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DETERMINATION OF THE POWER INTERACTION OF THE HYDRO TURBINE GRID WITH A FLUID FLOW FOR A DOUBLE-ROTOR MICRO HYDRO POWER PLANT

Abstract. The problem in given article consists in definition of power interaction of a lattice of the turbine with a liquid stream. The moment on the driving wheel is equal to change of the moment of quantity of movement of a proceeding liquid. To find the moment and capacity on a driving wheel shaft, it is necessary to define kinematic parameters of the stream which is flowing round a lattice of a wheel. At calculation new the blade systems the return problem of the theory of lattices is used. The return problem consists in definition of the form of a profile under the set law of distribution of speed (pressure) on a profile contour, and as in definition of power interaction of a stream and a lattice profile. For durability calculations of water-wheels it is necessary to know the hydrodynamic forces operating on the blade of the driving wheel. Analysis and study of the peculiarities of electromagnetic calculation disk generator in static mode does not allow to evaluate the work make full disk generator. This regard, studies have been conducted dynamic mode disk generator. Studies and calculations were carried out by computer simulation using the program «Ansoft Maxwell».Us essentially new design of micro hydroelectric power station with double-rotor the hydro generator is offered.

Keywords: water, method, calculation, spiral chamber, micro hydro power station.

1. Introduction

Renewable energy resources are gaining global attention due to depleting fossil fuels and harmful environmental effects associated with their usage. Hydro, wind, solar, biomass and geothermal energies form the bulk of renewable energy sources; among which hydro power offers one of the most exciting and sustainable proposition. Traditionally, hydropower has accounted for the bulk of the renewable energy production in the United States. The primary energy use in the U.S. in 2011 was 28,516 TWh/yr of which only 9% came from renewable [1]. Traditional hydroelectric or micro-hydro facilities contributed 35% of total renewable energy production [1]. However, growth of conventional hydropower plants are limited due to limitations on the number of available natural sites, large capital (initial) investment, pay-back time and environmental concerns. In lieu of this, marine and hydrokinetic (MHK) systems offer many advantages: these are portable systems with small initial cost, no large infrastructure and easy and quick deployment [2-5]. A study conducted by Electric Power Research Institute (EPRI) for US rivers estimated hydrokinetic power potential of 12,500 MW [6, 7]. This study was based on conservative assumption of turbine array deployment for rivers with discharge rates greater than 113 m³/s and flow velocities greater than 1.3 m/s. A study conducted by EPRI evaluated many, but not all tidal energy sites in U.S. and estimated 115 TWh/yr of tidal energy [6, 7]. These estimates show potential of MHK systems.

Hydrokinetic turbines (HKT) are a class of low head energy conversion devices which convert kinetic energy of flowing water into mechanical work [8, 9]. Tidal and marine current turbines also fall into similar category of (lift-drag) devices which utilize hydrodynamic blade shapes to derive power from flowing fluid. Depending on the flow direction of water relative to the axis of rotation, HKT can be classified as horizontal axis and vertical axis turbines. The performance of these turbines is governed by the three non-dimensional parameters defined below: (a) tip-speed ratio (TSR) that is defined as the ratio of blade tip speed to fluid speed; (b) solidity (σ) that is defined as the ratio of blade chord length times the number of blades to turbine circumference; and, (c) Reynolds number.

Over the last decade, the hydrodynamics of HKT has been investigated using computational fluid dynamics (CFD) [10-12] and laboratory scale experiments [13-15]. Blade-element-momentum (BEM) analysis which forms the backbone of wind turbine rotor design can be used for HKT design [16]. Apart from BEM, a series of inexpensive CFD tools based on the solution of the Euler or Navier-Stokes equations like panel method and vortex lattice method can be used for aerodynamic/hydrodynamic analysis of these devices [17]. In addition, computationally expensive techniques that involve solving Reynolds-averaged-Navier-Stokes equations (RANS) with turbulence models has been successfully used for hydrodynamic analysis of HKT [10, 12, 18]. Consul *et al.* [10] performed a two dimensional CFD analysis to understand the influence of number of blades on performance of cross flow turbines and found improved performance with higher number of blades. Higher solidity turbine performed better at low tip speed ratios and low angles of attack [10]. Duquette and co-workers [12] performed experiments and 2-D numerical analysis to study the effect of number of blades and solidity on the performance of horizontal axis wind turbine. The numerical analysis was performed using BEM and lifting line based wake theory [12]. The knowledge base derived from aerodynamic/hydrodynamic analysis of wind/hydrokinetic turbines can be used for further design optimization study. Most of the optimization studies for wind turbines [19- 21] were focused on maximizing coefficient of performance and annual energy production (AEP). Selig and Coverstone-Carroll [19] used a genetic algorithm (GA) for optimizing AEP and cost of energy of low-lift airfoils for stall regulated wind turbines (wind turbines that have their blades designed so that when fluid speeds are high, the rotational speed or the torque, and thus the power production, decreases with increasing fluid speed above a certain value that is usually not the same as the rated speed). Belesis[20] presented GA for constrained optimization of stall regulated wind turbine and found it to be superior to classical optimization methods. Researches were conducted in the given work and optimization cone a sucking away pipe. Transformation of kinetic energy to energy of pressure to a sucking away pipe occurs to losses of some part of energy. On length of a pipe they can be divided into losses on a friction and expansion. The more diffuser pipes, the there is less than loss of kinetic energy, however with increase diffuser increase as hydraulic losses in tap. Losses in a sucking away pipe reduce effect of restoration of energy. Calculations show that losses on a friction make insignificant size, and the cores are losses on the expansion, increasing with corner increase cone, and losses on an exit which size decreases with corner increase cone as the area of target section thus increases [21].

This paper explores the rotor core and pole double-rotor hydro generator for micro hydropower plants. To assemble the rotor core double-rotor hydro generator used forged multifaceted steel sheets thickness of 1-2 mm without insulation coating, where the number of faces of the core will match to the number of poles double-rotor hydro generator. Investigated the creation of EMF double-rotor hydro generator in one conductor. When calculating, EMF double-rotor hydro generator. Guides phase-shifted by the same angle α , and describe a circle. The induced EMF in them is equal in value but opposite in direction. Therefore, the EMF coiled twice EMF one conductor. Hydro generator designed with different number of poles, sometimes quite large. We studied double-rotor hydro pole is clearly synchronous generator with two poles. All along the bore north and south poles of the stator pole $2p$ double-rotor hydro generator has a p -wave magnetic field. Therefore, we can distinguish two pole divisions as one period of the magnetic field and treat them as some elementary machine -one period. Circle real model double-rotor hydro generator attributed the electrical angle of 360 (electrical degrees) or $2p$. Each geometric degrees double-rotor hydro generator corresponds to p electrical degrees elementary machine. For double-rotor hydro generator which is a low-power not exceeding 1,000 V and a capacity of less than 100 kW is used in designing a single-layer winding, which is to operate in a safe and cost-effective [22].

2. Experimental investigation

2.1. Apparatus

The major factor defining structure of a stream in the driving wheel, power interaction between the moving blade and a liquid which creates the driving wheel moment is.

If we will consider flows of a separate profile the infinite established stream on infinity from a profile not indignant stream which is characterized in the constant speed V_∞ drawing 1 is had. As approaching a profile its influence on a current all becomes stronger that is shown in a curvature of lines of a current and change of distances between them. Over a streamline profile of a line of a current are condensed, and

under it to be rarefied. As the expense between two lines of a current is constant, over a profile of speed increase in comparison with V_{∞} , and under a profile decrease. According to the equation of Bernoulli at the expense of change of speed of a current pressure over a profile should go down, and under a profile to rise. It creates power influence of a stream on a profile.

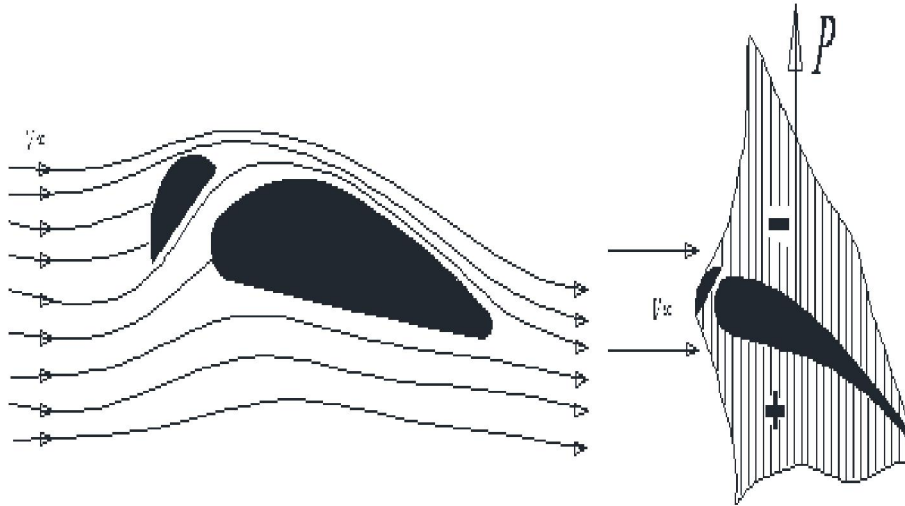


Figure 1 - A profile Flow

The driving wheel has a number of identical blades in regular intervals located on a circle under the form, limited to concentric surfaces of rotation or planes. A problem of the hydrodynamic theory of lattices is current definition in a rotating lattice of any form.

The problem decision in a general view for a lattice of any form difficultly, therefore we will present a current in the schematized and simplified kind fig.2.

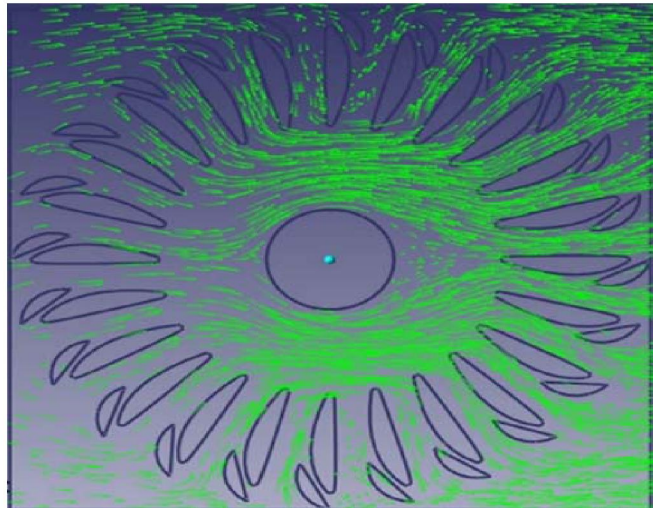


Figure 2 - A driving wheel General view

For the water-wheel of a surface of a current represent planes, perpendicular axes of rotation, and a current on different surfaces the identical. On various flat surfaces of a current there is a flow of identical lattices under the form. The difficult spatial current is approximately led to a flat current. For the decision of a problem of a flow of such kind of spatial lattices it is necessary to find the decision of a flat problem. The section of a lattice a plane, a perpendicular axis of the turbine, gives a flat circular lattice.

The problem consists in definition of power interaction of a lattice of the turbine with a liquid stream. The moment on the driving wheel is equal to change of the moment of quantity of movement of a proceeding liquid. To find the moment and capacity on a driving wheel shaft, it is necessary to define kinematic parameters of the stream which is flowing round a lattice of a wheel. At calculation new лопастных systems the return problem of the theory of lattices is used. The return problem consists in definition of the form of a profile under the set law of distribution of speed (pressure) on a profile contour, and as in definition of power interaction of a stream and a lattice profile. For прочностных calculations of water-wheels it is necessary to know the hydrodynamic forces operating on the blade of the driving wheel.

In a general view for a viscous liquid it is necessary to search for the decision of problems from the equation of Nave - Stokes of movement of a viscous incompressible liquid

$$\frac{\overrightarrow{dv}}{dt} = \vec{F} - \frac{1}{\rho} \text{grad } p + \nu \nabla^2 \vec{\vartheta} \quad (1)$$

Where $\frac{\overrightarrow{dv}}{dt}$ - full acceleration of a particle of a liquid; \vec{F} - acceleration from mass forces; $-\frac{1}{\rho} \text{grad } p$ - acceleration from pressure forces; $\nu \nabla^2 \vec{\vartheta}$ - acceleration from forces of viscosity.

For a flat problem in projections on axes of co-ordinates (1) will register in a kind

$$\left. \begin{aligned} \frac{dv_x}{dt} &= F_x - \frac{1}{\rho} \frac{\partial p}{\partial x} + \nu \left(\frac{\partial^2 \vartheta_x}{\partial x^2} + \frac{\partial^2 \vartheta_x}{\partial y^2} \right) \\ \frac{dv_y}{dt} &= F_y - \frac{1}{\rho} \frac{\partial p}{\partial y} + \nu \left(\frac{\partial^2 \vartheta_y}{\partial y^2} + \frac{\partial^2 \vartheta_y}{\partial x^2} \right) \end{aligned} \right\} \quad (2)$$

Euler's equation of movement of an ideal incompressible liquid

$$\frac{\overrightarrow{dv}}{dt} = \vec{F} - \frac{1}{\rho} \text{grad } p \quad (3)$$

Differs from the equation of Naveir - Stocks absence of the third member in the right part, caused by viscosity presence. Use of the equation of Euler it is possible only when the member including acceleration from forces of viscosity, is small in comparison with other members of the equation. It is possible if a liquid a little viscous, having small factor of kinematic viscosity and size $\frac{\partial^2 \vartheta_x}{\partial x^2} \cdot \frac{\partial^2 \vartheta_x}{\partial y^2}$ etc. in (2) were insignificant.

At a flow of a body a liquid on a surface a tangent speed is equal to zero, i.e. a liquid, sticks to a surface. At removal from a body speed rather quickly increases within an interface. Outside of an interface change of speed from a point to a point the insignificant. Therefore, outside of an interface it is possible to neglect influence of viscosity and to consider that liquid movement submits to the equation (3) received for an ideal liquid.

Us essentially new design of micro hydroelectric power station with double-rotor the hydro generator is offered. The principle of work of micro hydroelectric power station with double-rotor the hydro generator essentially does not differ from микро HYDROELECTRIC POWER STATION, only in one hydraulic stream two driving wheels which are located vertically on work one axis one after another and rotating, thus every which way rather to each other fig. 3.

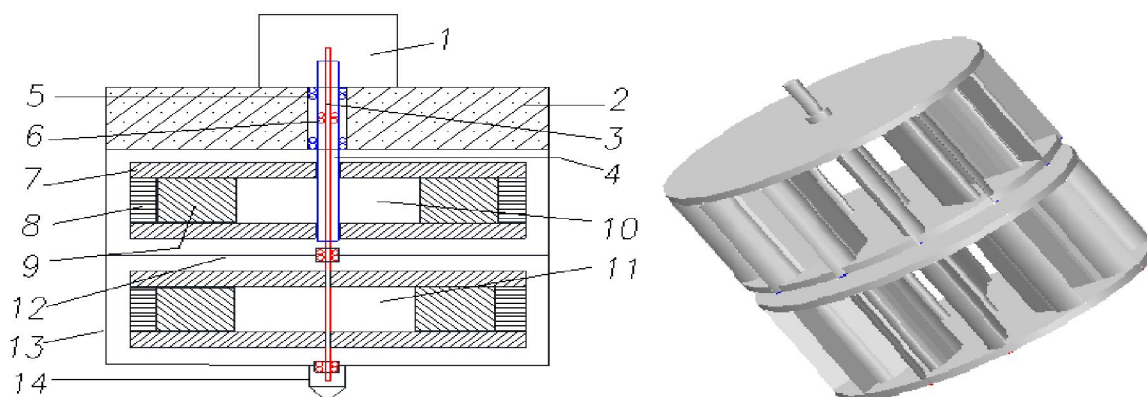


Figure 3 -The Circuit diagrammed double-rotor micro hydroelectric power station and model double-rotor turbines

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.

The blade looks like an asymmetrical aviation wing with *предкрылком* which back form has the roundish form. The profile before a wing has the segment form. At a flow of a firm body the stream is exposed to deformation that leads to change of speed, pressure, temperatures and density in stream streams. In drawing 4 the settlement model of interaction of a water stream with the turbine blade is resulted. P - full hydrodynamic force, a resultant of all pressure forces and viscosity of a water stream; Y - hydrodynamic force is a projection of full hydrodynamic force to a perpendicular to a vector of speed of a running water stream; Q - front resistance - a projection of full hydrodynamic force to a vector of speed of a running water stream; P' , Y' , Q' , similar hydrodynamic forces that operate on fixed *предкрылки*. Apparently from settlement model, about a surface of a streamline body the area of variable speeds and pressure is created. Presence of various pressure on size at a surface of a firm body leads to occurrence of hydrodynamic forces (Y , P , Q) and the moments. Distribution of these forces depends on character of a flow of a body, its position in a stream and a body configuration. On the top surface of a body, in a place of the greatest *поджатия* streams, according to the law of indissolubility of streams will observe local increase in speed of a stream (V) and, hence, pressure reduction. On the bottom surface stream deformation will be less and, hence, less change of speed and pressure.

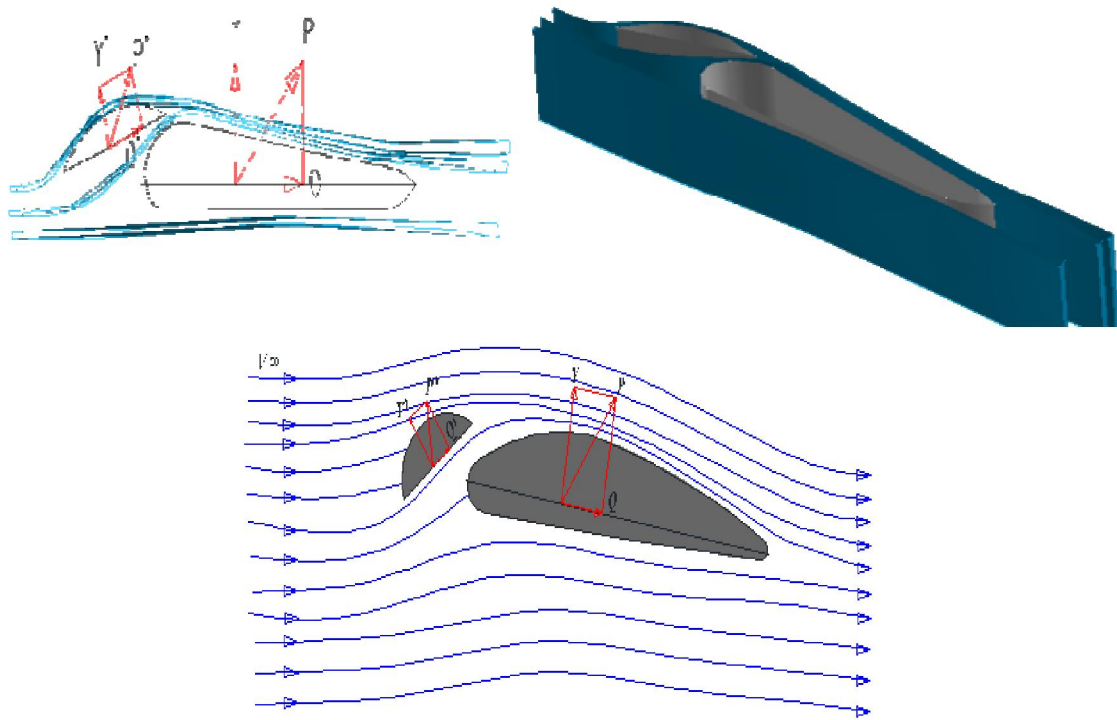


Figure 4 - The Hydrodynamic forces operating on the blade with предкрылком

Knowing a spectrum of a flow of a body, it is possible to count up size of pressure for its each point and thus to judge sizes and character of action of hydrodynamic forces. As on various points of a surface of a streamline body pressure forces different in size operate, their resultant will be distinct from zero. This distinction of pressure in different points of a surface of the moving blade is a major factor causing occurrence of hydro dynamic forces.

2.Results

The most important characteristic is the synchronous hydro generator rotor speed, which allows you to get the necessary speed standard values. As can be seen from the formula 1, an increase in hydro-generator rotor speed n reduces the number of pole pairs p .

$$p=60 \cdot f/n \quad (8)$$

To increase the hydro-generator rotor speed must increase flow or pressure hydraulic flow in the supply of the micro hydro generator. However, increasing the hydraulic parameters of micro hydro generator is not always possible and expedient.

In the case of hydro-generator, as seen from (1), requires fewer pairs of poles than the conventional hydroelectric generators because at a certain value of rotor speed can be obtained by hydro-generator stator speed in the opposite direction with the same values (Fig. 4) . In this case the rotation of the rotor and stator of hydraulic, as already indicated above, is carried out with respect to each other in the opposite side. This leads to an increase in the frequency of crossing the magnetic field of electric generator windings. This principle of doubling the speed will hydro generator.

Produced analysis and study of electromagnetic calculation hydro generator including a selection of the main dimensions of the stator and rotor hydro generator show that the number of winding turns W_0 , the inner diameter of the stator core hydro generator $D_-(0)$ is almost two times less than traditional hydro generator W_1, D_1 . These results can be achieved only in the case of the hydroelectric principle, which generally leads to a reduction in the geometric and mass-dimensions hydro generator.

$$w_0 = \frac{N_{n1} \cdot p \cdot q_1}{a_1} = 180 \quad (9)$$

$$D_0 = 6 + 0.69 \cdot D_{H1} = 90.18 \text{ mm} \quad (10)$$

$$w_1 = \frac{N_{n1} \cdot p \cdot q_1}{a_1} = 594 \quad (11)$$

$$D_1 = 6 + 0.69 \cdot D_{H1} = 126.75 \text{ mm} \quad (12)$$

where - W_0 - the number of windings hydro generator; $p = 1$ - number of pole pairs hydro generator; $N_{n1} = 60$, the number of effective-conductors in the slot hydro generator; $Q_1 = 3$, the number of slots hydro generator; $a_1 = 1$, the number of parallel branches in the stator winding hydro generator; D_0 -inner diameter of the stator core hydro generator; $D_{H1} = 122 \text{ mm}$ -the outer diameter of the stator core hydro generator; W_1 the number of windings of traditional hydro-generator; $p = 2$, the number of pole pairs of the traditional hydro-generator; N_{n1} -99-effective amount of conductors in the groove of traditional hydro-generator; $q_1 = 3$, the number-hydro generator traditional slots; D_1 - inner diameter of the stator core of traditional hydro-generator; $D_{H1} = 175 \text{ mm}$,-the outer diameter of the stator core of traditional hydro-generator.

Analysis and study of the peculiarities of electromagnetic calculation disk generator in static mode does not allow to evaluate the work make full disk generator. This regard, studies have been conducted dynamic mode disk generator. Studies and calculations were carried out by computer simulation using the program «Ansoft Maxwell». During the simulation studied the characteristics induced EMF in the stator winding disk generator. On Fig.8.shows a fragment of the moment and the magnetic induction field lines at time $t = 0.2 \text{ sec}$.

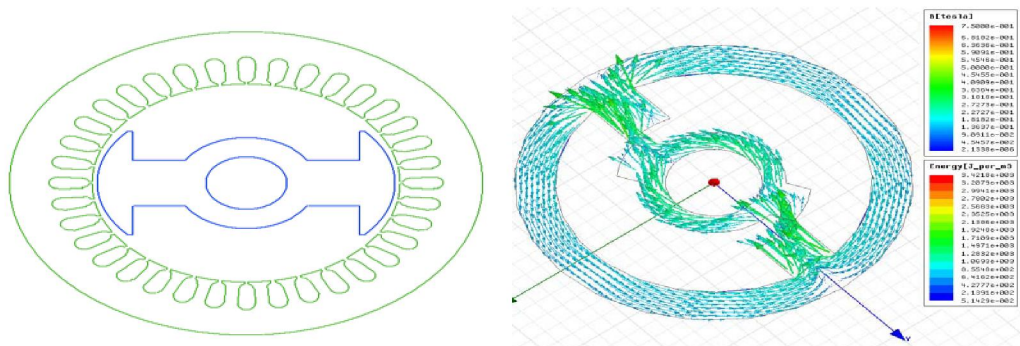


Figure 8 -Unit of magnetic induction and field lines at time $t = 0.2 \text{ sec}$

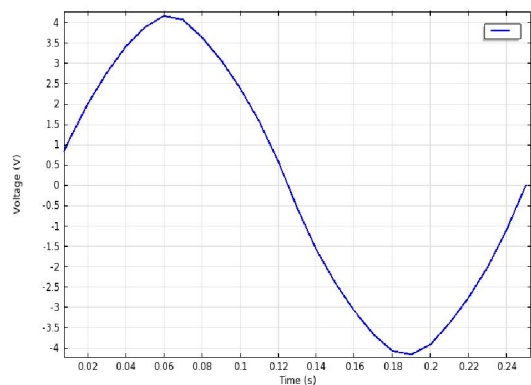


Figure 9 - Voltage waveform disk generator

3. Conclusion

Thus, in the first proposed new scheme for micro hydro disk generator with new technical solution and its structure. The analysis and study of electromagnetic processes by modeling disk generator shows that the creation of hydro-generator for micro hydro gives doubling speed hydro-generator, which allows to reduce the number of pole pairs, the number of windings, as well as to reduce the inner diameter of the stator core. This generally leads to a reduction of geometric and mass-dimensions of hydro-generator and as a result reduce the cost of micro hydro. In addition to these calculations, the computer simulation shows a complete dynamic stability of hydro-generator, which is characterized by forms of voltage and the induced emf (Fig. 9).

As a result of calculations the greatest influence on power indicators of the generator renders: width of a groove and size of an air backlash. From drawing 8 it is visible that at increase in number of grooves at a pole, the factor of dispersion of a pole that is an effective indicator for electric cars decreases. From this it follows that with reduction the width of a groove, increases its number of grooves on magnet of wires stator, the number of grooves thereby increases by one pole.

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ЕКІ РОТОРЛЫҚ ШАҒЫН ГИДРОЭЛЕКТРОСТАНЦИЯ ҮШІН СҰЙЫҚТЫҚ АҒЫНЫМЕН ГИДРО ТУРБИНАЛЫ ТОРДЫҢ ЭНЕРГЕТИКАЛЫҚ ӨЗАРА ӘРЕКЕТТЕСУІН АНЫҚТАУ

Аннотация. Берілген мақалада сұйықтық ағынымен турбиналық тордың энергетикалық өзара әрекеттесуін анықтау табылады. Қозғалтқыш дөңгелегіндегі сәтте жүретін сұйықтықтың қозғалыс санының өзгеруіне тең. Қозғалтқыш дөңгелегі білігінің сәті мен қуатын табу үшін дөңгелек тордың айналасында ағып жатқан ағынның кинематикалық параметрлерін анықтау қажет. Жаңа жүзгіш жүйелерді есептеу кезінде торлар теориясының қайтару мәселесі қолданылады. Қайтару мәселесі бейінді контурға жылдамдықты (қысым) бөлу заңымен және ағынның және торлы профильдің өзара әрекеттесуін анықтау сияқты профильдің формасын анықтаудан тұрады. Су дөңгелектерінің беріктігін есептеу үшін жетекші дөңгелек жүзінде жұмыс істейтін гидродинамикалық күштерді білу қажет. Диск генераторының электромагниттік генератордың статикалық режимде ерекшеліктерін зерттеу және талдау жұмыстың толық диск генераторын жасауына мүмкіндік бермейді. Осыған байланысты, зерттеулер динамикалық режим диск генераторы жүргізілді. Зерттеулер мен есептер «Ansoft Maxwell» бағдарламасын қолдана отырып компьютерлік модельдеу арқылы жүргізілді. Екі роторлы гидроэлектростанциямен бірге микроэлектростанцияның жаңа дизайны ұсынылған.

Түйін сөздер: су, әдіс, есептеу, спиралды камера, микроэлектростанция.

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ОПРЕДЕЛЕНИЕ СИЛОВОГО ВЗАИМОДЕЙСТВИЯ ГИДРОТУРБИННОЙ СЕТКИ С ПОТОКОМ ЖИДКОСТИ ДЛЯ ДВУХРОТОРНОЙ МИКРО ГЭС

Аннотация. Задача в данной статье состоит в определении силового взаимодействия решетки турбины с потоком жидкости. Момент на рабочем колесе равен изменению момента количества движения протекающей жидкости. Чтобы найти момент и мощность на валу рабочего колеса, необходимо определить кинематические параметры потока, обтекающего решетку колеса. При расчете новых блейд-систем используется обратная задача теории решеток. Обратная задача заключается в определении формы профиля по заданному закону распределения скорости (давления) по контуру профиля, а так же в определении силового взаимодействия потока и профиля решетки. Для расчета долговечности водяных колес необходимо знать гидродинамические силы, действующие на лопасти рабочего колеса. Анализ и изучение особенностей электромагнитного расчета дискового генератора в статическом режиме не позволяет оценить работу полного дискового генератора. В связи с этим были проведены исследования динамического режима работы дискового генератора. Исследования и расчеты проводились путем компьютерного моделирования с использованием программы «Ansoft Maxwell». Предложена принципиально новая конструкция микро ГЭС с двухроторным гидрогенератором.

Ключевые слова: вода, метод, расчет, спиральная камера, микро ГЭС.

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