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DEVELOPMENT OF BLADE DESIGN FOR SMALL HAWT ADAPTED FOR LOWER VALUES OF WIND SPEED

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ABSTRACT

The paper aims at studing, theoretically and experimentally, the influence of turbines blade profile on output power, in order to decrease effective domain to smaller wind speed, specific to Galati area. Studies have been made using a type of turbine with variable blade profile and another type using a blade with enlarged surface and variable angle of attack. The blade shape was designed for a torque maximization at lower wind speed values. A scale experimental model of blades and of AIR-X horizontal axis wind turbine featuring the optimized blade design was constructed and tested in the low speed wind tunnel. Research results confirm the possibility that using these two methods, the effective increasing performances of the domain of AIR-X wind turbine and increasing energy to be transferred without modifications to the electric generator.

KEYWORDS: wind energy, HAWT

1. Introduction

The extraction of energy from wind energy is the purpose of all wind turbines [1]. The wind energy is in concordance with increasing the renewable energy usage and DER concept [4, 5]. To solving engineering problems for energy caption maximization, a multi criteria design and selection of materials are necessary. Each component of the wind turbine system has to be optimized for that goal.

The paper is based by the theoretic and experimental over the small unit AIR-X wind turbine is used for generation of electricity in residential and commercial locations. Getting electricity from wind conversion intermediate of energy in mechanic work is strongly influenced by the rotation speed of the turbine shaft.

Electric generators work on a specific area of speeds for which feature are useful electricity. Because of that wind turbines are select features according to local wind [1]. The wind turbine theory is based on active disk model (Betz model - 1926). This model was developed by similarity with plane propeller based on principles of mass conservation, energy and momentum [3].

The power coefficient is defined:

$$C_p = \frac{p}{\frac{1}{2}\rho S_p V_\infty^3} \tag{1}$$

where P – in power, W; ρ – air density, kg/m^3; S_p – surface reference turbine disk.

The induction coefficient is:

$a = 1 - V/V_\infty$

A maximum efficiency is obtaining for a=1/3 and Cp=0,593 (Betz coefficient).

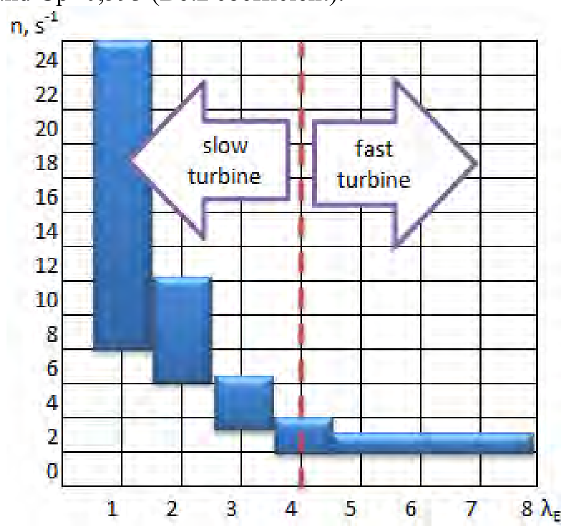

Fig. 1. *Classification of wind turbines based the number of blades and λ_E*

The rotation speed of wind turbine has variability and is dependent on wind speed. Rotation

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speed and rotation momentum are actually the most important factors for wind turbine selection.

Specific speed λ_E is defined by:

$$\lambda_E = \frac{\Omega R}{V_\infty}$$

where: λ_E - = specific speed; Ω – rotation speed, s^{-1}; R – maximum length of blade, m; V_∞ - wind speed.

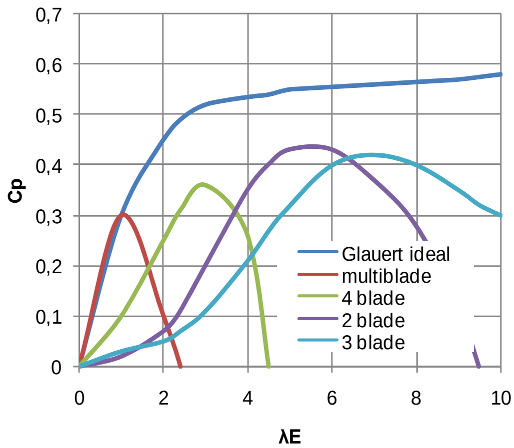

Fig. 2. *The influence of the number of blade over the power coefficient*

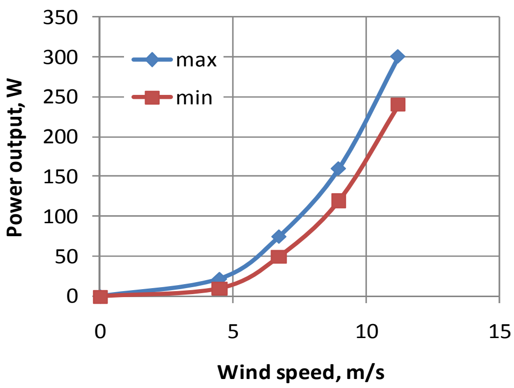

Fig. 3. *Instantaneous wind speed influence over power output for AirX small HAWT*

Increased sensitivity to low wind speeds is achieved by increasing the surface of the blades in plan disk (solidity number σ) or by increasing the number of blades) [1]. High starting torque is obtained by subtracting the increase σ and λ_E.

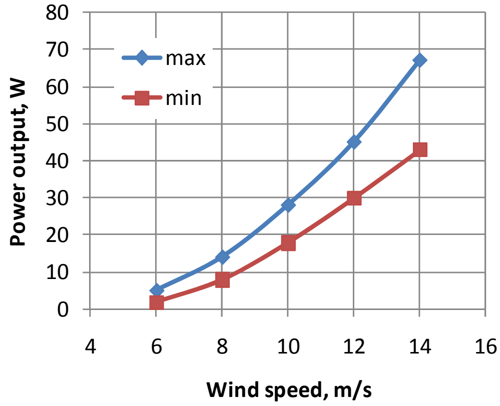

Fig. 4. *Annual average wind speed influence over power output for AirX small HAWT*

The number of blades is chosen in figure 1: λ_E = 1 (8 ... 24 blades), λ_E = 2 (6 ... 12 blades), λ_E = 3 (2 ... 4 blades), λ_E = 4 (2 ... 4 blades) 5 ≥ λ_E (2 ... 3 Performances of wind turbine AIR-X (max. 400W) are dependent on wind speed and are reached at a speed value of approximately 12,5m/s (figure 3). The rotation of electric generator is limited without 170...260 rot/min (which maintaining charging level for 12V battery). The band-width of the AIR-X HAWT is smaller for conditions of Galati city and the wind speed is lower for an efficient exploitation (figure 4).

The approach taken by this work was to improve the efficiency of the AIR-X (400W) wind turbine by modifying the blades. Studies have been made using a type of turbine with variable blade profile and another type using a blade with enlarged surface and fixed angle of attack. Increasing the total blade surface is necessary to increase sensibility of wind turbine for lower wind speed.

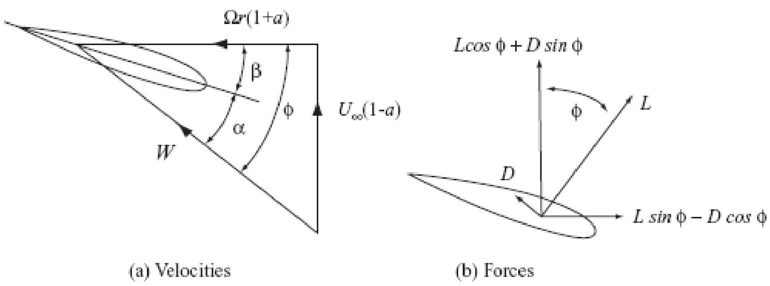

Fig 5. *Blade element velocities and forces*

Blade design is influenced by the mode of operation of the turbine that is, fixed rotational speed or variable rotational speed. Blade element velocities and forces are shown in figure 5. For AirX HAWT a fixed rotational speed is accepted without modifying the electrical conversion systems. The blades for AirX small HAWT wind turbines must satisfy a wide range of objectives [0]: maximize annual energy yield for specific wind speed distribution, maximum power limitation, resist to extreme conditions, avoid resonance, avoid resonance, minimizing weight and cost, restrictions for up-wind conditions and collisions. The aerodynamic design for geometry (Flex PDE software simulations) was made for experimental blade aerofoil (variable chord based by NACA 4412). Hand built wind turbines blade is easy because the bottom (high pressure) side of the profile is almost flat (Reynolds number of about 5…3 10^5), the maximum lift/drag ratio occurs at a lift coefficient of about 0.7 and an attack angle of 10...20º.

The measurable component of lift force of blade has a normal position on the wind direction and that values will conduce to rotation moment and main energy.

2. Experimental conditions

For behaviour of experimental variable blade for smaller |HAWT, a wind tunnel for small dimensions was assembled. A variable speed of air lamellar flow was obtained by variable speed of a three phase motor fan using a frequency converter. Experiments were made on an original blade and experimental blade with variable profile. Blade was mounted in horizontal position and a compensation weight was necessary. A measure system in correlation with a real working system, with two perpendicular axes was fixed for lift and drag forces. Measurements were made by compensations and dynamometrically. The attack angle of original AirX blade is variable according to the blade length.

Fig. 6. *Experimental wind tunnel and system for variable wind speed*

Original surface (figure 7) are fixed to approx. 0,021 m^2. Experimental blade having a constant attack angle and was fixed at 90, 85 and 80° and a variable surfaces (S1=0.029m^2; S1=0.032m^2; S1=0.034m^2). Increasing the blade surface is necessary to increasing wind turbine sensibility to lower values of wind. Wind speed was measured by LCA 6000 (AIRFLOW Ltd.) anemometer.

Fig. 7. *Experimental variable surface blade and original AirX blade*

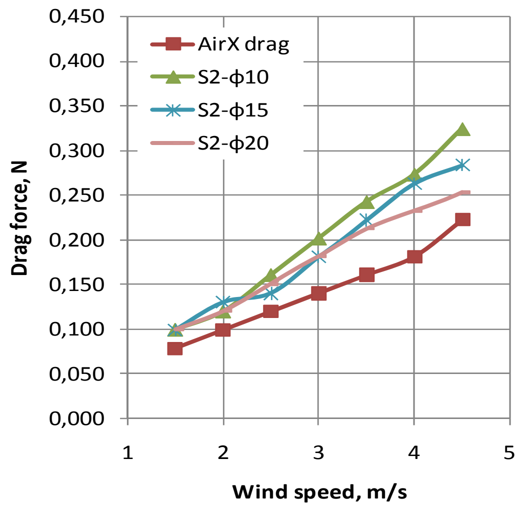

Fig. 8. *Wind speed influence over the drag force for S1*

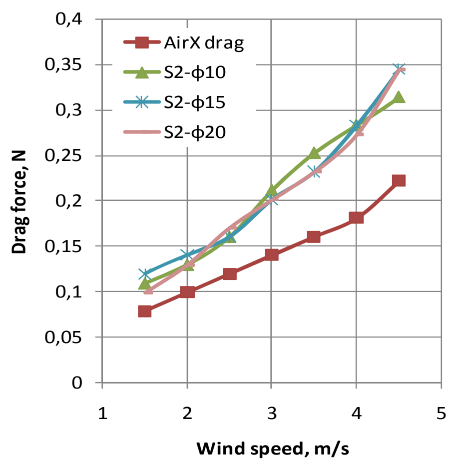

Fig. 9. *Wind speed influence over the drag force for S2*

Some important characteristics of wind tunnel (figure 6) were:

- wind speed range: 0...4.5m/s
- section (1190mm x 500mm)
- total linear length: 3750
- ¼ cylindrical blades for flow deflection (two sets) two mesh (75% transparency) transversal sections in ejector section.

Experimental procedure classical required a “full factorial” array with three factors (attack angle, wind speed and blade surface) and three levels for each factor.

3. Results and discussion

Experimental data were plotted for graphical interpretations. Original AirX blade was a constant reference for experiments.

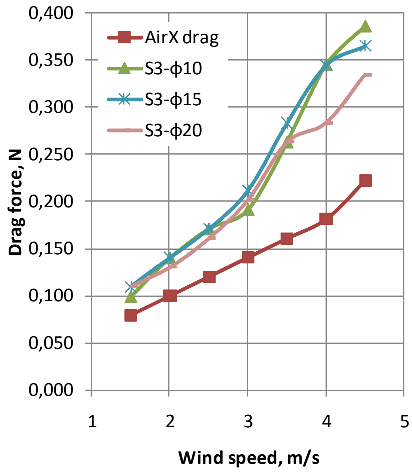

Fig. 10. *Wind speed influence over the drag force for S3*

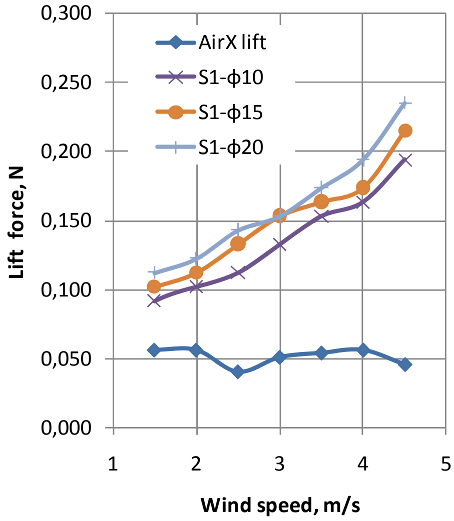

Fig. 11. *Wind speed influence over the lift force for S1*

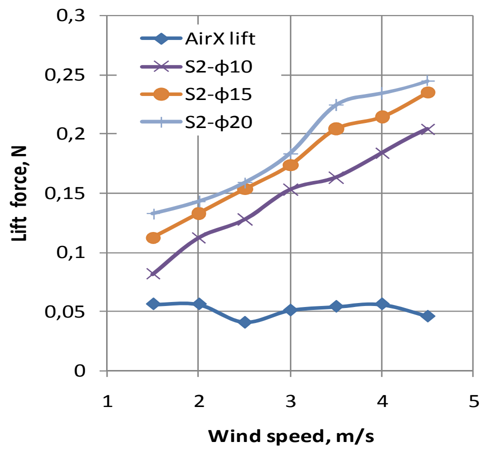

Fig. 12. *Wind speed influence over the lift force for S2*

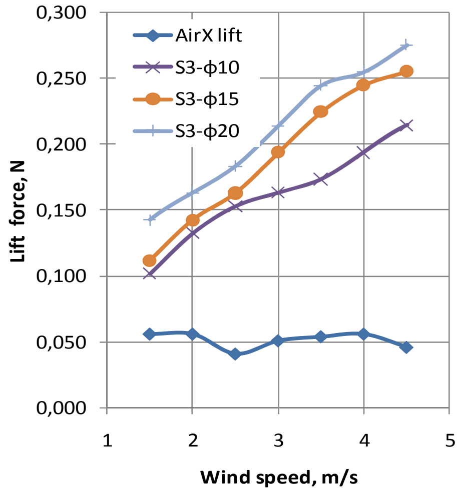

Fig. 13. *Wind speed influence over the lift force for S3*

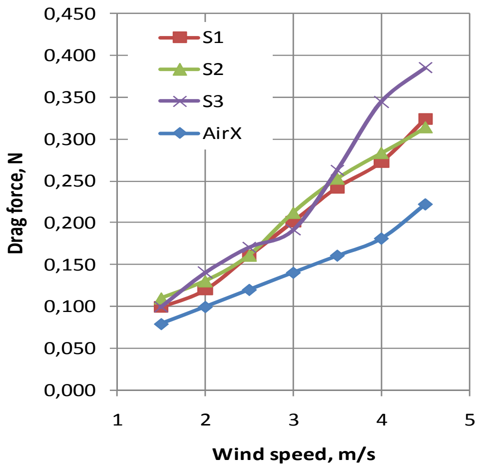

Fig. 14. *Wind speed influence over the drag force for different blade surface and 10° attack angle*

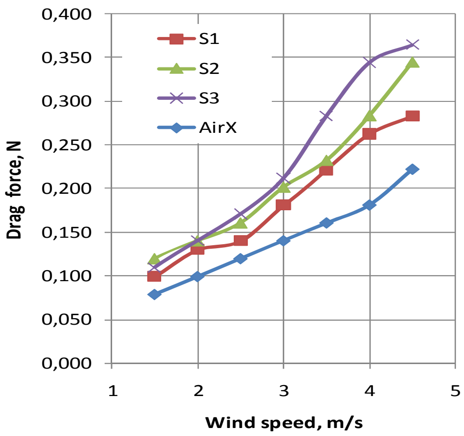

Fig. 15. *Wind speed influence over the drag force for different blade surface and 15° attack angle*

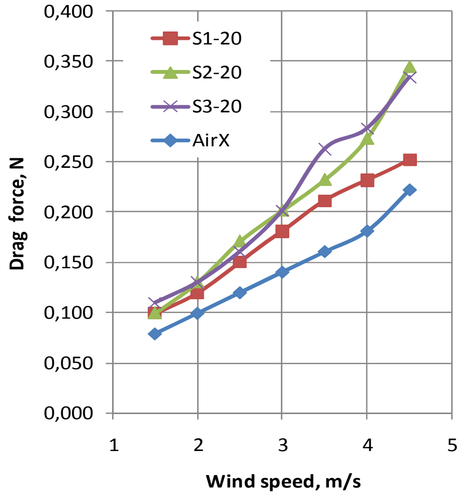

Fig. 16. *Wind speed influence over the drag force for different experimental blade surface and 20° attack angle*

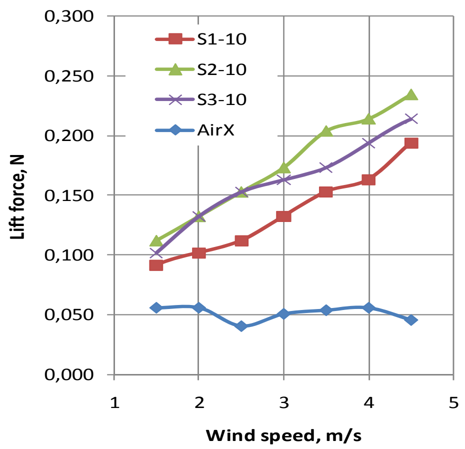

Fig. 17. *Wind speed influence over the lift force for different experimental blade surface and 10° attack angle*

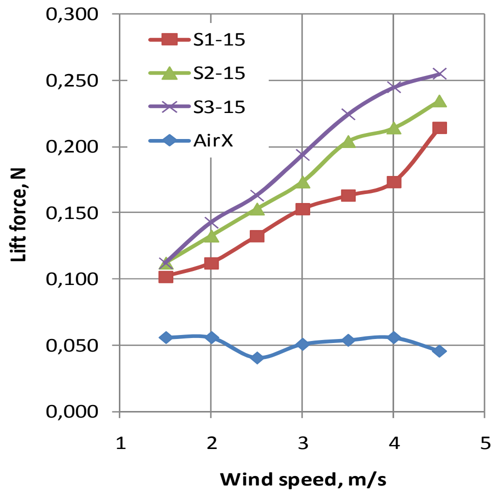

Fig. 18. *Wind speed influence over the lift force for different experimental blade surface and 15° attack angle*

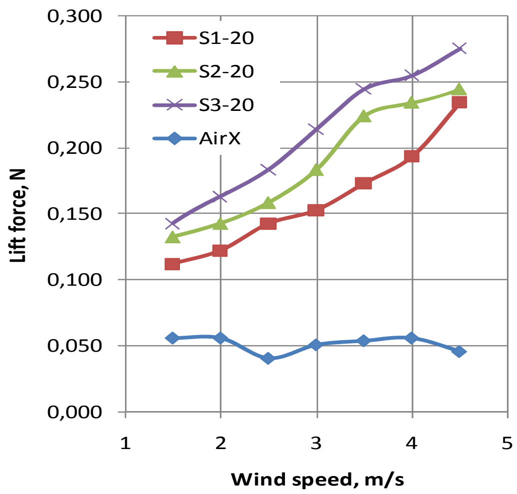

Fig. 19. *Wind speed influence over the lift force for different experimental blade surface and 20° attack angle*

Wind speed influence over drag force for S1, S2 and S3 are shows in Figure 8...10 and influence over lift force are shows in Figure 11...13, all plotted for different attack angle values. At the same attack angle the influence of the wind speed and the surface of experimental blade over drag force and lift force are shown in figure 14...16, respectively figure 17..19.

4. Conclusions

For all experimental conditions (maximum wind speed 4.5m/s) a reciprocal increasing of lift force and drag force are present. Sensibility of experimental blade for lower values of wind speed is in direct dependence of a surface blade and attack angle.

For all experiments, the increasing of attack angle made the lift force. Increasing the maximum lift force was obtaining for maximum surface of experimental blade (0.28N for 4.5m/s). For original AirX blade the lift force was constant for wind speed 1.5…4.5m/s at value 0.05N. The drag force had a linear increasing from 0.08N at 1.5m/s to 0.22N at 4.5m/s. In these conditions, the original AirX blade are unusable for speed wind at values lower than 5m/s, which are specified in catalog data for the smaller wind turbine.

Decreasing lift forces al lower specified wind speed will determine lower values of output power (figure 1). Output of AirX wind turbine is in direct influence of the annual average wind speed (figure 2).

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