THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI.
FASCICLE IX, METALLURGY AND MATERIALS SCIENCE
N°. 2 - 2018, ISSN 1453-083X

IMPROVING THE POWERFUL BEHAVIOR OF AN EXPERIMENTAL MODEL OF SAVONIUS TURBINE (S-ROTOR) WITH COUPLED AERODYNAMIC ADDITIONAL BLADES

Nelu CAZACU
“Dunarea de Jos” University of Galati, Faculty of Engineering, Romania
email: nelu.cazacu@ugal.ro

ABSTRACT

The proposed experimental model brings an improvement in the start of turbine rotation and torque uniformity in load. Constructively, the original blades of the turbine have gap and overlay. Additional blades are placed at 90° from the classic layout of the blades at the Savonius turbine and are attached to the original blades. The model was tested on the wind tunnel at low wind speeds (<4.5 m/s). The results confirm the validity of the concept, without significantly increasing the yield of the experimental model.

KEYWORDS: Savonius Turbine, S-rotor, adjacent blades

1. Introduction

The Savonius wind turbine with a level (1L) and two blades or a pair of blades (1PB) is perhaps the simplest structure. From a gas-dynamic point of view, the hemispherical blades offer the maximum torque when they have a diametrically planar plane perpendicular to the wind direction. This is because the coefficients of drag (drag) for the spherical cup in the convex position $c_D = 0.3$ and for the concave position $c_D = 1.2$. The values are taken in relation to the disc with the same surface as the cup bases.

Like the semi-cylindrical blades, which are easier to obtain, for the axial plane comprising the bases of the semi-cylindrical blades, perpendicular to the wind, the highest torque value is obtained [1].

Wind energy is pure kinetic energy and can be partially transformed into mechanical work [2, 3].

$$E = 0{,}5mv^2 \tag{1}$$

The volume flow over the swept area is:

$$\dot{V} = Av \tag{2}$$

And the mass flow is:

$$\dot{m} = \rho Av \tag{3}$$

The power of wind is depending by wind speed (v), air density (ρ) and swept area (A):

$$P = 0{,}5\rho Av^3 \tag{4}$$

For the VAWT, the Betz limit is (14.81%) [2].

The power extracted from a wind power by a VAWT Savonius type is depending by Drag force is:

$$D = C_D \frac{1}{2}\rho(v-u)^2 A \tag{5}$$

where *u* is tip speed of blade. P becomes:

$$P = Du = C_D \frac{1}{2}\rho v^3 (1-\frac{u}{v})^2 \frac{u}{v} A \tag{6}$$

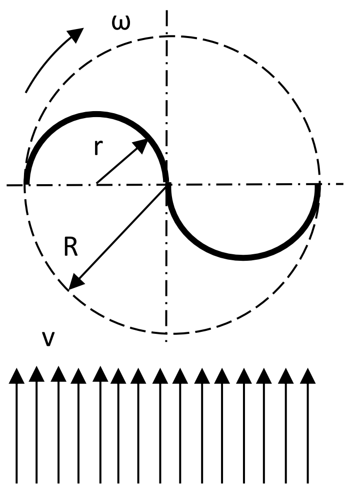

***Fig. 2.** Transversal sections through SWT with overlay (o) and gap (g)*

And specific speed (TSR):

$$TSR = \lambda = u/v \quad (7)$$

The extracted power (4) is:

$$P = C_D \frac{1}{2} \rho v^3 (1-\lambda)^2 \lambda A \quad (8)$$

Abbreviations

WT - Wind Tunnel;
EM - Experimental Model;
VAWT - Vertical Axis Wind Turbine;
LED - Light Emitting Diode;
SWT - Savonius Wind Turbine,"S" rotor;
L - Level;
PB - Pair of Blades;
BL - Betz Limit;
TSR - Tip Speed Ratio.

Notations:

v - Speed wind, m/s;
P - Wind power, W;
ρ - Air density, kg/m3;
λ - Specific speed;
r - exterior cup radius, mm;
R - rotation radius, mm;
g - cup thickness, mm;
g - Gap, mm;
o - Overlap, mm;
σ - Solidity;
f - axial turbine frequency, Hz.

2. Experiments

For experimentation in the wind tunnel we used experimental models according to the table (H395 mm, D150 mm).

- savonius model (1L1PB)

- savonius model with a pair of additional semi-cylindrical (Fig. 3) (1L2PB) light pairs, and in which the first PB are placed according to Benesh configuration (g = 15 mm, o = 1/3 of diametral blade projection).

Experiments were performed on a wind tunnel with the characteristics: measure sections 0.5 m x 0.5 m, wind speeds less than 4.5 m/s.

The tests were performed using the free model and the load-coupled model.

Free rotation in the wind was performed using a graphite-bearing device to have minimal mechanical friction.

Experiments on behaviour under mechanical, and electrical load assumed the use of a speed multiplication system (x3.5) and a DC generator (5V).

At the terminals of the generator were connected electric elements and a LED and then electric loads of 1, 1.5 kΩ and 2 kΩ.

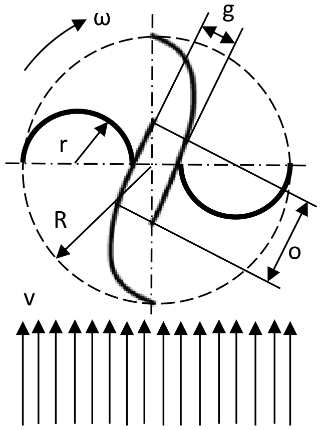

***Fig. 3.** Experimental model (transversal section) with a pair of semicilindrical additional blades.*

At the terminals of the generator were connected electric elements and a LED and then electric loads of 1, 1.5 kΩ and 2 kΩ.

For comparison, a SWT model with the same swept area with 1L1PB (one level and one pair of blades) was used.

Experiments are encoded as follows:

- N experimental model without mechanical or electrical loads;

- M-experimental model with mechanical load (speed multiplier and DC generator);

- ML-idem plus LED to indicate working voltage;

- ML1-mechanical load, LED and in parallel a 1kΩ resistor;

- ML1.5-mechanical load, LED and in parallel a 1.5k Ω resistor;

- ML2-mechanical load, LED and in parallel a 2 kΩ resistor.

Obs. For many experiments, the electrical loads on the DC generator of 1.5 kΩ and 2 kΩ were too high and the experimental model did not rotate.

3. Results and discussions

For each model and electrical or mechanical load conditions, measurements were made from the maximum speed to the zero-wind speed and if the pattern did not stop rotating the measurements.

Regarding the movement of the models under the above mentioned conditions, it can be noticed that the models which rotate freely (only mechanical friction in the bearings and the specific friction in the air) for the same wind speed have x2 to x4 rotation speeds compared to the models with different mechanical loads and / or electric (Fig. 1). The specific speed (λ, TSR) has the same variation: for example, at 4 m/s wind speed, TSR in free models is x4 ... x5 times higher.

The load tests of the experimental models (M, ML, ML1) show the correct behaviour of the models in the sense that as the load increases on the wind turbine experimental model, its speed decreases (Fig. 1) and the TSR (Fig. 2, Fig. 3).

The analysis of the dynamic behaviour was done following the Re number evolution for the experiments performed. (Fig. 7, Fig. 8). It is observed that the higher values Re number to freely rotate experimental models (<85,000) and the values of <30,000 models tested under load.

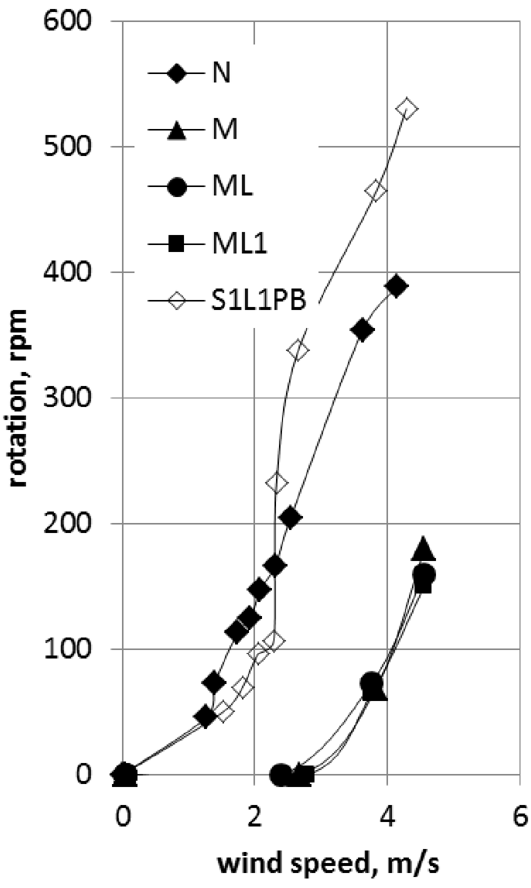

Fig. 4. *Rotations of EM with wind speed*

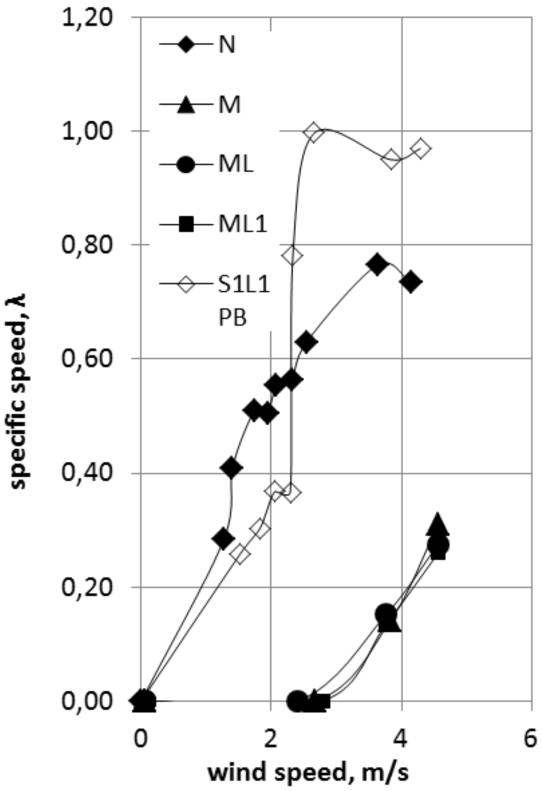

Fig. 5. *Evolution of λ (TSR) with wind speed*

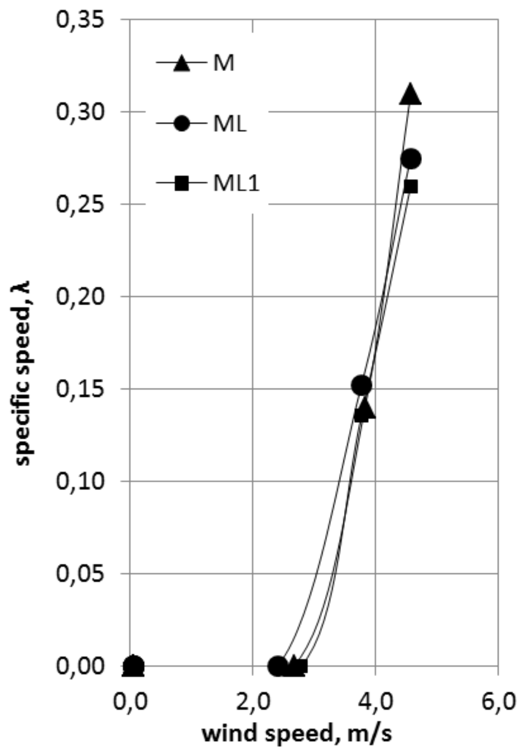

Fig. 6. *TSR (or λ) only for experiments under load*

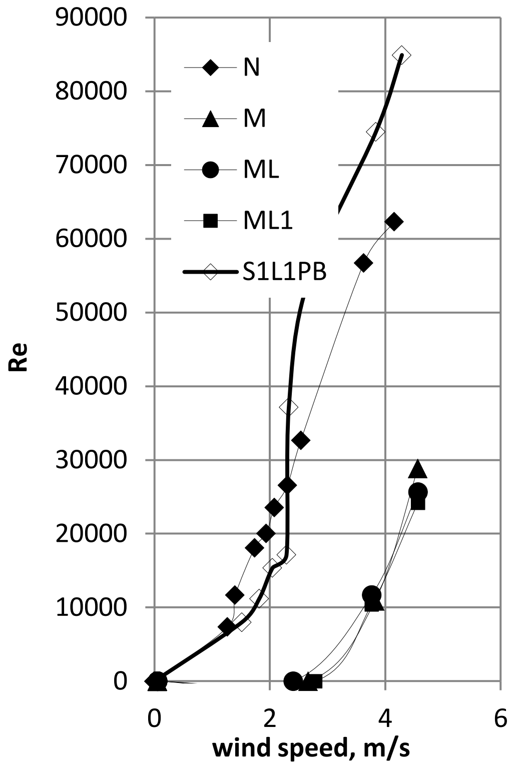

Fig. 7. *Re number with wind speed for all experiments*

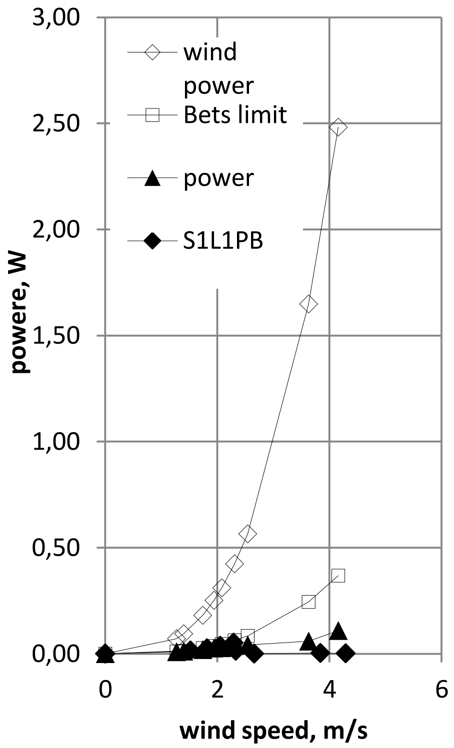

Fig. 9. *Power of models with wind speed versus wind power and Betz limit*

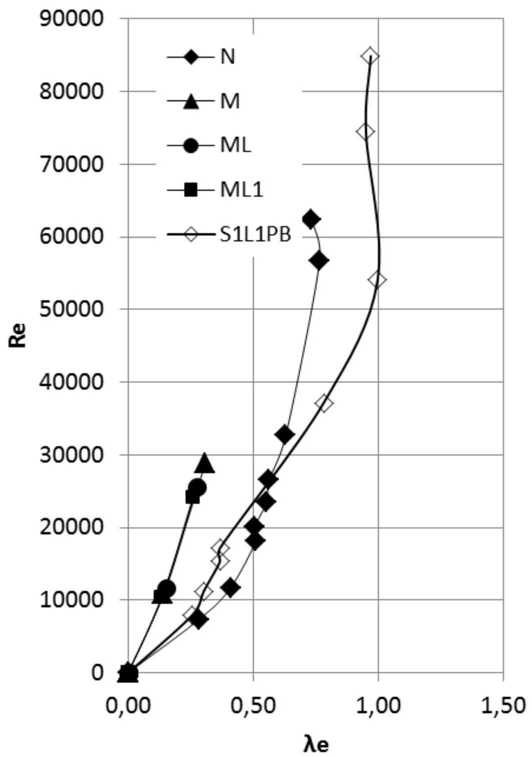

Fig. 8. *Re number variation with TSR of experimental models*

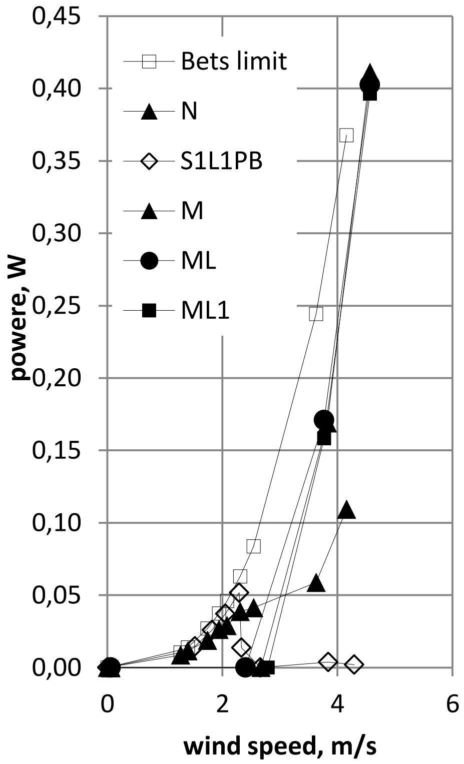

Fig. 10. *Power of experimental models with wind speed under Betz limit*

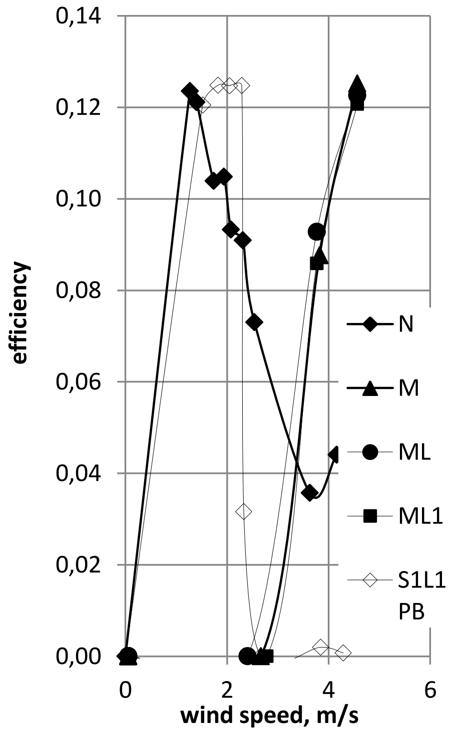

Fig. 11. *Efficiency over experiments with wind speed*

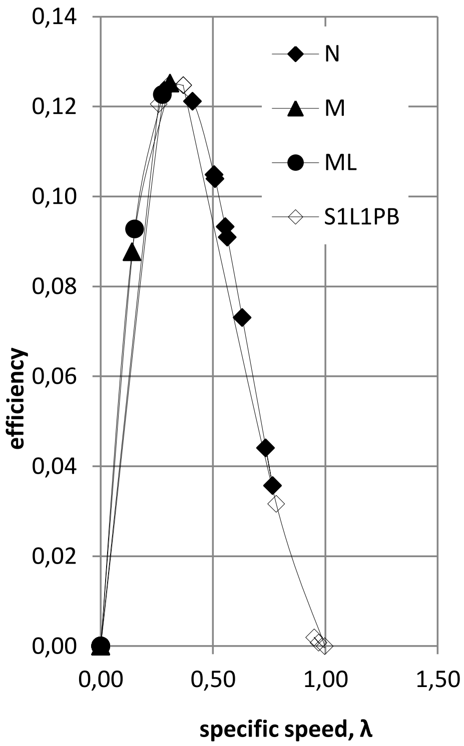

Fig. 12. *Efficiency over experiments with specific speed (TSR, λ)*

Energy efficiency is about 12.5% (Fig. 12). The study of energy efficiency dependency on wind speed (Fig. 11) shows that free models (N, SWT 1L1PB) achieve maximum efficiency at low wind velocities (1.5-2 m/s) and experimental models under load achieve the maximum efficiency at maximum test speeds (4.5-4.6 m/s).

4. Conclusions

Experiments fall within the VAWT theory, i.e.: the extracted power is less than the Betz limit (Fig. 9, Fig. 10) [2, 5].

The increase in load on the experimental wind turbine model with vertical axis (VAWT, Fig. 3) has following effects:

- decreasing TSR (λ) (Fig. 5, Fig. 6);
- Re number down to 30000 at 4.6m / s wind speed (Fig. 7, Fig. 8);
- achieving a maximum efficiency of wind energy conversion at 4.6m / s (Fig. 11);
- maintaining the maximum efficiency of the wind energy conversion to the mechanical and electrical energy at λ = 0.3-0.4 (Fig. 12).

The presence of a pair of additional blades positioned perpendicularly (cross-sectional) on the base pair of blades (Benesh) brings changes to the SWT (1L1PB).

References

[1]. Menet J. L., Bourabaa N., *Increase in a savonius rotor efficiency*.
[2]. Hau Erich, *Wind Turbines, Fundamentals, Technologies, Applications, Economics*, s.l.: Springler, 2006.
[3]. Manwell J. F., McGowan J. G., Rogers A. L., *Wind Energy Explained. Theory, Design And Application*, s.l.: John Wiley & Sons Ltd, p. 590, 2002.
[4]. Smulders P. T., *Rotors for wind power*, Eindhoven: University of Technology, Eindhoven, Faculty of Physics, 1st edition October 1991, (revised edition January 2004).
[5]. Dumitrescu H., Georgescu A., *Calculul elicei, Cap. 4 - Elicea eoliana*, s.l.: Editura Academiei Romane, 1990.
[6]. Manwell J. V., McGowan J. G., Rogers A. L., *Wind Energy Explained. Theory, Design And Application*.
[7]. Benesh A., *Wind turbine system using a vertical axis Savonius-type rotor*, US Patent 4784568, 1988.