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EFFICIENCY ANALYSIS OF THE UNDERWATER TURBINES WITH A VERTICAL AXIS ORIENTATION FOR CLEAN MARINE ENERGY HARVESTING

Haisha Olena
ORCID: 0009-0000-4543-912X
"Dunarea de Jos" University of Galati,
Romania, Galati, str. Domneasca, 47, 800008
Haisha Oleksandr
c.t.s., as.prof.
ORCID: 0000-0003-3711-547X
Institut de Ciències del Mar,
Spain, Barcelona, Pg. Marítim de la Barceloneta, 37, 08003

Abstract. *The disadvantages of wind turbines with a vertical orientation of the turbine rotation axis are considered. To increase the efficiency factor, it is proposed to place such turbines in a stream of water (in a river or tidal current, etc.). First approximation estimate shows that for a specific configuration of turbine blades, placing it in a flow of liquid, rather than air, should lead to an increase in efficiency, i.e. the system must be technically efficient (capable of taking energy from the water flow and converting it into rotor rotation energy).*

Key words: *vertical axis turbine, VAWT, clean energy generation, water flow energy, Darrieus rotor, helical rotor, Savonius rotor.*

Introduction.

Regardless of the rapid development in other sectors of the national economy, in energy sector there is constant search for new sources of energy, as well as options for its harvesting within the framework of the operation of relevant power plants. Wind power plants today in industrial scale are represented almost exclusively by horizontal axis wind turbines (HAWT), however, active research and development work is also underway on the implementation of vertical axis wind turbines (VAWT). To date, several basic designs of such turbines are known [1], shown in Fig. 1.

The implementation of VAWT to date has been limited to selected isolated cases. The widespread introduction of vertical axis wind turbines is hampered by certain disadvantages, among which, in comparison with HAWT, are:

- less commercial and technical development of this technology;
- worse scalability;
- technological complexity of manufacturing the geometry of the blades (in most designs this is a complex geometry);
- a slightly larger value of the minimum mechanical moment required to start the movement of the turbine.

However, the main disadvantage of VAWT is the lower value of the efficiency coefficient, that is, the worse ability to generate energy from one unit of the surface area, swept by the blades. This paper proposes a solution to increase the efficiency of such turbines (that is expedient if to take into account their advantages, which were not described here), which firstly requires some initial grounding, carried out as a first approximation.

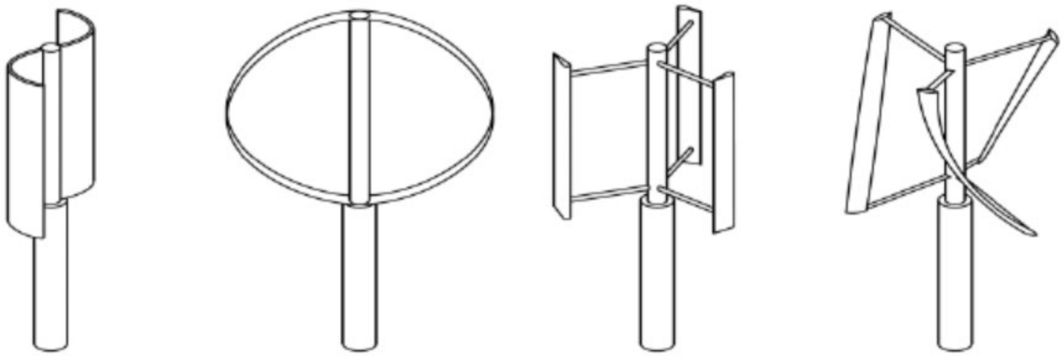

Fig. 1 – Known design options for wind turbines with a vertical axis:
***a** – Savonius rotor, **b** – Darrieus rotor, **c** – H-type rotor, **d** – helical-type rotor*
A source: [1]

Main text

To eliminate the described main VAWT disadvantage, it is proposed to place turbines of a similar design under water [2] to harvest the energy of water rather than air flows. Although the speed of water flows is usually significantly lower than the speed of air masses movements, this should be totally compensated by the fact that the density of the moving substance is approximately 780 times greater for water than for air. To consider this idea, initial evaluation calculations are required, and if they do not confirm its inconsistency, then more accurate mathematical modeling of the processes of water flow around a vertically oriented turbine should be carried out.

The following considerations can be taken intoo account as an initial assessment. The rotation of a vertically oriented turbine occurs due to the pressure forces of the continuous medium directed from areas with low flow velocities to areas with high flow velocities. In essence, this force is similar to the lifting force of a flying wing, which, as is known, is caused by different flow rates around its upper and lower surfaces, which in turn is caused by the different geometry of these two surfaces. For estimated calculations, it can be assumed that the difference in pressure on the two surfaces of the body will be:

$$\Delta p = \frac{\rho V_1^2}{2} - \frac{\rho V_2^2}{2} \quad (1)$$

In the case where there is no specific wing structure, and the entire system has complex geometry, as shown in Fig. 1, of course, the pressure difference will not be expressed by a simple formula of the form (1). First of all, this is so because in the case of VAWT rotation it is difficult to distinguish two specific speeds V_1 and V_2 (which are quite naturally defined for a wing-type structure as the flow velocity above and below the wing). However, it can be argued that the total torque M depends on the value of the complex ρV^2 (which is the part of the Euler similarity number):

$$M = M(\rho V^2), \qquad M \sim \rho V^2 \quad (2)$$

It should be taken into account that the dependence (2) is not inverse, but under any conditions is direct. Based on formula (2), we can make rough estimates of the efficiency of replacing one flow medium with another. Thus, if it is known that a certain vertically oriented turbine operates effectively at a value of ρ = 1.29 kg/m^3 and a flow velocity V = 15 m/s (which approximately corresponds to the maximum of the efficiency curve of a certain generalized wind generator), then the value of the proposed complex is about ρV^2 = 300 Pa. At the same time, when water with the density of ρ = 1000 kg/m^3 flows around the same turbine at flow speed of V = 1 m/s the value of the specified criterion will be equal to ρV^2 = 1000 Pa. Based on dependence (2), a larger value of the complex corresponds to a better torque value, and therefore more efficient operation of the turbine.

Summary and conclusions.

Thus, it can be stated that by the initial evaluation calculations, the efficiency of the same turbine's design with a vertically oriented axis (in other words, with an axis perpendicular to the flow velocity) will be higher if it is placed not in an air environment with a high speed of movement of matter, but in water with low flow speed. The increase in density of water relatively to air appears to be greater than the decrease in the square of the fluid velocity relative to the square of the air velocity, and the overall efficiency of the turbine should increase. For more accurate estimates, mathematical modeling is required, for example, by simulating the flow of water around a rotating turbine, which is planned for future work.

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