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COMPUTATIONAL METHOD TO DETERMINE OPTIMAL PITCH ANGLES OF BLADES FOR DARRIEUS H-ROTOR

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***Abstract*—*Computational method to determine the optimal pitch angles of straight blades for Darrieus rotor was produced. It was shown that the controlling of the blades deflection provides to create and increase the starting torque and also to enlarge the rotor efficiency.*

Index Terms—Aerodynamics; controlled pitch angles; Darrieus rotor; wind turbine.

I. INTRODUCTION

It is well known that the Darrieus rotor is rather efficient among vertical axis wind turbines. But it is not self starting at low wind speed and there is a problem of having excessive runaway in strong wind. This paper conducts with the controlled ways of providing the Darrieus rotor with the self starting, cutting of the runaway and further increase of its efficiency.

II. REVIEW OF EXISTING APPROACHES

Two principal views of blades control (passive and active) are distinguished. At passive blades control each turbine blade has turn possibility due to crosspiece and, depending on a site of this axis on chord blade, aerodynamic (or inertial) forces will try to turn the blade towards the reduction of angle of attack. If putting any elastic catchers of blade turn on crosspiece a possibility arises to passively regulate an angle of attack of blade depending on turbine rotation speed. The detailed review of designs of such devices is presented in [1], as well as results of tests, models and the natural sample of vertical-axis wind turbines with passive blades control.

An active pitch control presumes optimal individual angles of attack for every blade. In (Fig. 1) [2] there is presented vector chart for determining the local angle α of attack for a blade and incident wind speed U with the wind speed upstream U_∞ and with the circumferential (rotational) one ωR.

III. TASK STATEMENT

It may be written from the vector triangle of speed (Fig. 1):

$$\left.\begin{aligned} U^2 &= U_\infty^2 + (\omega R)^2 + 2U_\infty \omega R \cos\theta, \\ \frac{U_\infty}{\sin\alpha} &= \frac{U}{\sin\theta}. \end{aligned}\right\}$$

Introducing dimensionless values for the incident wind speed U and the rotational one ωR respectively:

$$\overline{U} = \frac{U}{U_\infty}, \quad \lambda = \frac{\omega R}{U_\infty},$$

we have the more compact formulae:

$$\left.\begin{aligned} \overline{U}^2 &= \lambda^2 + 2\lambda\cos\theta + 1, \\ \sin\alpha &= \frac{1}{\overline{U}}\sin\theta. \end{aligned}\right\} \qquad (1)$$

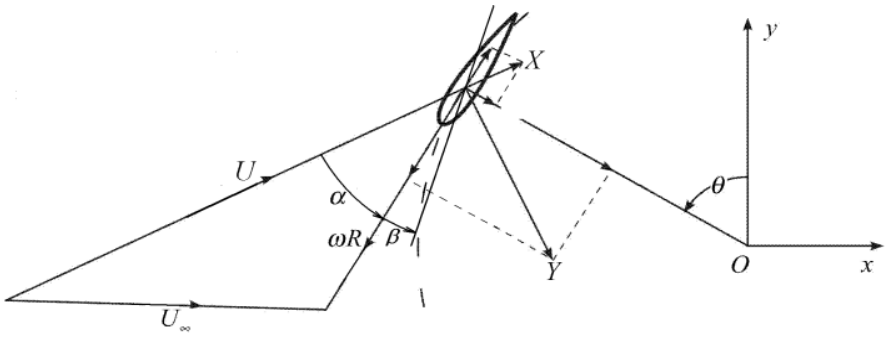


Fig. 1. Vector chart of velocities and forces acting the blade. θ is the azimuth angle of the blade, ω is the angular velocity of the rotor, R is the rotor radius, β is the pitch angle

Dependence of the local angle α of attack for the non-deflected blade versus the tip speed ratio (TSR) λ is calculated and the azimuth angle θ using the formulae (1) is presented in (Fig. 2).

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Fig. 4. Torque coefficient

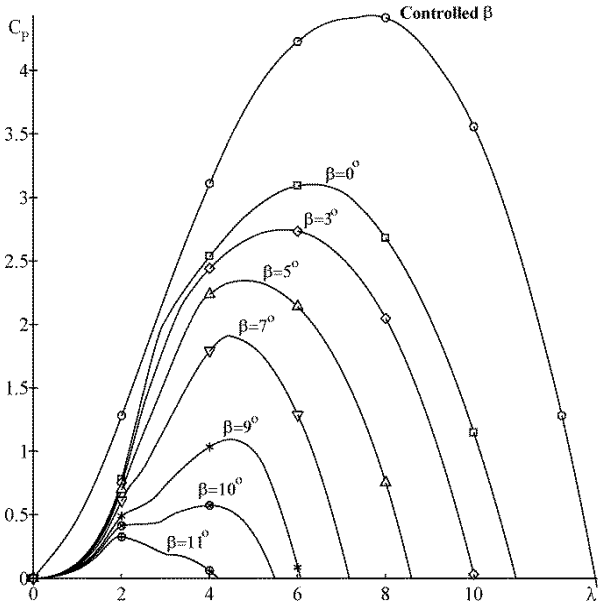


Fig. 5. Power coefficient

IV. CONCLUSIONS

Expressions for calculate the rotor torque and power coefficients via TSR λ and pitch angles β of the blades for the whole range of azimuth location θ of blades have been obtained.

The suitable computer aided algorithm was produced to determine the optimal values of pitch angles β_{opt} throughout the full range of azimuth angles θ of blades position for various values of tip speed ratio λ.

Controlling the blades deflection provides:

– to create and increase the starting torque coefficient C_T (which was absolutely absent earlier) at low wind speed that leads to decreasing of the cut in wind speed;

– to enlarge the rotor efficiency C_P at exploitation range of wind speeds (up to 40 % of increasing for the value of TSR λ = 6);

– to impair the work of rotor with zero rotation with the zero torque coefficient C_T to avoid its damage at excessive strong wind;

– to increase the cut off (autorotational) value of TSR λ.

Thus controlling of pitch angles widens the work range of the rotor TSR.

Controlling of the pitch angles may be successfully used in tidal and water wave energies where it takes place alternating to and from the coast stream direction apart from the rotation of the rotor itself.

The values of the optimal pitch angles diminish with the increasing of the TSR.

Further investigations must be made taking into account the interference between the rotor blades and damping with the rotation ω of the blades.

It is probable controlling of the pitch angles of blades may essentially diminish:

– the appearance of vortices and turbulence in the downstream airflow, that would improve efficiency of the leeward side blades;

– the aerodynamic load on the rotor shaft.

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А. А. Зіганшин. Числовий метод визначення оптимальних кутів відхилення лопатей Н-ротора Дар'є

Створений комп'ютерний метод по визначенню оптимальних кутів відхилення прямих лопатей ротора Дар'є. Показано, що керування відхиленням лопатей дозволяє створити и збільшити пусковий момент і також покращити ефективність роботи ротора.

Ключові слова: аеродинаміка; керовані кути відхилення; ротор Дар'є; вітрова турбина.

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Напрям наукової діяльності: системи автоматизації проєктувальних робіт, числові методи в аеродинаміці, поновлювальні джерела енергії.
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А. А. Зиганшин. Численный метод определения оптимальных углов отклонения лопастей Н-ротора Дарье

Создан компьютерный метод по определению оптимальных углов отклонения прямых лопастей ротора Дарье. Показано, что управление отклонением лопастей позволяет создать и увеличить пусковой момент и также повысить эффективность работы ротора.

Ключевые слова: аэродинамика; управляемые углы отклонения; ротор Дарье; ветровая турбина.

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Направление научной деятельности: системи автоматизированного проектирования, численные методы в аэродинамике, возобновляемые источники энергии.
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