Some aspects regarding torque study and elaboration of the blades orientation mechanism for microhydropower plant

BOSTAN Viorel, BOSTAN Ion, DULGHERU Valeriu, and CIOBANU Oleg

In the following, we calculate the hydrodynamic coefficients for the reference profile NACA 0016 with length rope, for example $c = 1,3m$. The calculation methods described in [4, 7, 8, 9] are applied to calculate the coefficients corresponding to the profile NACA 0016 with rope length $c_{ref} = 1m$: $C_{L,ref}, C_{M,ref}$ and $C_{D,ref}$. The coefficients corresponding to the profile with the length rope are calculated from the relations (1)

$$\begin{aligned} C_L &= C_{L,ref} \cdot 1,3, \\ C_M &= C_{M,ref} \cdot (1,3)^2, \\ C_D &= C_{D,ref} \cdot 1,3. \end{aligned} \tag{1}$$

Knowing the values of the hydrodynamic coefficients and, it is calculated by formulas (2) and (3), respectively, the load-bearing and resistance forces,

$$F_L = \frac{1}{2} C_L \rho V_\infty^2 S_p, \tag{2}$$

$$F_D = \frac{1}{2} C_D \rho V_\infty^2 S_p, \tag{3}$$

and formula (4) provides us with the hydro-dynamic force acting on the blade (figure 2 (b)).

$$\begin{aligned} F_{x'} &= -F_L \sin\varphi + F_D \cos\varphi, \\ F_{y'} &= F_L \cos\varphi + F_D \sin\varphi. \end{aligned} \tag{4}$$

To determine the optimal working attack angle, we calculate the value of the moment developed by a blade and the total moment for several values of the angle of attack, namely: $\alpha = 15^o, 17^o, 18^o, 20^o$. Thus, the attack angle for the blade with the hydrodynamic profile NACA 0016 was chosen $\alpha = 18^o$. The rotor performance with 3, 4 and 5 blades was also analyzed. Thus, the total torque developed at the rotor shaft was calculated, the results being presented in figure 1. In the elaboration of the microhydropower plants, the experience gained at the stage of "research - design - manufacture" of the pilot station exposed in

[1, 2, 3] was used. The efficiency of operation of micro-hydropower plants by individual consumers for a given destination depends both on the correct choice of the constructive configuration of the micro-hydropower plant and on the functional characteristics of the component aggregates.

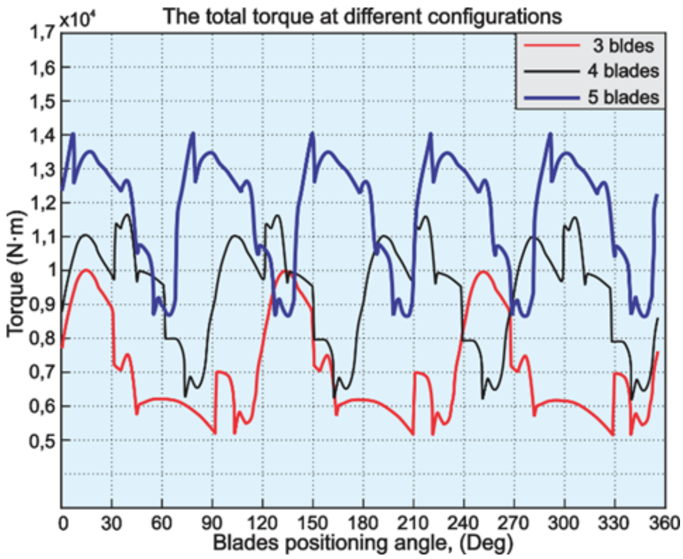
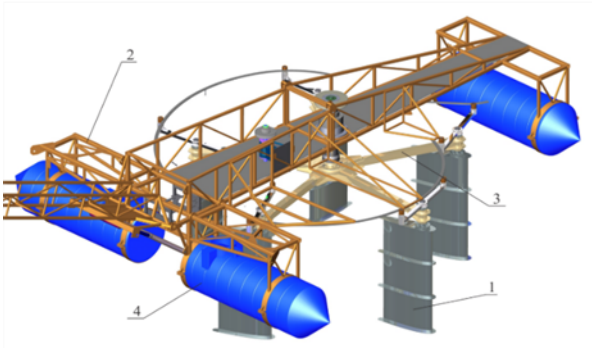


Figure 1. The total torque Tr, Σ developed at the rotor shaft with 3, 4 and 5 blades depending on the positioning angle.

For the mentioned microhydropower plants, 2 types of rotors with 3 and 5 blades were developed. The installed power of micro hydropower plants with a diameter D = 4 m, the height of the blades submerged in water h = 1.4 m and the length of the blade cord c = 1.3 m at the water flow speed V = 1 - 2 m / s can be within P = 2 - 19 kW. Based on research on the hydrodynamic rotor with blade cord c = 1300 mm it was found that at speed V = 1.2 - 1.3 m / s the turbulence of the water flow caused by the upstream blade influences the neighboring blade in the downstream area. Analyzing the results of CFD simulations for the speed of water currents V> 1.3 m / s, the profile of the blade with cord length c = 800 mm was elaborated. For the first time, it was proposed to build hydrodynamic blades equipped with screens to direct the flow of fluid along the cord. This technical solution helps to reduce the negative influence on the conversion efficiency of the boundary layer separation [5, 6, 10]. Based on the results of scientific research, Autodesk Motion Inventor, Solid Works software were designed and 3 types of MHCF modularly designed with different application areas were manufactured. Increasing the efficiency of the kinetic energy conversion of the water flow both by contributing to the formation of the summary torque of the blades in the transition zone from the upstream area to the downstream area, and by positioning the blades according to the flow rate of the water flow, leads to the increase of the hydrodynamic forces developed by each blade and to the simultaneous decrease of the hydraulic resistance forces when the blades rotate. Figure 2 (a, b) shows the industrial prototype of the micro-hydropower plant with tipping rotor with blades with cord length c = 800 mm and height h = 1600 mm equipped with screens.



a)

b)

Figure 2. Flow micro hydropower plant with 5-blade tilting hydrodynamic rotor with cord length c = 800 mm, submerged height h = 1600 mm and screens for directing fluid flow (a). Industrial prototype of the micro hydropower plant installed on the test site on the Prut River (com. Stoienești, Cantemir) (b).

The proposed hydrodynamic rotors and the technical solutions developed as a result of CFD simulations, meant to increase the efficiency of energy conversion in MHCF, have been protected with 11 patents.

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(BOSTAN Viorel, BOSTAN Ion, DULGHERU Valeriu, CIOBANU Oleg) Technical University of Moldova, Chișinău, Republic of Moldova

E-mail address: viorel.bostan@adm.utm.md, ion.bostan@cnts.utm.md, valeriu.dulgheru@bpm.utm.md, oleg.ciobanu@bpm.utm.md