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THE INFLUENCE OF THE NUMBER OF LEVELS ON THE BEHAVIOR OF A VERTICAL AXIS WIND TURBINE WITH TWO PAIRS OF BLADES AND PERIODIC AERODINAMIC COUPLINGS

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ABSTRACT

Vertical-axis wind turbines (VAWT) with 1 pair of semi-cylindrical and overlapping blades have an uneven torque. The work is based on wind tunnel experiments on experimental models that still contain a couple of auxiliary blades. The model has several levels and constructively the role of the blades changes from one level to another. The experiments in the wind tunnel confirm the important effect of the levels with changing the role of the blades until the complexity of accomplishment increases.

KEYWORDS: wind turbines, wind tunnel, wind speed

1. Introduction

The paper continues the search for practical methods to slightly increase the efficiency but reduce the disadvantages of the wind turbine Savonius (s-rotor). A thing mentioned in many works is that the wind turbine has the advantage of constructive simplicity, independence from the wind direction and high solidity. That is why it is suitable for aircraft and pumping systems. The evolutions in the field of electrotechnics and electronics make it possible to use this wind turbine also in the generation of electricity by converting it into mechanical work and then converting it into electricity. The development of low and medium power electronic converters, at affordable prices, causes this disadvantage to fall, and at the output of the inverter system a constant continuous voltage is obtained in order to charge a battery. There is still the cancellation of an important obstacle, namely, the wind behaviour at high wind speeds. There have been found some solutions such as shading, tilting or more complex transformation of the wind into a sphere or a cylinder. There would also be a final disadvantage, namely the unevenness of the torque on a rotary, which in a two-bladed wind turbine is obvious, in this case there is a danger that the wind turbine will lock in the minimum torque position and not start the rotation.

In this case the disadvantages of the turbine are highlighted, and it is the low rotational speed which makes it necessary for special generators with a large number of pole pairs or mechanical speed multiplication systems. The low rotational speed and the wind speed make the wind directly dependent on the speed of the wind, resulting in brown variations of the generated voltages.

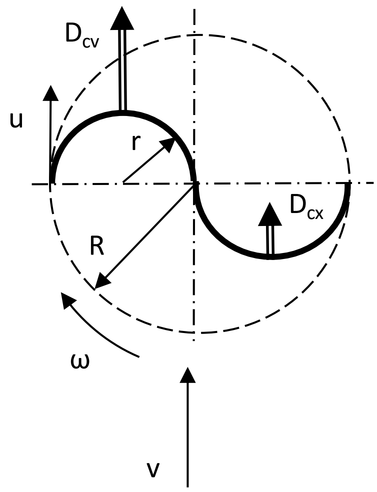

Fig. 1. *Scheme of “S-rotor” turbine with one pair of cups (1PC)* [1]

This problem is addressed in this paper to find a simple method to standardize the torque of the S-rotor wind without negatively affecting the mentioned advantages. A classic way to standardize torque is to introduce a flywheel, which is very useful when rotating at constant speed. This method brings a major disadvantage in increasing the couple when

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starting and accessing an existing disadvantage that is sought to be minimized.

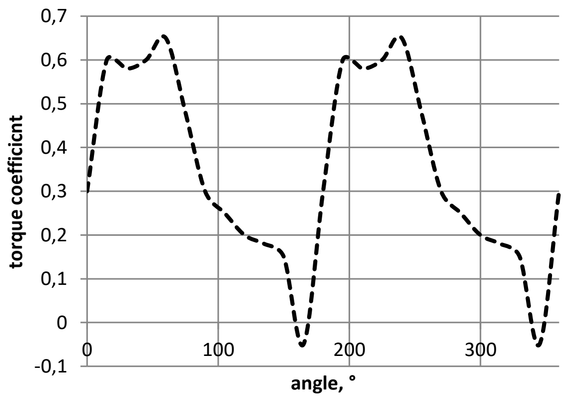

***Fig. 2.** Torque for "S-rotor" (1PC) versus the rotation angle plot* [2]

In this paper we analyse the influence of multi-storey (pseudo-storey). It is considered a wind turbine Savonius with 4 semi-cylindrical cups equidistant.

Normally this structure ensures the fast and efficient starting of the S-rotor, but the load operation is defective due to the effect of the cup on the return stroke when the resistive force is high and repeated more often (at 90°).

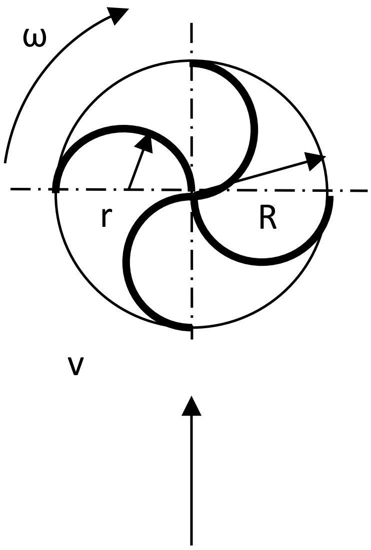

***Fig. 3.** "S-rotor" with one level and two pair of cups (2PC)*

The multi-storey wind turbine with three stages offers a starting solution but does not solve the load behaviour. Each stage is offset to 120° from the previous one and, in this way, the couple is uniformized, but their starting is favoured by eliminating the dead point.

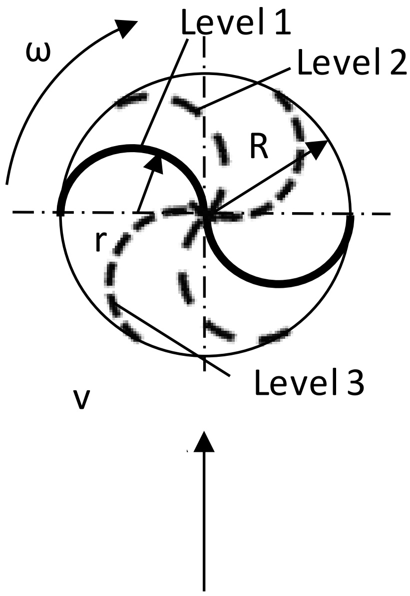

***Fig. 4.** S-rotor with 3 stage and 3PC (1PC/1S)*

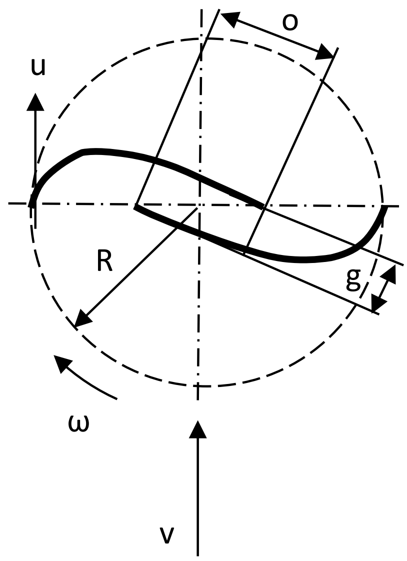

***Fig. 5.** "S-rotor" of blades Benesh with gap (g) and overlay (a)* [3]

The Benesh (Fig. 2) type structure, meaning the two classic couplings no longer form an S, but the cups become separate, and thus it brings great advantages for the load-bearing operation on balance depression behind the cup at the reverse stroke on account of directing an overpressure air stream on the direct stroke

The power of wind is calculated with relation:

$$P = 0{,}5\rho A v^3 \quad (1)$$

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2. Experimental conditions

The power extracted from a wind power by a VAWT "S-rotor" turbine depends on Drag force [4]:

$$D = 0,5C_D\rho(v-u)^2A \quad (2)$$

Where u is speed of blade and Power extracted is:

$$P = Du = 0,5C_D\rho v^3(1-\frac{u}{v})^2\frac{u}{v} \quad (3)$$

When:

$$\lambda = TSR = u/v \quad (4)$$

The extracted power is:

$$P = 0,5C_D\rho v^3(1-\lambda)^2\lambda A \quad (5)$$

And the conversion efficiency is:

$$\eta = \frac{P}{P_v} = \frac{0,5\rho(v-u)^2C_D uA}{0,5\rho A v^3} \quad (6)$$

$$\eta = \frac{(v-u)^2C_D u}{v^3} \quad (7)$$

Notations:
v - wind velocity(input), m/s
u - tip blade speed, m/s
R - the radius of the disc base, m
o - overlap, m
d - width of blade, m
h - height of blade, m
ω - angular speed, radians/s
λ - specific speed
C_p - power index
D_{cv} - drag force for concave surface
D_{cx} - drag force for convex surface

Abbreviations:
VAWT - vertical axes wind turbine
TSR - tip speed ratio
PB - pair of blades
dc - direct current
Re - Reynolds number
EM - experimental model
VCC - positive potential
GND - ground potential
EM - experimental model

3. Results

The work aims to alternate structures on an experimental model (EM) of "S-rotor" Benesh type cup structures (Fig. 2) on different floors by a simple and efficient method of periodically aerodynamically coupling the opposite blades, by overlapping and creating a pseudorandom S-rotor structure with two pairs of blades (2PB). This structure is shown in Fig. 4 and Fig. 5. In the situations presented for the loading of the experimental models, it used a multiplier (3.5x) and a 5V Dc generator.

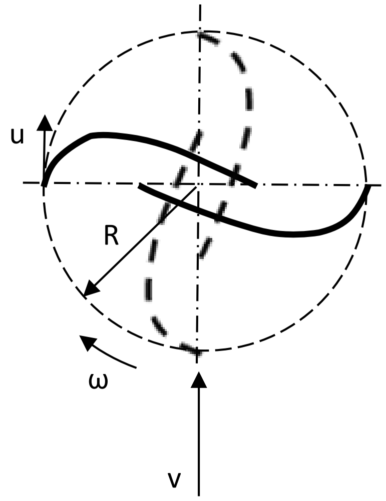

Fig. 6. *"S-rotor" with 2 level an 1PC per level in Benesh profile*

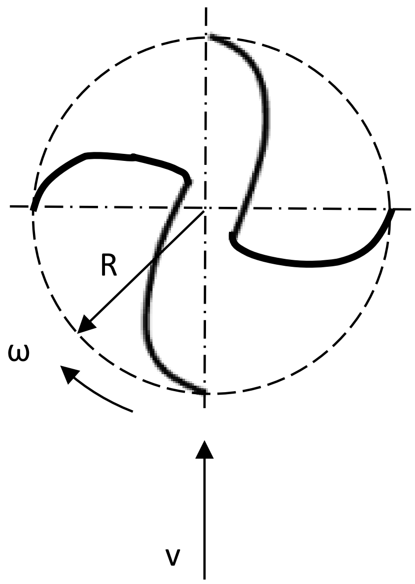

Fig. 7. *"S-rotor" through the real profile of the turbine with 2PC*

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The test conditions are coded as follows: N (no load mechanical or electrical), M (mechanical load multiplier x3.5 and rotor of dc generator), ML (idem M plus a white LED), ML1 (idem ML plus a 1 kΩ resistor connected VCC to GND), ML1.5 (idem ML plus a 1.5 kΩ resistor connected VCC to GND), ML2 (idem ML plus a 2 kΩ resistor connected VCC to GND).

The experiments were carried out on a wind tunnel with a wind speed between 0...4.5 m/s (measured with LCA6000).

Fig. 8-13 represents the graphs of the behaviour of the models of the experiments.

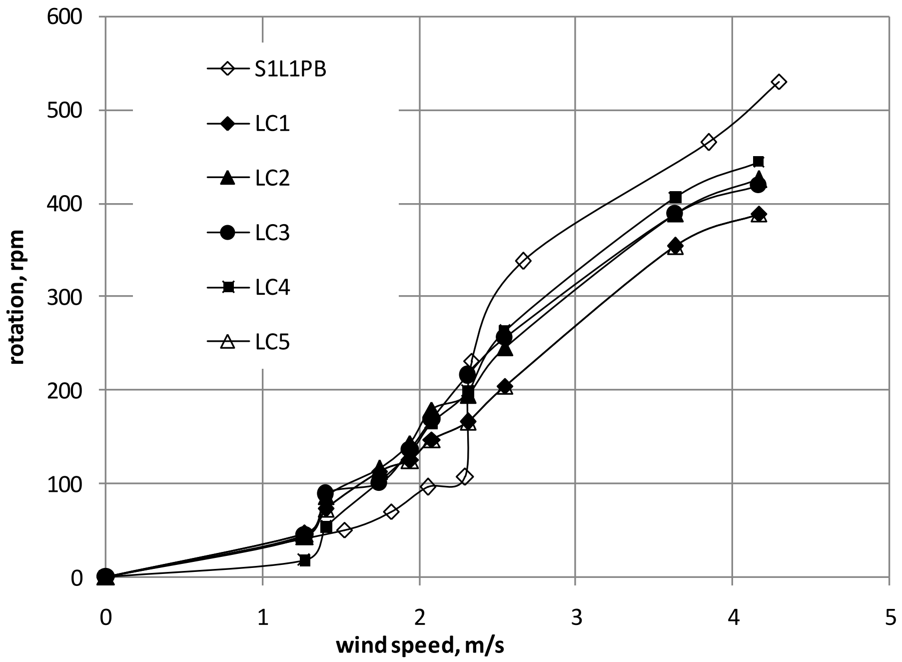

Fig. 8. *Behaviour of experimental model at N (no load)*

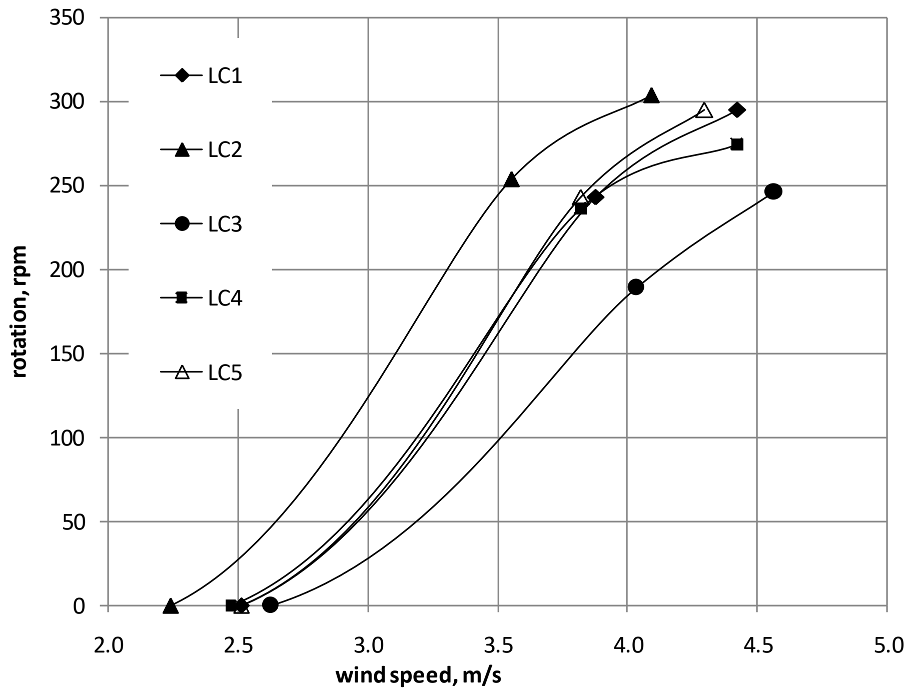

Fig. 9. *Behaviour of experimental models at load M*

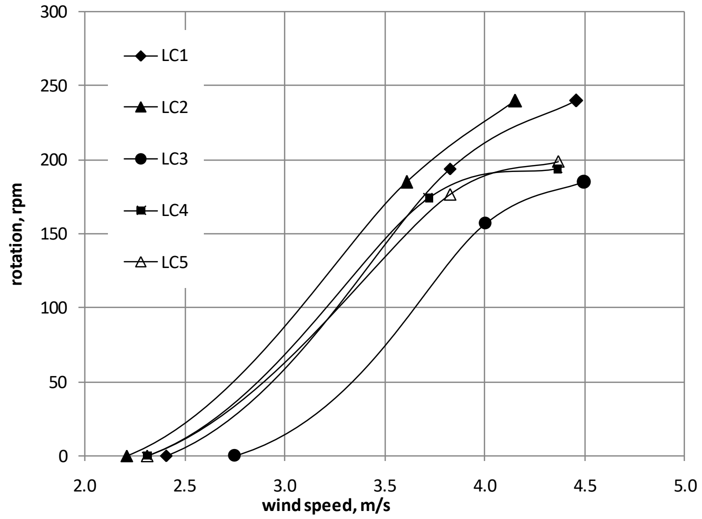

Fig. 10. *Behaviour of experimental models at load ML*

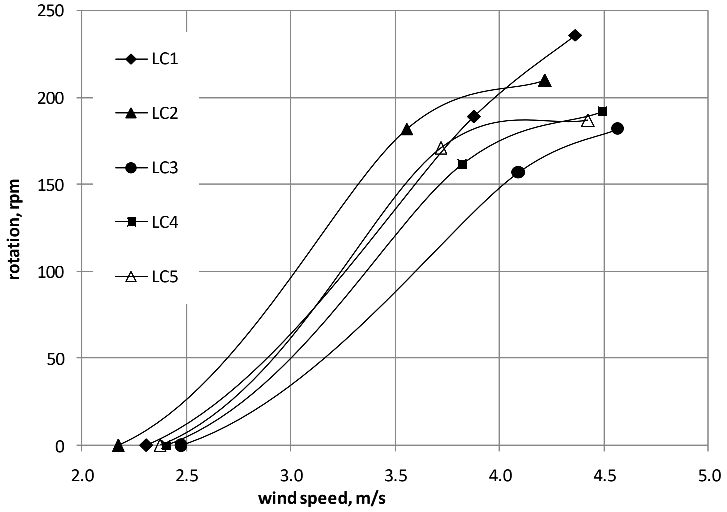

Fig. 11. *Behaviour of experimental models at load ML1*

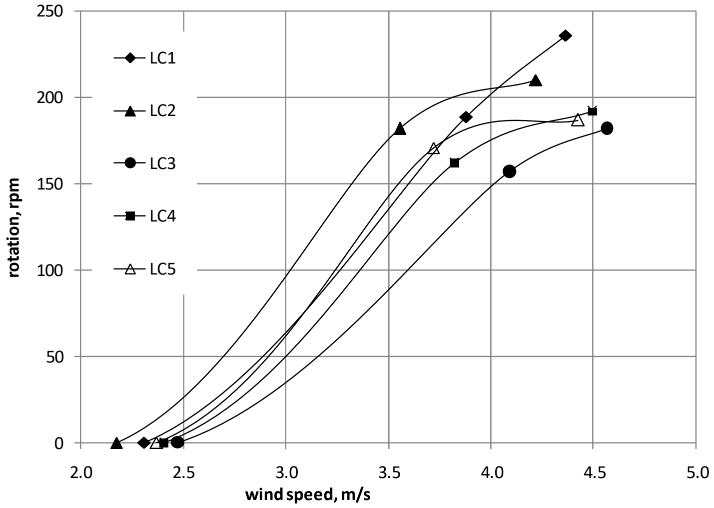

Fig. 12. *Behaviour of experimental models at load ML1.5*

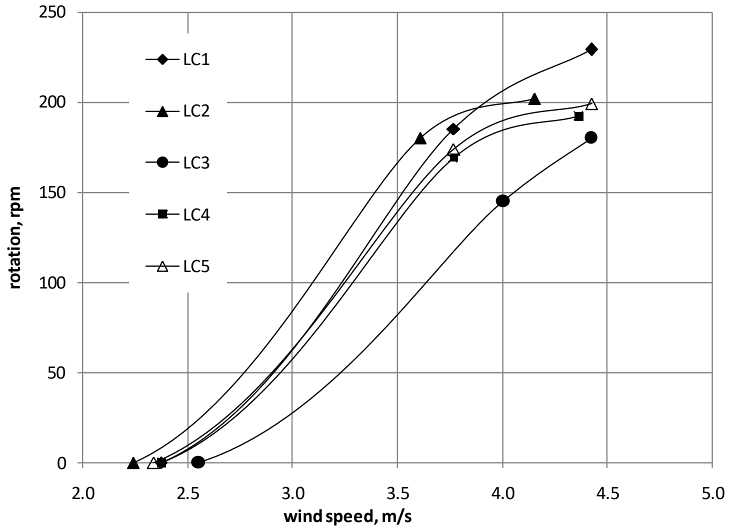

***Fig. 13.** Behaviour of experimental models at load ML2*

4. Conclusions

At wind speeds less than 2 m/s, no EM starts the rotation movement. The LC2 has the best starting load.

In all experiments, the model with three equivalent levels behaved the worst with the highest starting wind speed, and at v = 4 m/s has the lowest rotations for all 5 loads.

The speed of the models is of slope and therefore with the increase of the load their speed decreases significantly. At the same speed of wind, the speed has a minimum at LC3 (Fig. 2-6) because LC2 corresponds to the lowest load resistance and therefore to the highest current. At idle (N, no load) experimental models behave very closely.

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