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Modeling of the water-wheel with a water stream by means of the computer program «FloWision»

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Abstract
This paper presents modeling of the water-wheel with a water stream by means of the computer program «FloWision». For the decision of problems in package FloWision before the beginning of process of modeling double-rotor water-wheels have generated sequence of actions. For creation of model of the water-wheel in Flow Vision, by means of the external program it is carried out - a geometrical preprocessor. As such preprocessor package Solid Works was used. Computer program Flow Vision is based on the equation of Naver - Stocks who also is applied together with the indissolubility equation. Before the beginning of process of modeling double rotor water-wheels, the mathematical model (a set of the equations) gets out. On principles of two basic equations in program Flow Vision interactions of a water stream with the turbine blade, sizes and character of action of hydrodynamic forces are shown. Pressure or speed are found in any point of settlement model. In program Flow Vision it is visible as pressure and speed of a hydraulic stream in points along a red line on a surface of a profile of the blade changes. The analysis of interaction of forces of a water stream with turbine blades has shown that, probably to carry out opposite rotation of two turbines in one current. It provides more effective transformation of a water stream, and to receive micro hydroelectric power station with the improved technical and economic indicators.

Keywords: A water stream, modeling, water-wheels, FloWision, micro hydroelectric power station

I. Introduction
Electric energy on today's is the most important goods which have great value for any economy. One of the most important and achievable methods for electric power manufacture is introduction independent manufacture of the electric power with use of renewed energy sources [1]. The technology of working out and manufacturing micro hydroelectric power stations is rather cheap for environment, other mechanisms of generation of renewed energy on smaller capacity some court yard, villages or roadside commercial can electrify the enterprise [2,3]. It becomes very comprehensible technology which can be now to be considered as alternative in technically possible areas, as in comparison with expansion with diesel engines-generators and solar энергий photo-electric stations. One of the primary goals of working out of methodical bases and designing micro hydroelectric power stations of low power for a food of independent consumers, dwellings of shepherds and other low-power consumers in remote areas, is model working out micro hydroelectric power stations for definition of development of energy depending on key parameters micro hydroelectric power station and water conditions.

In the offered scheme micro hydroelectric power stations system of development of energy which makes 3 kw of capacity which can be used for rural electrification.

The water-wheel is one of most prominent aspects of a power supply system. At carrying out of researches and workings out in the field of water-power engineering physical and mathematical models as natural experiments are not always possible both on technical, and for economic reasons are widely used. The mathematical model describes real object only with some degree of approach (detailed elaboration). Thus the model kind depends as by nature investigated object, and on research problems, the technique of modeling necessary for accuracy of the description of object. Division of mathematical modeling into three principal views is standard: analytical, imitating and combined [1,2]. Prominent feature of analytical modeling is the description of processes of functioning of elements of modeled system in the form of some parities −differential, integral-differential, certainly-difference or logic conditions. The analytical model can be investigated following methods [4]: analytical (thus the purpose is reception of various dependences for required characteristics in a general view); numerical (in this case the purpose is reception of numerical results at the certain initial data, and the decision is not in a general view);Qualitative (the decision in an explicit form is absent, but it is possible to estimate some properties of the decision).

II. Model of the proposed micro-hydro power plant
In the offered scheme micro hydroelectric power stations system of development of energy which makes 1 kW of capacity which can be used for rural electrification.

The water-wheel is one of most prominent aspects of a power supply system.

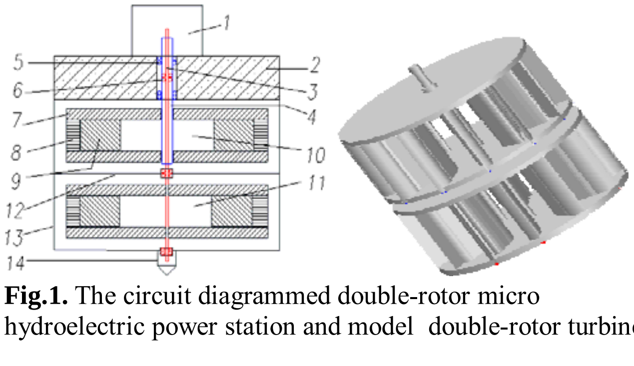

Fig.1. The circuit diagrammed double-rotor micro hydroelectric power station and model double-rotor turbines

Installation as follows works. Installation consists of two independent vertical driving wheels 10 and 11, located one over another. Each driving wheel has the shaft of rotation 3 and 4. On external a floor to a shaft 4 with the help radials - the basic bearing 5 the tank - a float 2 fastens. It is not placed double-rotor the generator 1. In the middle of a hollow external shaft 4 it is established radials - the basic bearing 6 on which internal ring takes place an internal integral shaft 3 bottom driving wheels. Each driving wheel consists from: the top and bottom rim 7, blades 9 and before a wing 8. Two turbines are divided among themselves by a dividing plane 12 and protected by a metal grid 13. At installation immersing on water installation work is carried out as follows: the water stream arrives on turbines and they start to rotate every which way at the expense of various installations of blades and before a wing. The bottom driving wheel it is connected to a rotor of the generator by means of an internal shaft and rotates clockwise. The top driving wheel it is connected with stator the generator by means of an external shaft and rotates counter-clockwise. Thus rotation of a rotor and stator is carried out rather each other in the opposite sides that provides increase in frequency of crossing with a magnetic field of an electric winding of the hydro generator.

Such technical decision allows to avoid presence of the animator for increase in frequency of rotation of a rotor as in the classical generator. Moreover there is a possibility to simplify a design such double-rotor the hydro generator and to lower it mass dimensions the sizes.

Hydraulic capacity is accessible from the hydraulic turbine, can be expressed as follows [5]

$$P = \rho * g * H \qquad (1)$$

The electric part of model of the car is described system of the equations, with a rotor:

$$\frac{d}{dt} i_d = \frac{1}{L_d} U_d - \frac{R}{L_d} i_d + \frac{L_q}{L_d} p\omega_r i_q \qquad (2)$$

$$\frac{d}{dt} i_q = \frac{1}{L_q} U_q - \frac{R}{L_q} i_q + \frac{L_d}{L_q} p\omega_r i_d - \frac{\lambda p\omega_r}{L_q} \qquad (3)$$

$$T_e = 1{,}5p\,[\lambda i_q + (L_d - L_q)\, i_d i_q] \qquad (4)$$

In system the equation following designations are accepted:

L_d, L_q - inductive of stator on axes d and q;

R - active interfaces stator;

i_d, i_q –current projections stator on an axis d and q;

U_d, U_q - pressure projections stator on an axis d and q;

ω_r - angular frequency of rotation of a rotor;

λ- a magnetic stream of constant magnets;

P - number of pairs poles;

T_e- electromagnetic the moment.

The mechanical part of model is described

$$\frac{d}{dt}\omega_r = \frac{1}{J}(T_e - F\omega_r - T_m) \qquad (5)$$

$$\frac{d}{dt}\theta = \omega_r \qquad (6)$$

Where j - the total moment of inertia of a rotor and loading;

F -factor friction;

T_m- the resistance moment.

Capacity of micro hydroelectric power station is defined under the formula:

$$P = Q \cdot (H_g - H_п) \cdot \eta \cdot g \qquad (7)$$

Where P - capacity, kw;

Q - the water expense through the turbine, a km/s cube;

H_g –geometrical height from top to bottom, m;

$H_п$- hydraulic losses in which pipelines;

η- factor useful (0,5... 0,7);

g – a accelerations of free falling ($9{,}8 m/s^2$).

At carrying out of researches and workings out in area waterpower physical and mathematical models as natural experiments are not always possible both on technical, and for economic reasons are widely used. The mathematical model describes real object only with some degree of approach (detailed elaboration). Thus the model kind depends as by nature investigated object, and on research problems, the technique of modeling necessary for accuracy of the description of object. Division of mathematical modeling into three principal views is standard: analytical, imitating and combined [6,7]. Prominent feature of analytical modeling is the description of processes of functioning of elements of modeled system in the form of some parities –differential, Integra-differential, certainly or logic conditions. The analytical model can be investigated following methods [8]: Analytical (thus the purpose is reception of various dependences for required characteristics in a general view); numerical (in this case the purpose is reception of numerical results at the certain initial data, and the decision is not in a general view);

Qualitative (the decision in an explicit form is absent, but it is possible to estimate some properties of the decision).

III. The program description

Computer program Flow Vision has been applied to calculation and driving wheel modeling double rotor water-wheels. Computer program Flow Vision is based on the equation of Nave - Stokes who also is applied together with the indissolubility equation. For short circuit of these equations depending on a specific target the additional parities describing change of density, turbulent carrying over can be used and etc. In Flow Vision following models most full are presented:

- Approach of Bussinesk (small changes of density) for the description of a laminar current of a viscous liquid at Reynolds's small numbers;
- K - ε model of turbulent flow of a viscous liquid with density little changes at Reynolds's great numbers;
- Model poorly compressed liquids (in terminology Flow Vision) which allows to count a stationary subsonic current of a stream at any changes of density; model of completely compressed liquid (in terminology Flow Vision): a stationary and non-stationary current.

Flow Vision use of a wide set of the boundary conditions depending on concrete model is supposed, however all of them are based on following most often meeting conditions on hydrodynamic variable (pressure and speeds):

- Conditions of sticking or to slip the liquids set for a vector of speed on borders with firm bodies;
- Conditions on the values of pressure usually set on borders;
- Conditions on values of speed of a stream on a normal to border or at an angle to a normal;
- A condition to follow with a zero gradient of pressure;
- Combinations of the conditions listed above, for example, free to follow to a liquid with zero gradients of pressure and speed or values set on border of pressure and speed.

It is necessary to notice that concrete boundary conditions, as well as values of parameters of the equations (density, viscosity, and etc.), can be set by variables on time.

Entry conditions are necessary for setting by consideration of the models corresponding to non-stationary movements. Depending on a kind of the modeling equations during the initial moment of time in all points of settlement area values of required functions and (or) some derivative of them are set, and these values can be various in different parts of area [52].

IV. Algorithm of modeling of the water-wheel in package Flow Vision

Before the beginning of process of modeling double rotor water-wheels we form sequence of the actions, necessary for the decision of problems in a package. It is necessary to notice that for creation of model of the water-wheel in Flow Vision, at first the water-wheel geometry is carried out by means of the external program - a geometrical preprocessor.

As such preprocessor package Solid Works, AutoCad concerning family CaDov (Computer-Aided Design - the automated designing) which were widely adopted in modern scientific and engineering practice [52] is used.

1. Geometricalpreprocessor (SolidWorks)

Export/import of geometry of the water-wheel from Solid Works in Flow Vision. We export created three-dimensional model of the water-wheel and to keep in format VRML through menu point «the File/keep as …» (file type *.WRL). To start program Flow Vision and to import the created geometry for what to press button "Create", then to specify a way to created in Solid Works to a file *.WRL. After that in the right part of window Flow Vision should there is a three-dimensional image of the water-wheel (driving wheel) (fig 2).

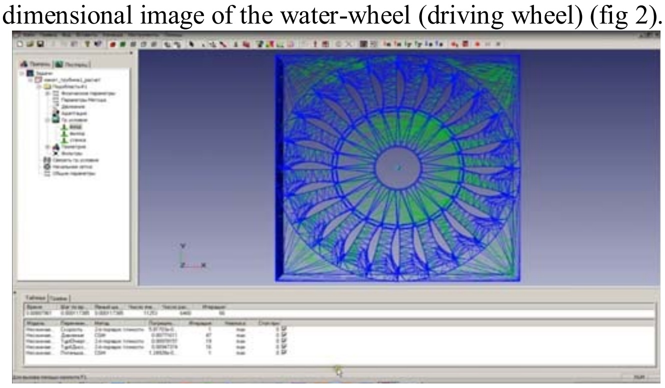

Fig. 2. Three-dimensional model double-rotor water-wheels

2. Choice of mathematical model (set of the equations). We open a tree, having clicked the left button of the mouse on knot ⊞, and then the tree knot «Under area #1» is allocated by the right button. In the appeared contextual menu we will shave point «to Change model …», further in the opened window it is chosen one their points of the revealing list "Model".

For model «Incompressible liquid» it is possible to choose turbulence model. It can be made in a window of properties «model Parameters» in a bookmark "Turbulence" in the field "Model".

It is by default used «Standard k- model».

3. Input of physical parameters. Through the contextual menu of knot of a tree «Substance 0» we open a window of property of substance (liquid/gas); we choose the necessary parameters. Then in the top line tables ("Value") of numerical values of parameters we press the button ✓, and then or to close a window of properties, or to "attach" ( ) it to the screen. Key parameters are "Density" and «Molecular viscosity». For example, in вкладке "density" in the revealing list "Dependence" it is necessary to choose «Value + (d Value /d Temperature)» and to establish value 0.001 Pa*s (water).

4. Input of boundary conditions. In a tree branch «BoundaryConditions» it is allocated corresponding border in a tree (thus in right (the basic) window parts the marked border is painted in the color set earlier). Further we open a window of editing of a boundary condition, or through point of the contextual menu to "Edit", or through button "Ed" in a window of properties. Following characteristic combinations of types of boundary conditions are possible:

a) «Border type» - "Wall"; «Type of a boundary condition» - «the Wall with проскальзыванием» (the reference in zero normal components of speed) or "Wall" (the reference in zero of all a component of speed);
b) «Border type» - "Input/exit", «Type of a boundary condition» - «the Normal input/exit» or «Pressure upon an input»;
c) «Border type» - «the Free exit», «Type of a boundary condition» - «Zero pressure/exit».

5. Problem calculation is carried out by button pressing (for the first time) or buttons . In the course of calculations it is necessary to pay attention to the bottom part of window Flow Vision where are displayed current time, a step on time and (in a column "Error") the maximum errors in calculation of pressure and speeds. In correct calculation these errors should not exceed 0.01 (1 %). It is necessary to note, this error concerns one step on time and has only indirect relation to accuracy of the received final decision. Calculation stops button pressing STOP. Calculation is spent after adjustment of parameters of the postprocessor. Thus calculation of stationary problems should be finished, when it is possible to consider a current established (the visual picture of the received current remains to a constant, and values of parameters change in due course "a little") (fig 3) [50].

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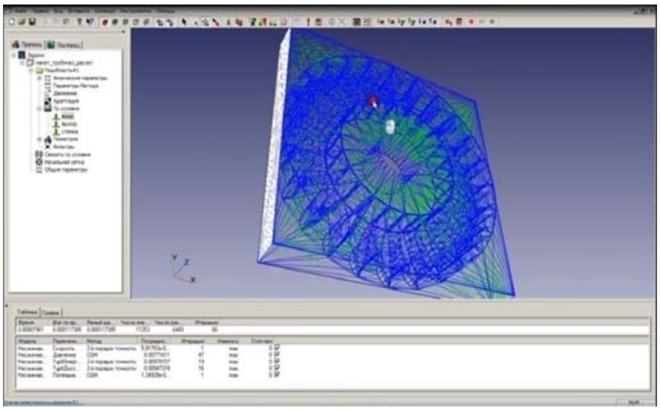


Fig. 3. The Fragment of modeling (calculation) double-rotor water-wheels

Interactions of a hydraulic stream with the blade and blade double rotor water-wheels

Interactions of a water stream with the blade of the turbine and about sizes and character of action of hydrodynamic forces, us was program Flow Vision which works on principles of two basic equations of a stream of a liquid of the equation of indissolubility and the equation of Bernoulli is used. The equation of indissolubility of a stream reflects the law of preservation of weight: the quantity of a flowing liquid is equal to quantity of the following

$$q_1 = q_2. \quad (8)$$

With the account that $q = \vartheta \cdot \omega$,, we will receive the equation of indissolubility of a stream:

$$\vartheta_1\omega_1 = \vartheta_2\omega_2. \quad (9)$$

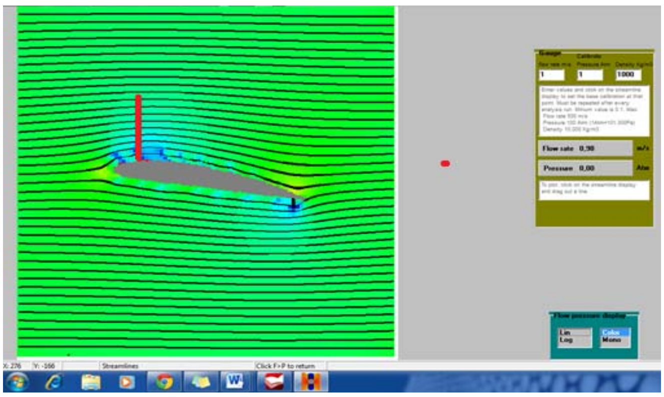
From here speed for target section

$$\vartheta_2 = \frac{\vartheta_1\omega_1}{\omega_2}. \quad (10)$$

The equation of Bernoulli connects pressure, speed of a stream, density of a liquid and liquid height

$$P_1 + \rho g r_1 + \frac{\rho\vartheta_1^2}{2} = P_2 + \rho g r_2 + \frac{\rho\vartheta_2^2}{2}. \quad (11)$$

So that to find pressure or speed in any point of settlement model in program Flow Vision reference values of pressure, speed and density of a hydraulic stream till the moment of interaction with the blade should be set. In figure 4 it is accurately visible as pressure and speed of a hydraulic stream in points along a red line on a surface of a profile of the blade changes.



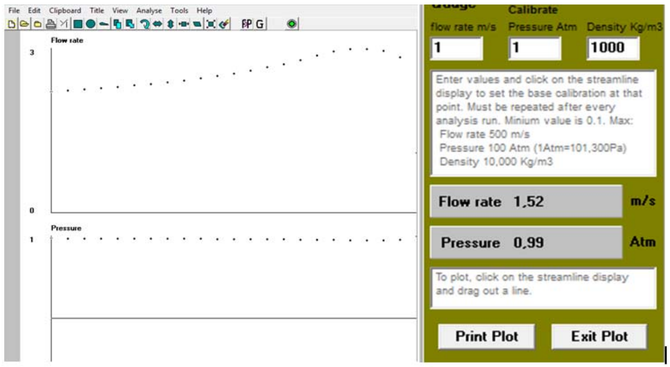


Fig. 4. Modelling of process of interaction of a hydraulic stream with a profile of the blade of the turbine with program use «Flow Vision»

Placing of profiles of rotating turbines on the top and bottom driving wheels of installation is chosen so that on them powerful twisting moments from hydrodynamic forces which are created at a flow by a water stream of blades (figure 5) were constantly created.

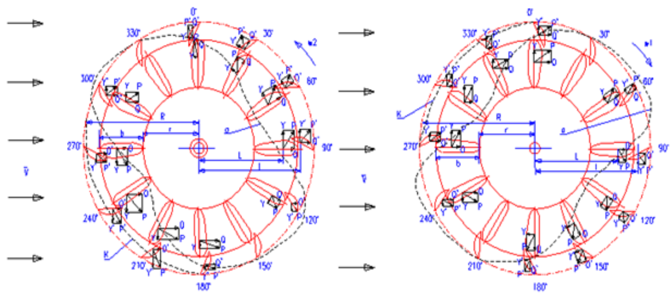


Fig.5. The Scheme of interaction of kinematic and dynamic parameters of a waterway on the blade and предкрылки turbines

In creation of twisting moments, constantly participate hydrodynamic force of blade Y_b on shoulder L, hydrodynamic force before blade Y_{bb} on a shoulder l

$$M_\Sigma = 2n(Y_b \cdot L + Y_{bb} \cdot l) \quad (12)$$

Where 2 - quantity of driving wheels of installation; n - quantity of blades (before blade) the driving wheel; Y_b - rotating hydrodynamic force of the blade; Y_{bb} - rotating hydrodynamic force before blade

$$Y_b = C_{bb}S_b 0.5\rho\vartheta^2 \quad (13)$$

$$Y_{bb} = C_{Ybb}S_{bb} 0.5\rho\vartheta^2 \quad (14)$$

Where, $C_{Ybb}S_{bb}$ - factors of rotating hydrodynamic force; and - the area of the blade and accordingly before blade; S_b, S_{bb}- density of a water stream in kgs^2/m^4; ϑ- speed of a water stream in km/s.

Thus, the analysis of interaction of forces of a water stream with turbine blades has shown that, probably to carry out opposite rotation of two turbines in one current. It provides more effective transformation of a water stream, and to receive microhydroelectric power station with the improved technical and economic indicators.

V. Conclusion

Computer program Flow Vision has been applied to calculation and driving wheel modeling double rotor water-wheels. Computer program Flow Vision is based on the equation of Nave – Stokes who also is applied together with the indissolubility equation. For short circuit of these equations depending on a specific target the additional parities describing change of density, turbulent carrying over and etc. For creation of model of the water-wheel in Flow Vision were used, the water-wheel geometry is executed by means of the external program - geometrical preprocessor Solid Works. Till the moment of interaction with the blade pressure, speed and density of a hydraulic stream are found in any point of settlement model in program Flow Vision.

VI. References

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