = 9.55\cdot 10^6 \frac{P}{n} = 9.55\cdot 10^6 \frac{1.1}{358.09}, \; T\text{=29336.2 Nmm.} \qquad (12)$$

The acting forces, for *Savonius*

$$F = \frac{T}{2R} = \frac{29336.2}{2 \cdot 400}\text{, } F\text{=36.67 N} \quad (13)$$

and for *Darrieus:*

$$F = \frac{T}{2(r+L)} = \frac{29336.2}{2(210+380)}\text{, } F\text{=24.86 N.} \quad (14)$$

4. Finite elements modelling

The rotors are modeled as different parts in CATIA's Part module (Figure 4) and then, the models are transferred to the finite elements module of CATIA's software and the finite elements are generated (the materials used are represented by carbon fibre).

There are modeled the connections to the ground and, the external loads (the gravity and the loads generated by the wind) – Figure 5.

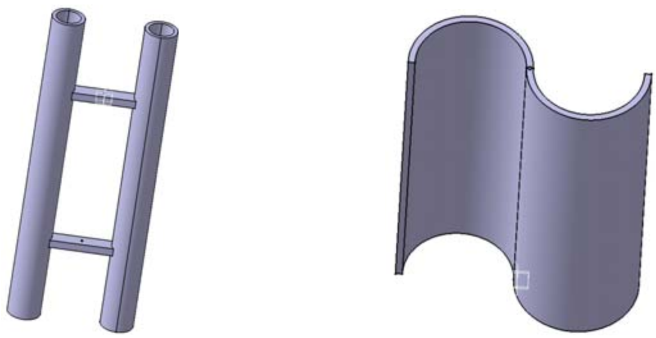

Figure 4: Darrieus and Savonius rotors geometrical models

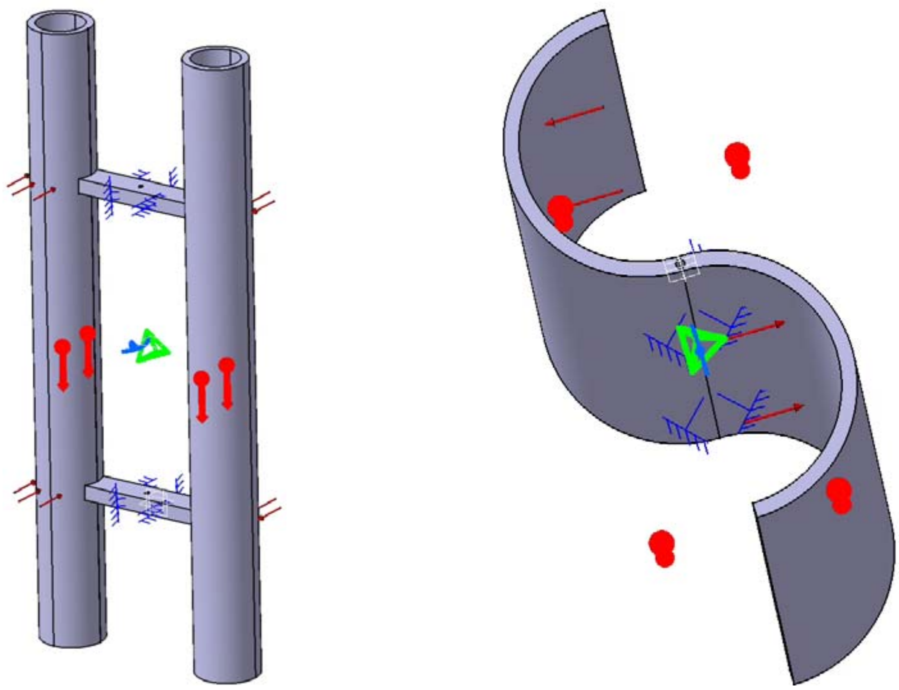

Figure 5: Darrieus and Savonius rotors finite elements models

Figure 6 and 7 shows the stresses and displacements fields for the *Darrieus* and *Savonius* rotors, respectively; as values, the *Savonius* type rotor assures less stresses values. The displacements values are, almost, identically (Figure 8 and 9).

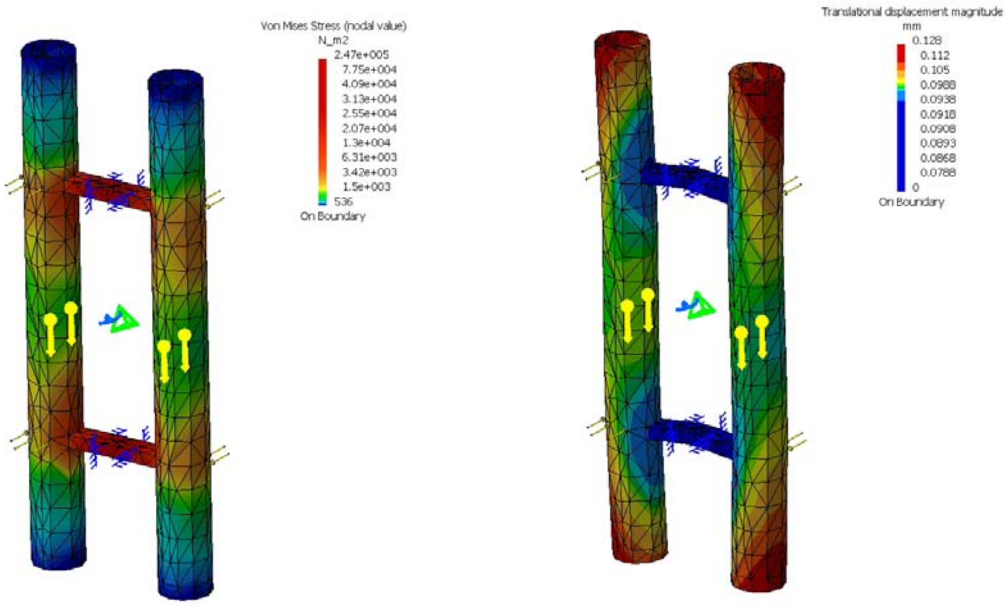

Figure 6: Stress and displacements fields for the Darrieus rotor

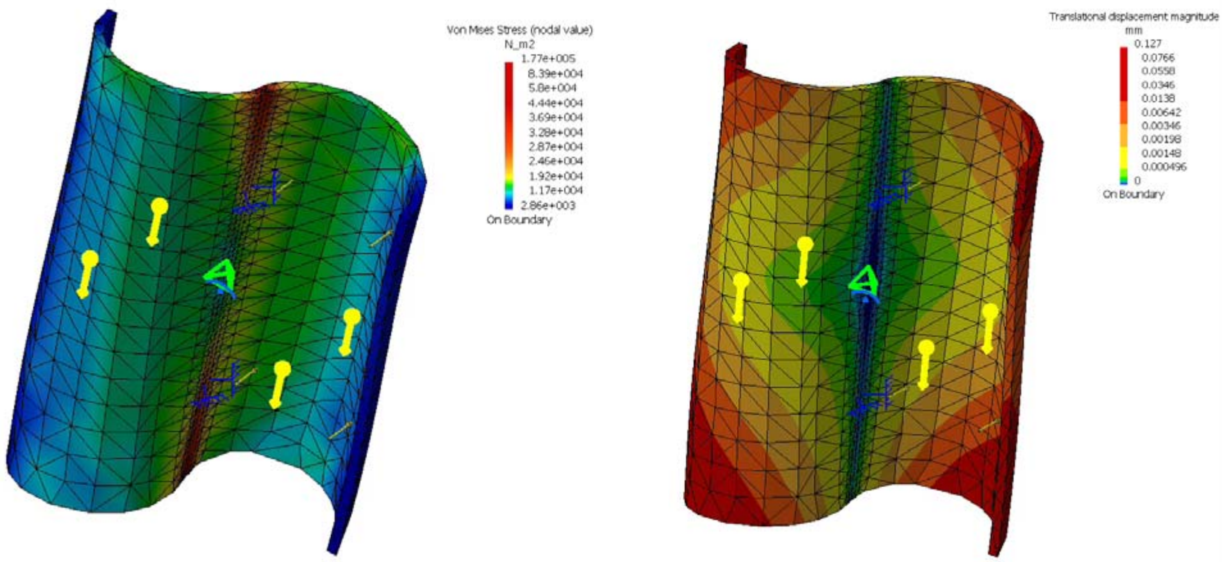

Figure 7: Stress and displacements fields for the Savonius rotor

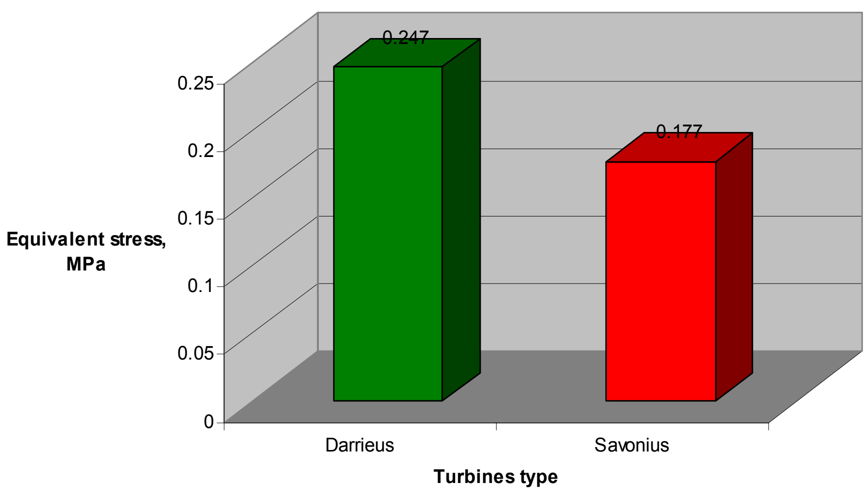

Figure 8: Equivallent maximum stresses vallues

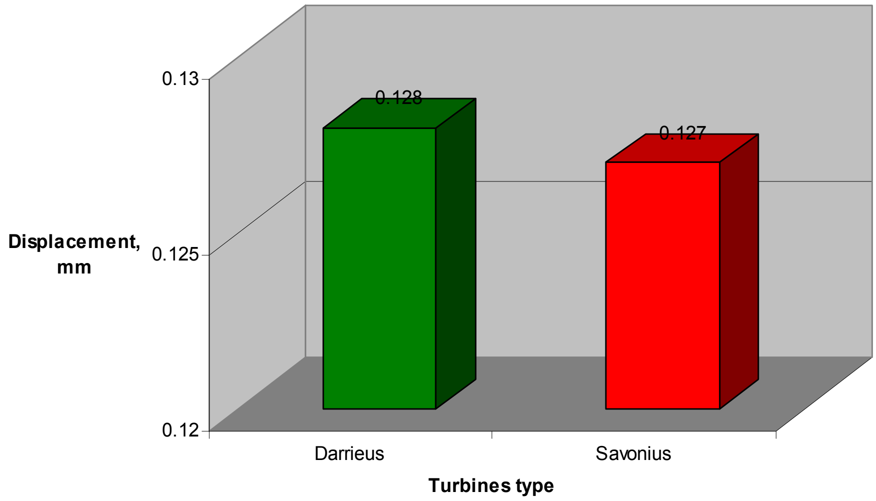

Figure 9: Displacements vallues

5. Conclusions

The vertical axis wind turbines, comparatively with the horizontal axis wind turbines, have less value for the efficiency but, the main advantage of the vertical axis wind turbines application results from the environmental conditions (the vertical axis wind turbines have a small working space – smaller than the horizontal axis wind turbine – and they can be applied in the case of small output power values, on the houses roofs).

Regarding the design typology, there are 2 main variants of vertical wind turbines: the *Darrieus* type and the *Savonius* type. The problem is, to establish the solution which assures small values for the equivalent stresses, when the same torque is acting. The answer is given by the finite elements analysis of the structures: from the mechanical stresses point of view, the *Savonius* type rotor assures less stresses values.

References

[1] E. Hau, Windkrafttanlagen, Springer Publisher, Munchen (2003).
[2] F. Iov, Advanced Tools for Modeling, Design and Optimization of Wind Turbine Systems, Riso Laboratory, Aalborg – Denmark (2002).
[3] M. T. Lates, Aspects regarding the small power type windmills implementation in Romania, Proceedings of International Conference on Sustainable Energy, 7 – 9 july, 2005, Braşov, România.
[4] M. T. Lates, Aspects regarding the offshore implementation of wind turbines in Romania, vol.VII, Tom I, International conference proceedings of TEHNONAV 2006, Constanta, 2006, pp.105-110.
[5] M. T. Lates, Stresses identification in offshore wind turbines structures, in Proc. TEHNONAV 2006 International conference, vol.VII, Tom I, Constanta – Romania (2006), pp. 111-116.
[6] B. Sorensen, Renewable Energy, Second Edition, Academic Press, Roskilde – Denmark (1997).