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INVESTIGATION OF FLUID FLOW IN TWO-DIMENSIONAL AND THREE-DIMENSIONAL FORMULATION IN THE FLOW PART OF A HIGH-PRESSURE FRANCIS TURBINE

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When designing the flow part of the turbine using the calculated and experimental research methods[1, c.28]. Recently, in order to reduce the amount of physical experiment, great attention has been given to a numerical experiment. This allows you to reduce the time and cost of design work, which leads to the comprehensive introduction of automated hydro turbine design systems into engineering practice.

In order to ensure high energy-cavitational parameters of the flow part of the hydro turbine, it is necessary to conduct a comprehensive hydrodynamic analysis of the flow part using modern CFD application software packages. These packages allow us to calculate the viscous turbulent flow in the cavity of a hydro turbine of any complexity [2, c.203].

The flow simulation in the hydraulic machine can be carried out in various approximations. One of the most common and effective approaches is the stationary cyclic statement, in which it is assumed that the currents in all interscapular channel of the guide vane and in the inter-blade channels of the runner are the same [1, c.63]. In this case, the calculation is carried out only in one of the channels of the guide vane and the runner, and on the side borders of the channels the conditions for the periodicity of the flow are set [3, c.184]. To transfer flow parameters from rotating segments to fixed and vice versa, their values are averaged in the circumferential direction [4]. Such an approach significantly saves computational resources, but it does not make it possible to take into account the circular irregularity of the flow and the non-stationary effects associated with it [5, c.120].

The article presents the results of a computational study of fluid flow in a spiral case and in the area of stator grids and guide vane of the high-pressure Francis turbine Fr500, performed using the CFX-TASCflow program [6, c.14] and the model developed at the hydraulic machines department [7, c.97].

Numerical modeling of the spatial flow in the flow part of the hydro turbine was carried out to determine the change in energy characteristics, therefore the k - ε model of turbulence was chosen, this model is the most successful model of first-level turbulence of the circuit [8]. To describe the turbulent quantities, it uses a system of two nonlinear diffusion equations - for the mass density of turbulent energy k and the dissipation rate of turbulent energy ε [9, c.216].

This model was developed in the 70s [10, c.272]. There are also modifications.

When using this model, the system of equations of fluid motion is supplemented by two differential equations describing the transfer, respectively, of the kinetic energy of turbulence k and dissipation rate ε [11, c.33].

We write two equations for k and ε:

$$\frac{\partial pk}{\partial t}+\nabla(pUk)=\nabla\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\nabla k\right]+P_k-p\varepsilon \tag{1}$$

$$\frac{\partial p\varepsilon}{\partial t}+\nabla(pU\varepsilon)=\nabla\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\nabla\varepsilon\right]+\frac{\varepsilon}{k(C_{S1}P)_k}-C_{S2}p\varepsilon\,, \tag{2}$$

where, constants for models with two differential equations $\mu_t = C_\mu p\frac{k^2}{\varepsilon}$, $C_\mu = 0.09$, $C_{S1} = 1.44$, $C_{S2} = 1.92$, $\sigma_k = 1.0$, $\sigma_\varepsilon = 1.3$, P_k – takes into account the occurrence of turbulence due to viscous friction forces and is determined by [12, c.193]:

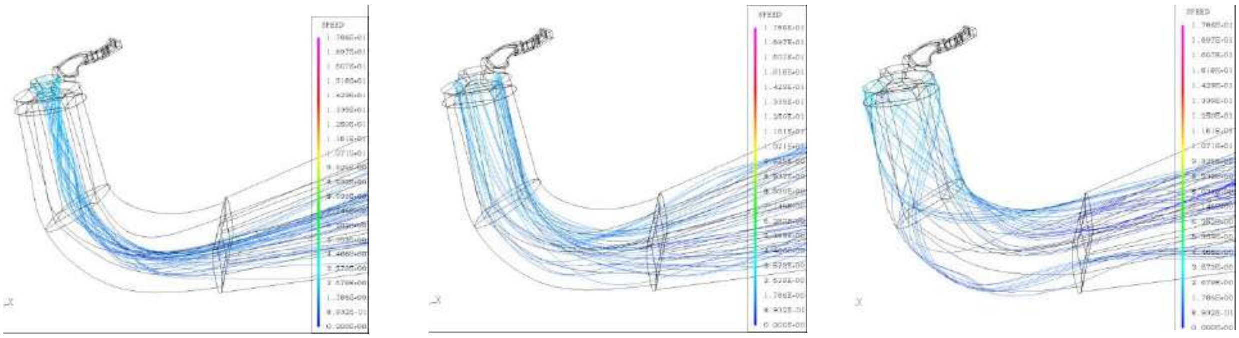
$$P_k = \mu_t\nabla U\left(\nabla U + \nabla U^T\right) - \frac{2}{3}\nabla U\left(3\mu_t\nabla U + pk\right) + P_{kb}$$

In more detail, models based on two differential equations are given in.

Numerical simulation of the flow in the flow parts of the hydro turbine Fr500 was carried out for the design area, including the intervene channel formed by stator columns, shoulder guide vanes, runner blades and draft tube for a model with a diameter runner D1=500 mm.

The obtained results of the calculation of the spatial flow are presented in the form of averaged values of the total and static pressures of flow, averaged flow angles in relative and absolute motion, and values of losses in individual elements of the flow parts. For runner at a mode point with minimal total losses close to optimal, a static and total pressure field in the computational domain, the distribution of the components of the meridional and peripheral components of the full velocity before entering and output the runner, as well as the trajectory of fluid particles in draft tube.

In fig. 1 shows the trajectories of the movement of the fluid particles in the draft tube (when the fluid flow from the runner falls out) at the optimum mode based on the calculation of the spatial flow.



a) upper rim b) middle c) lower rim

Fig. 1. The trajectories of the movement of fluid particles in the draft tube

The location of the current lines in the draft tube Fig. 4 shows that the speed decreases from the inlet to the outlet of the draft tube, due to which the kinetic energy is converted into pressure energy. There is a gradual drop in pressure from inlet to outlet along the suction and pressure side of the runner blades.

The pattern of fluid motion also shows the orderly nature of the flow in the draft tube (secondary flows in the draft tube are weak). This improves the recovery of static pressure in the draft tube and does not lead to additional losses. The reason for the favorable flow in the peripheral region of the draft tube is a sufficient swirl of flow beyond the runner.

The results of the calculation of the energy loss (at the optimal mode) in the flow parts of a high-pressure Francis turbine Fr500 are shown in the table.

Table 1 - The results of the calculation of the energy loss in the flow parts of a high-pressure Francis turbine

Turbine type	Calculation program	Energy losses, %				$\sum$
		Spiral case + Stator	Guide vane	Runner	Draft tube	
Fr500	Two-dimensional model	0,6	3,02	1,61		5,23
	3D model	0,77	2,5	1,66	0,2	5,13

The main conclusions obtained in the article:

1. To reduce the amount of physical experiment, it is necessary to pay more attention to the numerical experiment. This will reduce the time and cost of design work.

2. Considered in detail the nature of the movement of fluid in the flow part high-pressure hydro turbine.

3. The results of the calculation optimal mode of the hydro turbine using two-dimensional and three-dimensional flow models are given, the obtained data are in good agreement with each other.

4. To improve the energy performance of high-pressure Francis turbine, it is necessary to study in more detail the effect of the geometry of the guide vane on the formation of losses in the hydro turbine.

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АНАЛІЗ РЕЖИМІВ РОБОТИ КАБЕЛЬНИХ ЛІНІЙ ЕЛЕКТРОПЕРЕДАЧ ТА РОЗРОБКА ЗАХОДІВ ЩОДО ПІДВИЩЕННЯ ЇХ НАДІЙНОСТІ

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Для передачі і розподілу електроенергії використовуються повітряні і кабельні лінії; вартість кабельних ліній вище, однак вони знаходять широке застосування в великих містах і на промислових підприємствах, де рівень електроспоживання і щільність навантаження досить значні, а також в місцях, де застосування повітряних ліній важке (наприклад, при переходах траси лінії через водні території). В даний час при будівництві кабельних ліній широко використовуються силові кабелі середньої і високої напруги 6500 кВ сучасних конструкцій. Найбільшого поширення отримують силові однофазні кабелі з ізоляцією із зшитого поліетилену.

Високий рівень напруги жили однофазного кабелю в мережах класів 6 кВ і більше призводить до необхідності використання в конструкції кабелю металевого екрану, виконуваного у вигляді дротів і / або стрічки. Основними завданнями, які вирішує екран, є вирівнювання електричного поля, що впливає на головну ізоляцію кабелю (ізоляцію «жила-екран»), і усунення електричного поля на поверхні кабелю. Для зниження напруги на екрані виконується його заземлення