

RESEARCH ON PURPOSE OF DETERMINING THE OPTIMAL CONFIGURATION OF BLADES FOR IMPROVING THE ENERGY EFFICIENCY OF DIRECT FLOW HYDRO TURBINE

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In this paper we present the results of the research conducted to determine the effective variant of guide vane and hydro wheel blades of direct flow hydro turbine. The aim of the theoretical study is to determine the optimal configuration of hydro turbine blades to improve the energy efficiency of the hydro turbine. As a result of the theoretical study, a mathematical model of a hydro turbine was developed in the interactive COMSOL Multiphysics. With the help of the COMSOL Multiphysics application program, the change in velocity and pressure distribution of water through the guide vanes and hydro turbine blades the optimal shape and angle of the guide device and the hydro wheel blades of the hydro turbine were determined. Based on the results of the research, it was determined the optimal configurations of the hydro wheel blades with high energy efficiency.

Key words: hydro turbine, hydro wheel, blade, COMSOL Multiphysics, energy efficiency, guide vane. .

1. Introduction

Today, the whole world pays great attention to water flow energy as the effective source of energy. However, hydropower engineering is a complex architectural and engineering issue. For example, build the dam is a very complex construction, and it occupies a very large area, has a negative effect on the life of aquifers, when water accumulates in the dam, if there is a problem with the dam, can cause a serious catastrophe, may be dangerous to the environment. Investigated hydro turbine for small hydroelectric power station does not require a dam, therefore, eliminates the above mentioned shortcomings. There are no shortcomings mentioned above. Instead, it works in scheme as a part of the water given to head tube, after flowing through hydro turbine again dumped into the river. This direct flow hydro turbine's size is small, so to construct it needs less material accordingly it costs cheaper.

It is significant to correctly choosing of the structure of the turbine, the size and location of the blades, the parameters of the guide vane, the head of water, the structure of the hydro wheels when installing a hydro turbine on a water stream to generating sufficient energy and effective working. Scientific research working is aimed to improving low head hydro turbine efficiency by changing the stream flow to hydro wheel. The optimal version of the attack angle on guide vane and hydro wheel blades is for improving efficiency of hydro turbine. Investigated low head hydro turbine can be used in the small and medium rivers of the Central Asian countries and Kazakhstan. This low head hydro

turbine for small hydroelectric power station is for using for seasonal agriculture to farmers and for using in small settlements and remote villages [1-6].

2. Methodology

The method of investigation is a computational experiment. A theoretical study was carried out, a mathematical model of a hydro turbine was developed in the interactive COMSOL Multiphysics. By COMSOL Multiphysics application program, the change in velocity and pressure distribution of water through the guide vanes and hydro turbine blades. For the manufacture of a hydro turbine, it is important to study theoretically the parameters and efficiency of a hydro turbine. In that, the construction of the hydro turbine is a complex, its assembly is a very large-scale work. And so that, for a large-scale work to be correct and effective, it is important to preliminary study and make a conclusion. The accuracy of the numerical method is high. Using the mathematical model of a hydro turbine, it is possible to obtain an experimental and accurate model of a hydro turbine. If one of the parameters is erroneous in the experiment, it is difficult to change, it is necessary to change many settings, and it is easy to change in the simulation program and can be replaced by any parameter. We can analyze the increased process that passes. Without creating an experimental device, you can get the exact result in a computer program.

The hydro turbine is displayed in the COMSOL Multiphysics application package. The COMSOL Multiphysics application package examines the change in velocity and distribution of pressure of water through the guide vanes and the turbine blades [7]. The optimal shape and attack angle on guide vane and hydro wheel blades of the hydro turbine was determined. By investigating, the optimal configurations of the hydro turbine blades with high energy efficiency were determined.

External construction of 3 dimension model of hydro turbine which was made by Comsol Multiphysics application package is shown in Fig. 1. Inlet and outlet tube's length is 200 cm and diameter is 150 cm.

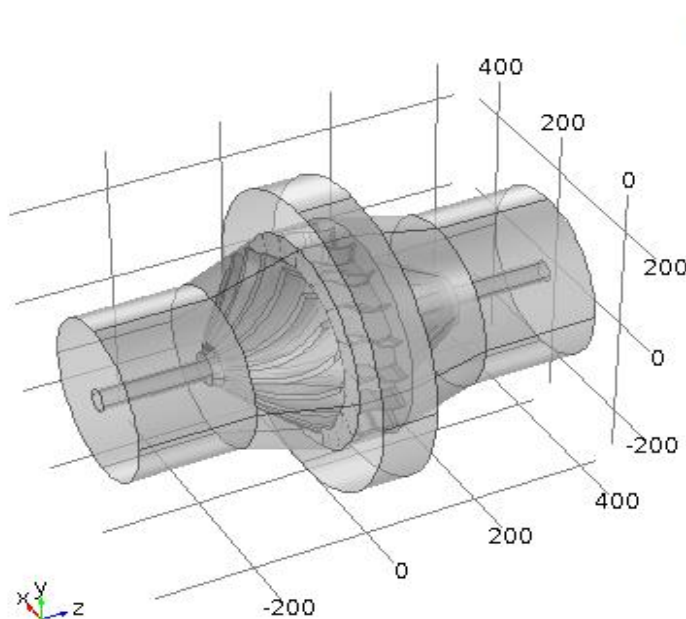


Figure 1. Hydro turbine model

Inlet and outlet tube, shaft, guide vane and hydro wheel blades of hydro turbine is demonstrated. Guide vane and hydro wheel of the hydro turbine are shown in Fig. 2. Guide vane as cone form on the front part and blades which is located on cylinder part.

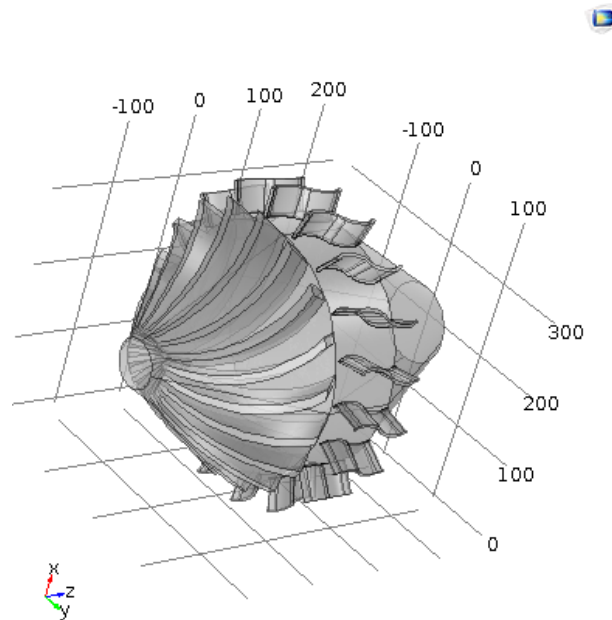


Figure 2. Hydro turbine guide vane and hydro wheel

The water with pressure enters through inlet tube, by rotating the rotor flows along the rotor and exit through the outlet tube. On the rotor's outer shell located generator with winding which generates electricity.

To take more energy is needed to turn as more the hydro wheel. Therefore, there is a guide vane with the aim to regulate impact and direction of water flow to the hydro wheel blades. When water flow through hydro turbine passing through guide vane and hit blades with pressure, and they rotate [8,9].

3. Numerical experiment

The energy efficiency of the hydro turbine is affected by the number, shape, location, and attack angle of the guide vane and blades [10]. Therefore, the results of the research of the attack angle on the guide vane and hydro wheel blades, angle between oncoming flow and chord of the blade, with the purpose of improving the energy efficiency of hydro turbine are presented.

Numerical calculation was performed by COMSOL Multiphysics application package. The results were obtained by changing the attack angle of the two blades of guide vane and two blades of hydro wheel for shaping the two dimensions. Three different angles were obtained to show the improving in energy efficiency and to compare. The distribution of velocity and pressure of water flow in COMSOL Multiphysics application packages during 10 seconds was analyzed with suggesting that the initial velocity 10 m / sec. The length of the guide vane blade is 160 cm, width 4 cm, the length of the hydro wheel blade is 80 cm, width 4 cm.

4. Mathematical model

Distribution of water flow velocity and pressure was calculated with using Reynolds Averaged Navier Stokes (RANS) method.

For incompressible fluid Navier-Stokes equations consists of motion and continuity equations [11]:

$$\rho \frac{\partial u}{\partial t} + \rho(u \cdot \nabla)u = \nabla \cdot [-pI + (\mu + \mu_T)(\nabla u + (\nabla u)^T)] + F \quad (1)$$

$$\rho \nabla \cdot (u) = 0$$

Task was calculated in Turbulent Flow, k- ω interface of COMSOL Multiphysics. It gives better results for considering internal flows and it takes into account wall functions.

Boundary conditions of the chosen blades in two dimension is shown in Fig.3.

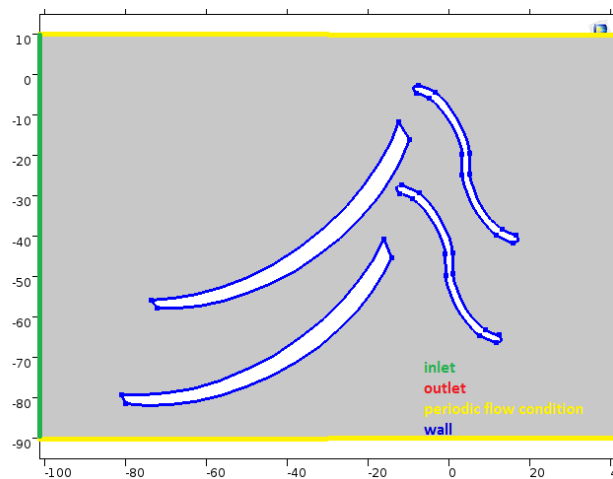


Figure 3. Boundary conditions

$$\text{Inlet: } u = -U_0 n, U_{ref} = U_0, k = \frac{3}{2} (U_{ref} / T)^2, \omega = \frac{k^{1/2}}{(\beta_0^*)^{1/4} L_T}$$

$$\text{Outlet: } [-pI + (\mu + \mu_T)(\nabla u + (\nabla u)^T)]n = -\hat{p}_0 n, -\hat{p}_0 \leq p_0, \nabla k \cdot n = 0, \nabla \omega \cdot n = 0$$

$$\text{Wall: } u \cdot n = 0, (\mu + \mu_T)(\nabla u + (\nabla u)^T)n = -\rho \frac{u_\tau}{\delta_w^+} u_{tang}$$

$$u_{tang} = u - (u \cdot n)n, \nabla k \cdot n = 0, \omega = \rho \frac{k}{k_v \delta_w^+ \mu}$$

$$\text{Periodic flow condition: } u_{source} = u_{dest}, p_{source} = p_{dest}, k_{source} = k_{dest}, \omega_{source} = \omega_{dest}$$

Mesh allocation is shown in Fig.4.

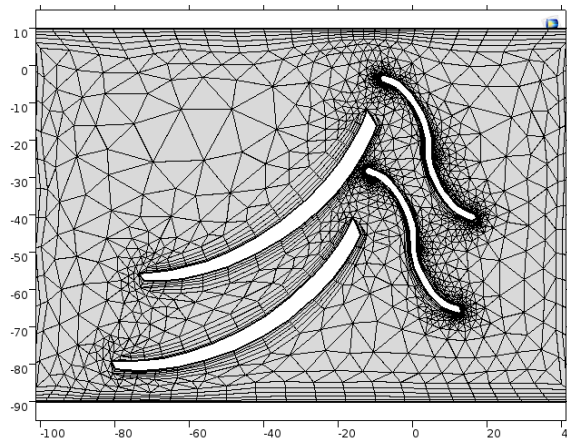


Figure 4. Mesh allocation

5. Defining efficiency attack angle of blades

Scheme of attack angle of the guide vane blade and attack angle of the hydro wheel blade is illustrated in Fig.5.

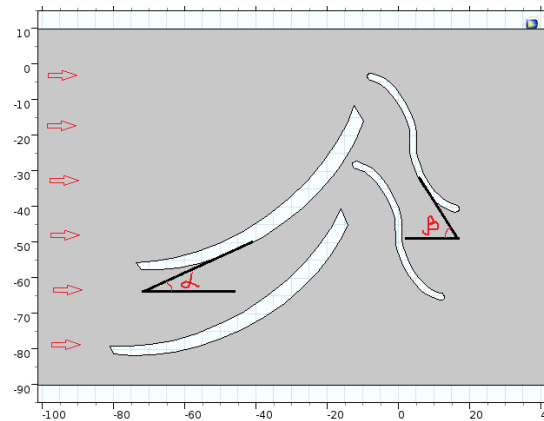


Figure 5. Attack angle

Firstly, guide vane blade's attack angle 0° and hydro wheel blade's attack angle 0° are obtained. For this case distribution of velocity and pressure are shown in Fig.6.

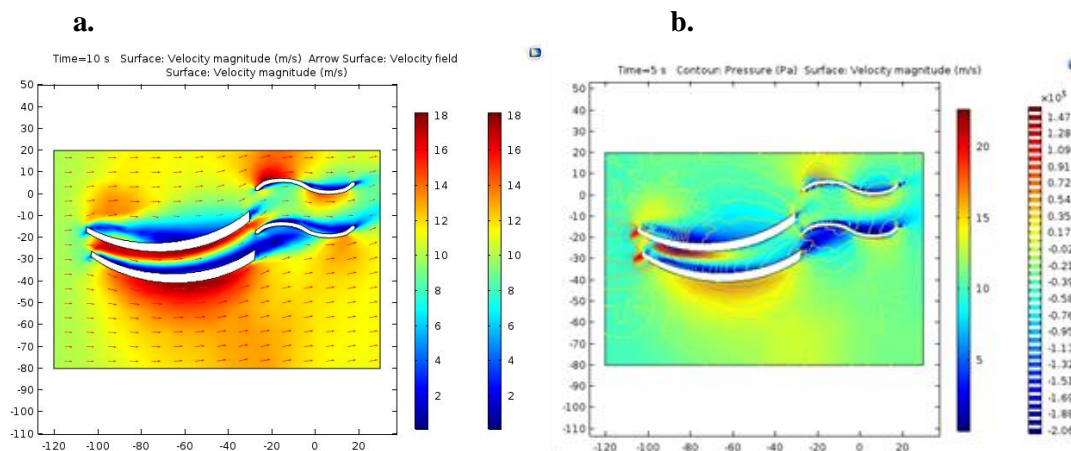


Figure 6. Guide vane attack angle 0° and blade's attack angle 0° : a. distribution of velocity, b. distribution of pressure

Maximum value of velocity is reached to 18 m/s and maximum values of pressure is reached to 152 kPa.

Then results of turning guide vane to 30° and blade to 60° are demonstrated in Fig. 7.

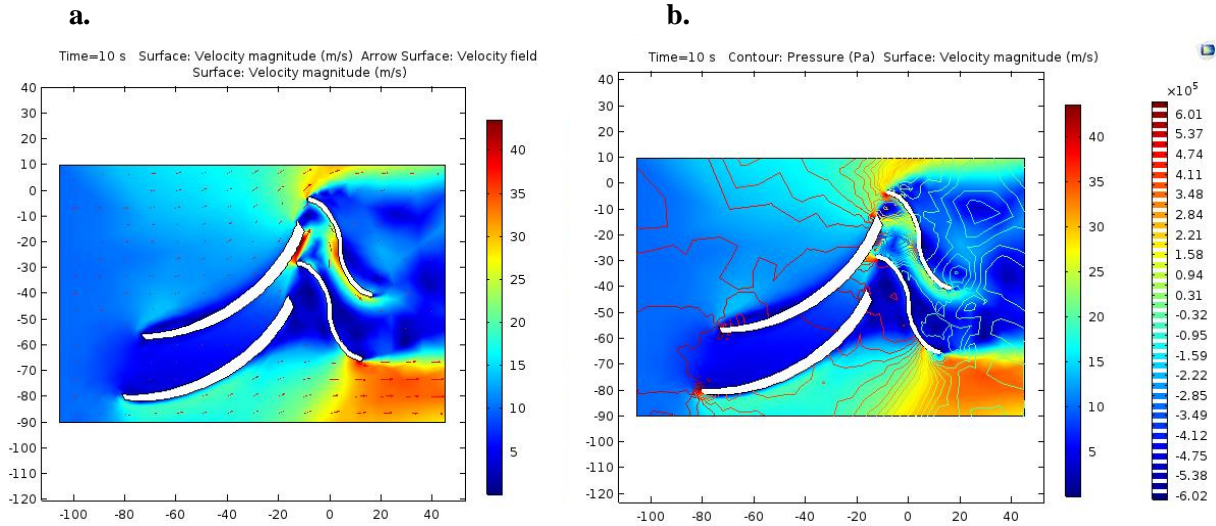


Figure 7. Guide vane`s attack angle 30° and blade`s attack angle 60°: a. distribution of velocity, b. distribution of pressure

In this case the maximum value of velocity is reached to 40 m/s and maximum value of pressure is reached to 601 kPa. Comparing with previous results is observed that this version is more efficiently. So we can see that the attack angle has affect.

The process of distribution of velocity and pressure of the next version is showed in Fig. 8.

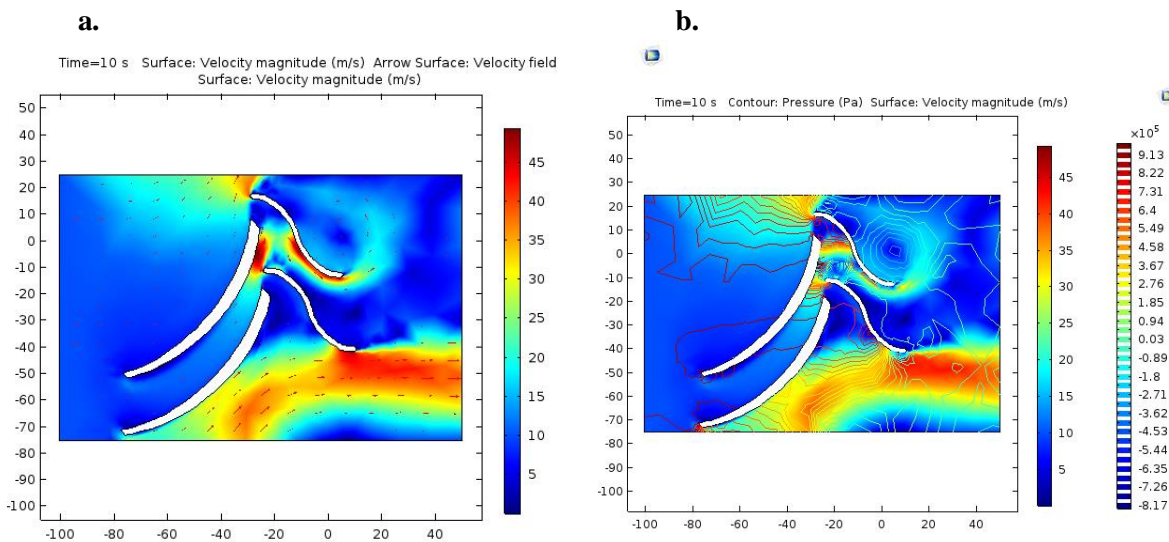


Figure 8. Guide vane`s attack angle 45° and blade`s attack angle 45°: a. distribution of velocity, b. distribution of pressure

There maximum value of velocity is reached to 45 m/s and maximum value of pressure is reached to 913kPa.

Guide vane attack angle 50° and blades attack angle 40° are selected as the next version and results of distribution are shown in Fig.9.

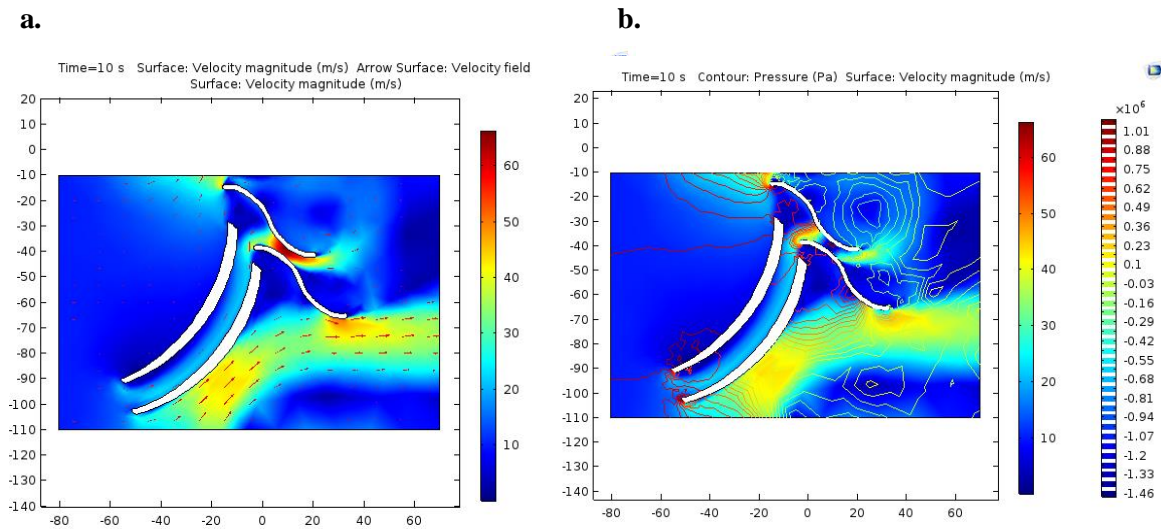


Figure 9. Guide vane's attack angle 50° and blade's attack angle 40° : a. distribution of velocity, b. distribution of pressure

There maximum value of velocity reached to 60m/s and maximum value of pressure are reached to 1010 kPa.

Results of numerical experiment by Comsol Multiphysics of the changing of velocity and pressure distribution of flow with changing attack angle of the blades are shown in Tab.1.

Table 1. Velocity and pressure changing with changing attack angle

Name	Attack angle of guide vane, $^\circ$	Attack angle of blades, $^\circ$	Maximum value of velocity of flow, m/s	Maximum value of pressure of flow, kPa
1	30	60	40	601
2	45	45	45	913
3	50	40	60	1010

In last version when guide vane's attack angle 50° and blade's attack angle 40° maximum value of velocity and pressure are reached. Water flow hits blade with stronger pressure, rotates it and flows through turbine with higher velocity, that is concluded that efficiency is improved, therefore this version is chosen as the most optimal.

6. Conclusions

The effective version of hydro wheel blades of direct flow hydro turbine was determined. Research with the aim of improving efficiency of low head hydro turbine was performed. Three various locations of the blades with changing attack angle were investigated by Comsol Multiphysics. Based on the results of the research, it was determined the optimal configurations of the hydro wheel blades with

effective efficiency. As optimal configuration was chosen guide vane with the attack angle 50 angle degrees and hydro wheel blade with the attack angle 40 angle degrees, where maximum value of velocity reached to 60 m/s and maximum value of pressure reached to 1010 kPa.

7. References

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