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КРУПНЕЙШИЕ ВЕТРОАГРЕГАТЫ НА ЗЕМЛЕ ИЛИ В МОРЕ

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Предлагается конструкция ветроагрегатов большой мощности с высокой энергетической эффективностью, обеспечиваемой за счет использования вертикального турбулентного переноса энергии воздушного потока и современной конструкции опорного и энергетического узлов с применением магнитного подвеса и линейных генераторов. Представлены результаты численного и физического моделирования.

Ключевые слова: ветроагрегаты, магнитный подвес, линейные генераторы.

THE LARGEST OPEN WINDMILLS ON THE GROUND OR SEA

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In article propose a new type of wind turbines of the big capacity with high energy efficiency achieved through the use of energy streams of wind, not passing directly through the turbine. The design included the modern technologies of transport on the magnetic suspension. The results of physical and numerical modeling are presented.

Keywords: windmills, maglev, linear generators.

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Область научных интересов: научные исследования и разработки в области гидравлического моделирования; гидравлики рек, озер и потоков океана; гидрологии, управления водными ресурсами, сейсмологии и сейсмостойкого строительства; гидроэнергетики, энергии приливов и отливов и строительства ветроэнергетического оборудования.

The idea of offered wind turbines of big power consists in use of effect of turbulent vertical hashing of the streams providing restoration of energy of a stream on the way to a back system of blades (fig. 1). This idea may be used in constructions of the largest windmills [1] or tidal watermills [2].

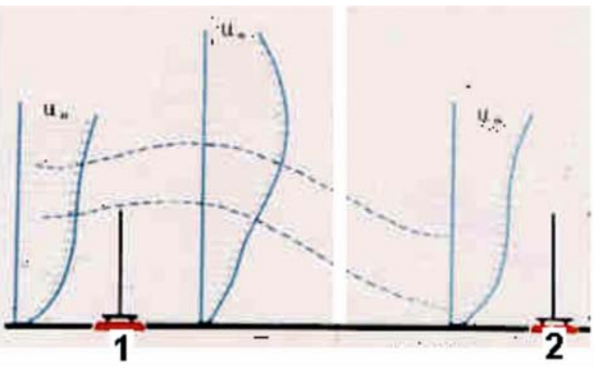

Рис. 1. Вертикальный турбулентный перенос обеспечивает восстановление энергии ветра перед тыльным строем лопастей
Fig. 1. The vertical turbulence mixing go up the power of wind before the rear order of blades

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Certainly, and in this case strict equality of speeds of a stream on all route of blades and outside the unit in the presence of selection of wind power is impossible. However, considering that the local potential capacity of a stream is proportional to the third degree of its speed, even small increase in local speed of a current at the expense of turbulent transfer of energy from the layers of a stream which aren't passing through cross section of the turbine, can give noticeable effect. Working blades of an aerodynamic profile in these installations settle down vertically (or obliquely) and move on the ring route of big diameter. For compensation of a torque and cross forces of the turbine can be placed one over another with the counter direction of movement.

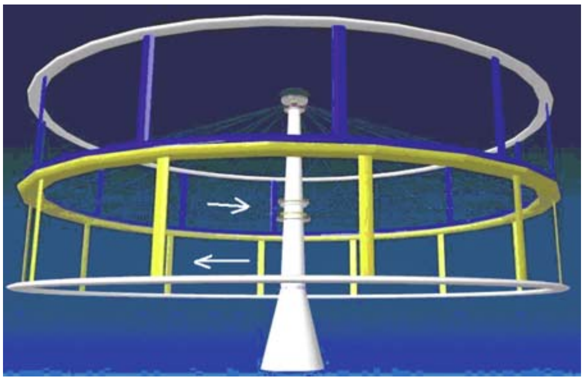

Рис. 2. Идея агрегата, в котором ярусы вращаются в противоположном направлении, состоит в компенсации крутящих моментов и поперечных сил, действующих на роторы, а также в удвоении скорости пересечения магнитных полей в генераторе, что повышает его электрическую эффективность и снижает материалоемкость
Fig. 2. The idea of the unit consists in the use of the effect of mutual compensation of torques and transverse forces, acting on the blades, which move in opposite directions; the effect of increase of efficiency of electric generator at doubling of speed of crossing the magnetic fields of inductor and armature of induction generator*)

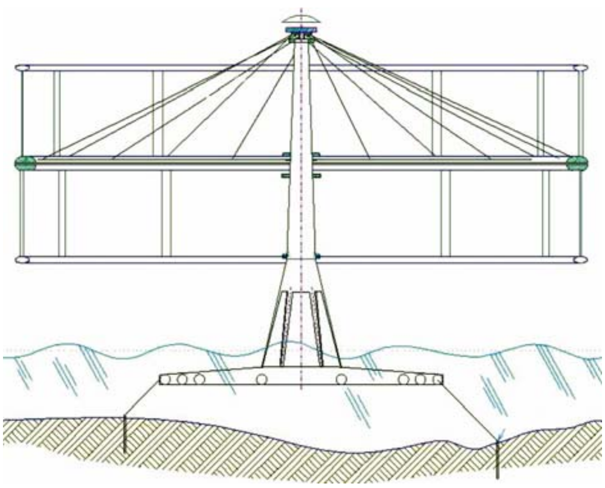

Рис. 3. Ветроагрегат на воде монтируется в сухом доке и на плавучем основании доставляется к месту эксплуатации, где фиксируется якорями или сваями
Fig. 3. Wind power unit on the water. The windmills are complicated in the dry dock and go to the power plant area by floating

In this case presence of a smooth surface of the earth (fig. 2) or a water surface (fig. 3) can carry out positive function of the concentrator of a wind.

Quantitative effect of restoration of energy behind a frontal system of blades for real conditions of a three-dimensional non-stationary task it was estimated on the example of numerical model of the turbine reproducing the main features of the two-level multi-blade unit with oncoming traffic of circles of the turbine (fig. 4).

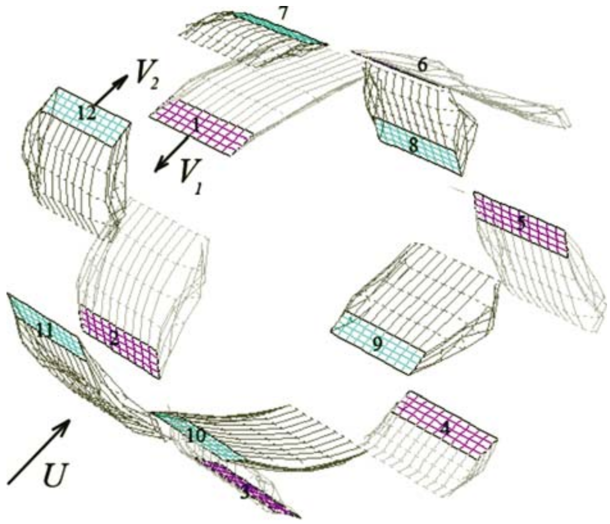

Рис. 4. Схема численного моделирования пространственного обтекания роторов, вращающихся в противоположном направлении
Fig. 4. Scheme of spatial calculation of turbines of counter rotation

For calculations the simple model developing known ideas of “discrete whirlwinds” which doesn't contain empirical coefficients was used and approved on a big material of classical experiments. In fig. 5 results of calculations of the unit with a diameter of D = 2.4 m for three options of length of blades – 0.3 m, 0.6 m and 0.9 m are presented. Calculations are carried out for the same speed of a wind of U = 10 m/s and the speed of blades of V = 20 m/s. Loading (radial force), operating on one of 6 blades decided on a chord of b = 160 mm (solidity $\sigma = ib/D = 0.4$). The turbine (top) rotates counterclockwise, bottom – clockwise. The beginning of coordinates answers the moment when the blade moves towards a wind. Apparently, while the blade is at the front loading negative (force is directed to the center) and the maximum effort to the short blade (0.3 m) is 3 times less, than on the longest blade (0.9 m) and points of maxima don't coincide. The maximum loads of blades of 0.6 m and 0.9 m are observed almost in one place and differ approximately at 1.6-1.7 time that approximately corresponds to a ratio of lengths of blades. The most interesting is observed on a back site of a course first maximum (240-275°) load of the short blade almost same, as well as on long. Stream speeds on the back party of the route of blades at short blades are much

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higher, than at long (fig. 6). The maximum load of the blade towards a rotation axis in this case doesn't exceed 23N, and from an axis of rotation 13N. The total longitudinal loading operating on one turbine with 6 blades 900 mm high and a chord 160 mm, doesn't exceed 12N on the blade. Loading on the back party of the route, naturally, is directed from the rotation center (positive), it pulses (the whirlwinds running from blades at the front) affect, but, the most important, is in a zone of the first maximum (240-275 degree) – load of the short blade almost same, as well as on long. Stream speeds on the back party of the route of blades at short blades are much higher, than at long (fig. 6).

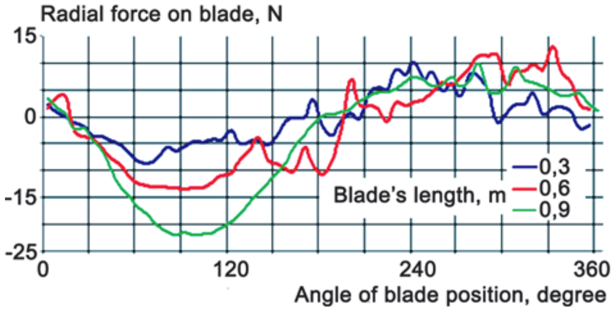

Рис. 5. Аэродинамические нагрузки на лопасть разной длины (длина лопастей 0,3, 0,6 и 0,9 м) в 6-лопастном агрегате в зависимости от положения лопасти на трассе. Скорость ветра 10 м/с, скорость лопастей 20 м/с. Диаметр ротора 2,4 м, хорда лопастей 0,16 м
Fig. 5. Load of one blade of the 6-blades two-story unit at a speed of U = 10 m/s and the speed of blades of V = 20 m/s. Diameter of the route is D = 2.4 m, a chord of b = 0.16 m

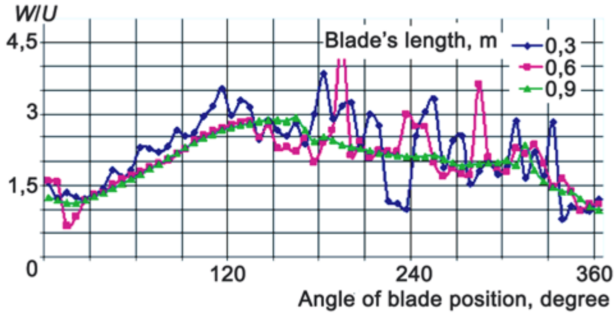

Рис. 6. Относительная величина модуля скорости потока перед носком лопасти в долях скорости потока на подходе к агрегату
Fig. 6. The module of local relative speed of a stream in points of the route of blades at distance of one chord before a blade sock. Speed is measured in shares of speed of a stream in front of the turbine

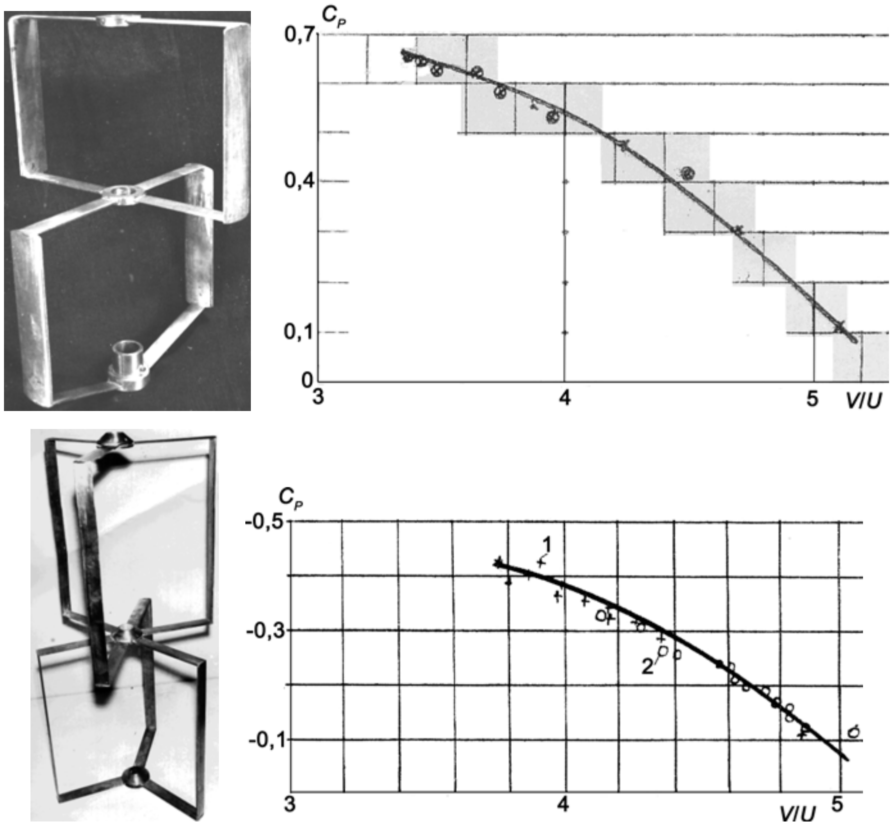

Рис. 7. Верх. Оптимизированная двухлопастная ортогональная турбина. Результаты испытаний в канале шириной 1 м. D = 200 мм, b = 30 мм, L/b = 4,16, b_t/b = 0,5, затенение 0,3, maxC_P = 0,661, V/U = 3,35
Низ. Трехлопастная модель ортогональной турбины. Испытания в канале шириной 2 м, глубиной 1,5 м, D = 400 мм, b = 30 мм, затенение 0,225. b_t = 30 мм, H = 800 мм, L = 400 мм. 1 – U = 0,84 м/с, 2 – U = 0,68 м/с
Fig. 7. Top. Optimized two-blades model of conventional orthogonal turbine.
Test in the channel width 1 m. D = 200 mm, b = 30 mm, L/b = 4.16, bt/b = 0.5, solidity 0.3, maxC_P = 0.661, V/U = 3.35
Low. Three-blades model of orthogonal turbine. Test in the channel width 2 m , depth 1.5 m. D = 400 mm, b = 30 mm, solidity 0.225, bt = 30 mm, H = 800 mm, L = 400 mm. 1 – U = 0.84 m/s, 2 – U = 0.68 m/s

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The results show that if the diameter of the turbine is only 4 times larger length of the blades, the effect of transverse turbulent transfer of momentum is significant and the energy efficiency of the rear part of the track of the blades is almost the same as the front section. Without this effect, the back part of the track gives energy to 4 times less than the front. Thus, the energy effectiveness of the system is expected to grow at 2/1.25 = 1.6 times. For accepted overall sizes the power of wind power unit rotor depending on the wind speed of U before the windmill is determined from the formula $P = C_P \rho U^3 D (L/2)$, where C_P is the power factor (efficiency). Efficiency of the best modern traditional windmills (HAWT) is not more 0.38 only. Optimized conventional orthogonal units with solidity 0.3÷0.4 power factor (efficiency) up to C_P = 0.45÷0.6 (fig.7).

Thus, the use of the turbulent transverse momentum transfer will increase the efficiency of the best units to C_P = 0.72÷0.96.

The aerodynamic characteristic of wind power unit rotor was obtained also as a result of the model tests of one half of the unit (upper or lower) in the hydraulic head channel with cross-section of 6×2.5 m^2 at flow water speed up to 2.2 m/s. The diameter of the blades route of the model was 2.7, 3.34 and 3.98 m; the length of blades was 0.72 m or 0.485 m at the chord of 0.12 m and GAW-1 profile. The quantity of blades varied from 3 to 12. The inductors of linear generator were reproduced on the model. The diameter of the ring with the short-circuited rotor was accepted as 2333 mm, the diameter of the blades route was larger due to the traverses rigidly fixed on the rotor ring. The blades were located cantilevery (fig. 8). In the proposed optimized construction the blade tips are united by ring that must decrease tip eddy losses and increase the effectiveness of wind power unit.

In the experiments was measuring the velocity distribution along the walls of the channel and in the axial cross sections, before and behind the model. The velocity along the walls changed not more 2%. The water flowing around the turbine in model with diameter 2.7 m and in prototype are considerably accelerated the same and test results were not invalid. The good efficiency of the turbine explained by the transverse turbulent power transition to the back row of blades. The efficiency of turbine in prototype will change for difference conditions of atmosphere turbulence and stratified degree. This problem must be researched in future.

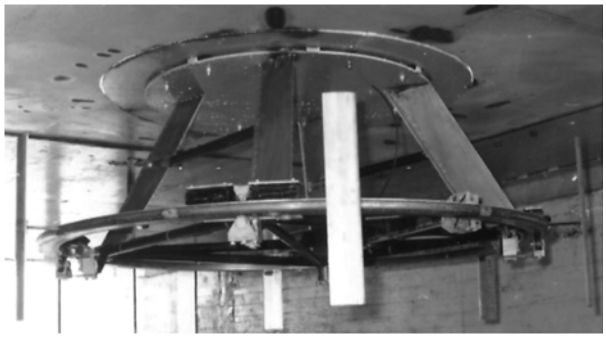

Рис. 8. Модель многолопастного ротора в гидравлическом напорном канале
Fig. 8. Model of multiblade rotor in hydraulic channel

The experiences showed that even in the tested, not optimized scheme with 6 blades (solidity was 0.22÷0.26) the efficiency of rotor can exceed C_P = **0.4÷0.58** at blades speed exceeding wind speed by a factor of 2.9÷3.2 [3, p.240].

In this basis we propose the project with ring rotor, which carries the inductors of linear generator, is connected by the stretching with the radial thrust bearing, located at the top of the central pylon. The mark of the bearing at the top of the pylon is 60-100 m. Diameter of the rings 160 m. The size of blades 25×6 m^2 for power of unit **10 MW** (fig. 2, 3).

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