DESIGN AND MANUFACTURE OF SOME BLADES FOR AEOLIAN

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Abstract **– The paper presents some theoretical aspects, design and the technical specification for an aeolian rotor blade two meters diameter size.**
Keywords*:* blade, aeolian, rotor

1. INTRODUCTION

The wind energy is one of the oldest sources of energy, but once discovered the fossil fuel, the wind energy was substituted. The diminution of conventional energy resources, the increasing of the oil price and the problems regarding the pollution also, made together the interest in the wind power re-emerged. For this reason, during the last 20 years, the use of wind turbines rapidly increased.

The conversion of wind energy to useful energy involves two processes: the primary process of extracting kinetic energy from wind and conversion to mechanical energy at the rotor axis, and the secondary process of the conversion into useful energy (mostly electrical, but also mechanical for water pumps or chemical for water desalination or hydrolyses).

The major field of science involved in this process is aerodynamics, but it needs meteorology (wind description) as input, and system dynamics for the interaction with the structure. The latter is important since all movement of the rotor blades, including bending of the blades out of their plane of rotation, induces apparent velocities that can influence or even destabilize the energy conversion process. Aerodynamic is the oldest science in wind energy: in 1915, Lanchester [1] was the first to predict the maximum power output of an ideal wind turbine. A major break-through was achieved by Glauert, [2] by formulating the blade element momentum (BEM) method. This method extended with many 'engineering rules' is still the basis for all rotor design codes. Recently, first results of complete Navier–Stokes calculations for the most simple wind turbine operational mode have been reported. Progress is significant in the 30-year history of modern wind energy. To name one example: a better understanding of the aerodynamics improved the efficiency of the primary process from 0.4 to 0.5 (out of a maximum of 0.592). Nevertheless, many phenomena are still not fully understood or quantified. This is due to several aspects that are unique for wind turbine aerodynamics.

Most aircraft try to fly high enough to avoid turbulence and extreme wind events, but for wind turbines steady wind is an off-design condition. All aerodynamic phenomena are essentially unsteady, which, however, is still beyond the scope of current design knowledge. Since many wind turbines rely on stall, a thorough understanding of unsteady (deep) stall is necessary.

The aerodynamic research for wind turbines has contributed significantly to the success of modern wind energy. For most unsolved problems, engineering rules have been developed and verified. All of these rules have a limited applicability, and the need to replace these rules by physical understanding and modeling is increasing. This is one of the reasons that the worldwide aerodynamic research on wind energy shows a shift towards a more fundamental approach. 'Back to basics', based on experiments in controlled conditions, is governing most research programs.

Wind turbine wakes have been a topic of research from the early start of the renewed interest in wind energy utilization in the late 1970s [3]. From an outsider's point of view, aerodynamics of wind turbines may seem quite simple. However, the description is complicated, by the fact that the inflow always is subject to stochastic wind fields and that, for machines that are not pitch regulated, stall is an intrinsic part of the operational envelope. Indeed, in spite of the wind turbine being one of the oldest devices for exploiting the energy of the wind (after the sailing boat), some of the most basic aerodynamic mechanisms governing the power output are not yet fully understood [4].

The method presented in the paper, involves the optimization of aeolian turbines rotors design, by means the correlation between volume tests analyze method and blade element theory.

Two methods are in discussion here:

1. Blade element theory for aeolian turbines – classic method (in which, by iterative way, it is determined the maximal power of blade element for several values of setting angle - β)
2. The method of maximum mechanical power pulled out means of turbine blades- own method (in which it

is determined, by analytical way, the expression of carrying capacity Cx and also the expression of advancement resistance coefficient Cy.
Reckon with the expression of carrying capacity and the expression of advancement resistance, according to the classical theory and experience regarding the profile of airplane wing.
By projection of these forces, i.e. in the case of peripheral blade profile, by peripheral movement direction, it obtains the speeds triangle and the components of hydrodynamic resultants, like in the figure 1, below:

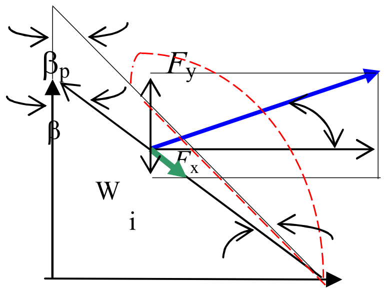

Figure 1: The speeds triangle and the components of hydrodynamic resultants

Where:

$$\beta p = \beta - i \qquad (1)$$

$$\beta = \text{arctg } V/U \qquad (2)$$

$$U = R\ \omega = W \cos\beta \qquad (3)$$

And

$$V = W \sin\beta \qquad (4)$$

If the axial force can be easy taking over by a ball bearing without big energy consuming, it can be determined the mechanical power assigned to the shaft.

$$P_m = UF_u = U\left(F_y \sin\beta - F_x \cos\beta\right) = \frac{\rho}{2}V^3 bl\left[c_y(i)\frac{\cos\beta}{\sin^2\beta} - c_x(i)\frac{\cos^2\beta}{\sin^3\beta}\right]$$

(5)

This, after the annulations of partial derivate relative of β angle, reaches the maximum value:

$$\frac{\partial P}{\partial \beta} = 0 = -c_y(i)\frac{1+\cos^2\beta}{\sin^3\beta} + c_x(i)\frac{\cos\beta\left(2+\cos^2\beta\right)}{\sin^4\beta} \qquad (6)$$

And leads to the equation:

$$\frac{c_y(i)}{c_x(i)} = f(i) = \frac{\cos\beta}{\sin\beta}\cdot\frac{2+\cos^2\beta}{1+\cos^2\beta} = \frac{\sqrt{1-\sin^2\beta}}{\sin\beta}\cdot\frac{3-\sin^2\beta}{2-\sin^2\beta} \qquad (7)$$

More profiles were analyzed in order to take in account the best geometry.
In the Figure 2 below are illustrated much geometry of blades:

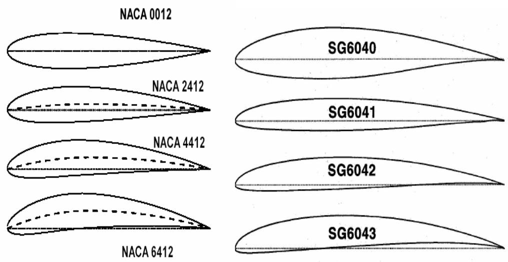

Figure 2: various profiles of blades.

From many profiles, it was choose the NACCA 4412 profile.

2. EXPERIMENTAL

Based on the mathematic model, it can be made the practical blade profile project
In this way, the follow steps were made:
- It was realized the execution project
- It was realized the wood blade model, 1 m length
- It was manufactured, after the wood model, the mould from plaster material (like in Figure 3, bellow):

Figure 3: The plaster mould

The support of the blade was made from polyurethane foam (like in Figure 4, bellow):

Figure 4: Polyurethane foam support blade

Regarding the material for blade itself, the option take in account the necessity to obtain a very easy composite material, with high mechanic and environment resistance.
According to this aim, the selected material is a composite based on polyester resins with curing at room temperature, over the polyurethane foam core material
The polyester resins are commonly used like matrix in the composite industry. These resins are styrene-based

and catalyzed when combined with Methyl Ethyl Ketone Peroxide.
These resins can be used with any type of fiberglass, carbon fibber or Kevlar, as well as used over urethane foam and other sandwich core materials.
These resins tend to be fairly rigid when cured and also more brittle than epoxy resins.
The polyester resin was reinforced with fiberglass tissue in order to obtain the necessary mechanical strength.
The final form of blade is illustrated in the Figure.5, bellow:

Figure 5: Blade for aeolian micro – turbines

The experimental aeolian rotor unit is equipped with three such blades, fixed at the same height with the central hub through clutch collars which assure the circumrotating and the blockage at the optimal incidence angle determined from experiments.
The central hub is directly jointed with the shaft of the electric generator (hard bushing).
In order to make some preliminary experiments, the Aeolian rotor was fixed on the traction shaft of some direct current electrical machine with disc rotor, in generator regime.
The necessary air flow for blades rotation was realized with the aid of one airscrew warmed up with a direct current electrical engine.
The aeolian rotor and the airscrew were placed on the same axis, on different holders, at the proper height.
The air speed was measured with a warm wire manometer, in many representative points.
The experiments were focused on the determination of the available couple and power to the aeolian rotor shaft according to the revolution, at different values of the wind speed.

3. RESULTS

Until this moment, were made measurements in the range of low values of the speed of wind (until 4 m/s). In the figures 4 and 5 below, are illustrated the curves which were considered representatives, at average of 3m/s speed of wind (in the starting wave zone of the aeolian rotor):

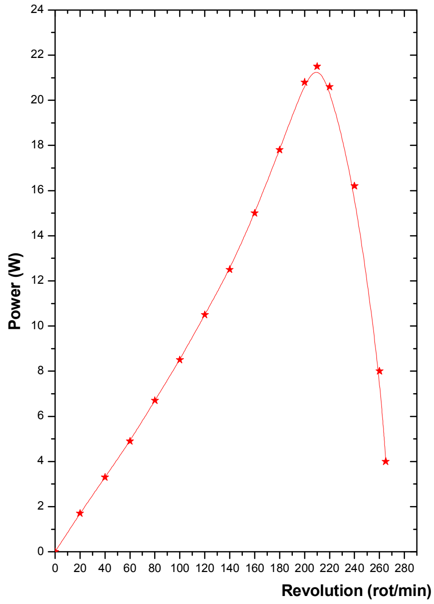

Figure 4: Variation of power with revolution

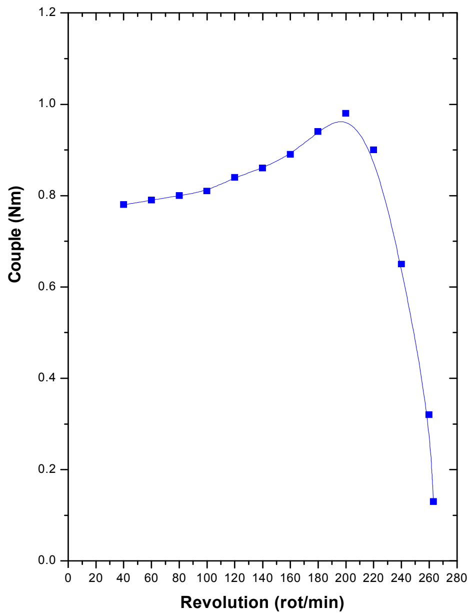

Figure 5: Variation of couple with revolution

Taking in account the maximal value of the available power (21,5 W) to the aeolian rotor shaft, its dimensions and also the environmental conditions at the moment when the experiments were made, the calculated value of the power coefficient is 0.35 at 3m/s speed of wind.

4. CONCLUSIONS

The experimental tests will be continued in order to make a complete characterization of the power conversion capacity of the Aeolian rotor. The results expected to obtain, will make possible a real design of some specific electrical generator (synchronic, three phase) in optimal parameters. Also, will be possible o real capitalization of the assembly by manufacture of aeolian micro power stations with 500 W powers fitted.

References

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