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INVESTIGATION OF THE WHIRLPOWER MINI-HYDROELECTRIC POWER STATION USING THE CFD MODULE IN THE COMSOL MULTIPHYSICS ENVIRONMENT

This article deals with the study of small HPP equipment (Hydroelectric Station) for water channels after large dams and energy-deficient areas, in particular, the study of the whirlpool mini hydropower plant using the CFD module in the COMSOL Multiphysics environment.

The main reason for studying this device is the problem of power supply in areas of our country with a shortage of electricity, located outside the central regions, and in the CIS countries this type of HPP is poorly studied due to the lack of design technology and the comparatively low use of alternative energy sources in general. Only in recent years have been allocated funds from the National Fund to address this problem of alternative energy. For example, in Western Europe, Japan and China, there are several companies that produce this small HPP.

Keywords*: HPP(Hydro Power Plant), renewable energy, cylindrical turbine, conical turbine.*

Introduction. The need to reduce environmental impact, the search for new opportunities for improving the quality of life of the population, ensuring sustainable energy-efficient economic development, development of new technologies, diversification of the energy sector-all this contributed to the development and improvement of a certain base for the development of the «green economy» [1].

Micro- and small HPPs play a major role in the energy supply of remote areas, which are energy-deficient and occupy up to 53.4% of the territory of Kazakhstan. The development of small hydropower in the regions ensures [2]:

- creation of own regional generating capacities and reduction of the power deficit in the region;
- reliable power supply of quality electricity to communities in remote areas and at the end of main power transmission lines;
- achievement of economic and social stability in settlements which are not yet connected to the unified energy system;
- decrease in the subsidy level in the regions related to the purchase and delivery of fuel to hard-to-reach areas.

Similar types of mini HPPs were previously studied by scientists at the University of Malaysia[3], they reviewed the development of gravity water vortex power plant as an alternative renewable energy sources, also considered the experimental study of the influence of water pressure, length and number of turbine blades on the model system of energy generation with free vortex. In these works considered the optimal efficiency factor, built a model of mini hydroelectric power plant design in a simulator. We can also note the joint work of Oxford. Texas Tech University and Tribune University[4], this project worked to simulate a mini hydroelectric power plant in 3-dimensional space. This study analyzes

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different basin structures that can form eddies, which can make a gravity vortex flow even from low head. Secondly, the results obtained have been experimentally carried out by measuring the power output [4,5].

Experimental technique. In almost all previous studies, laminar flow in a cylinder was considered based on the assumption of stable, axisymmetric and incompressible flow. For this flow we consider the incompressible form of the Navier-Stokes equations and the continuity equation as shown in (1)-(2) formula:

$$\rho\frac{\partial u}{\partial t}+\rho(u\cdot\nabla)u=\nabla\cdot[\rho I+K]+F \quad (1)$$

$$\rho\nabla\cdot(u)=0 \quad (2)$$

The physical meaning of this mini-HPP is that the flow is incompressible, weakly compressible flow (density depends on temperature, but not on pressure) and compressible flow at low Mach numbers (usually less than 0.3). The reference temperature is set to 293.15 K.

WE CONSIDER TWO DIFFERENT GEOMETRIES

Cylindrical turbine (figure 1) Conical turbine (figure 2)

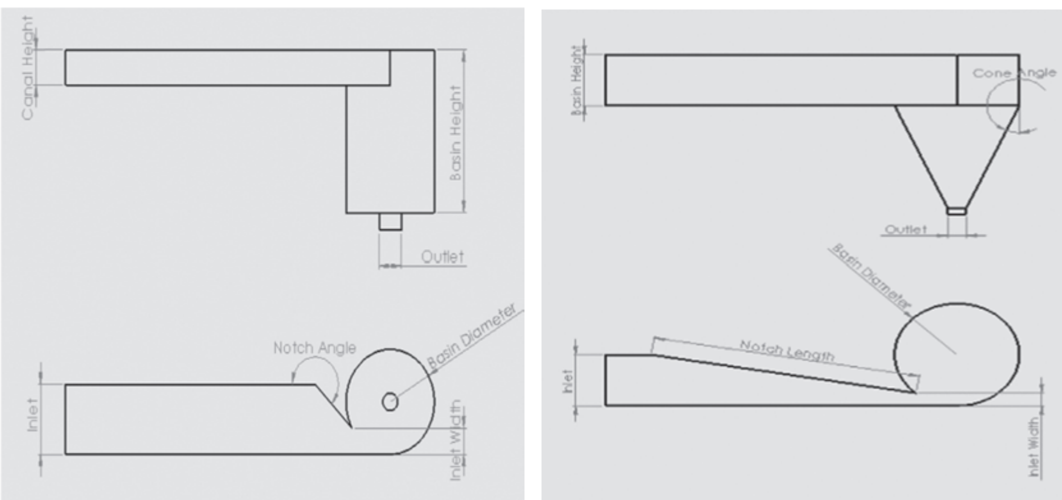


Figure 1 – Cylindrical view Fig. 2 Conical view

First, we consider the problem in two-dimensional space from the side and identify the best option for further study. This model is built for stationary flow in order to investigate the efficiency of different geometries considering velocity and angular velocity, thereby revealing a suitable model for us. In this work we make assumptions such as time dependent flow, also there is no slip condition. Here we take water as a fluid and consider it as an incompressible fluid with density ρ=998.2 kg/m3 and with viscosity μ=0.001003 kg/m*s. In addition, the experiment was carried out with the conditions that there is no slip on the wall and at the outlet pressure flows out. The inlet (water) velocity is 0.01 m/s and the pressure is atmospheric.

Parameters that we initially set:

H inlet – 0,5 m

V inlet – 0,1m\s

H length – 1m

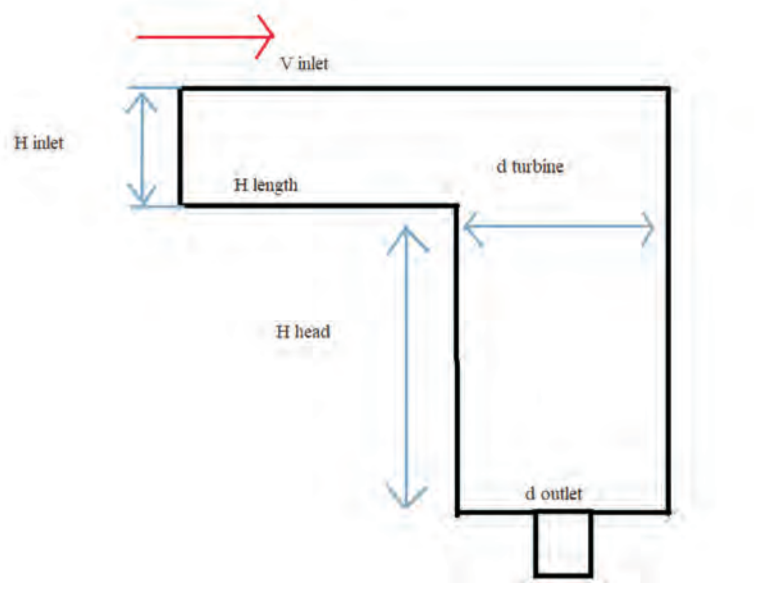


Figure 3 – Parameters that we set for Comsol Multiphysics

In the same way we will set the parameters for the conic view of the turbine. Now for both geometries we will change certain parameters for the study and modulate on the program Comsol Multiphysics.

Parameters that we investigate:

1) First of all we change the water pressure :
   H head
   H1=0,5m
   H2=0,6m
   H3=0,7m
2) Secondly, we change the diameter of the hole at the outlet:
   D outlet
   D1=0,1m
   D2=0,05m
   D3=0,03m
3) Now we will change the diameter of the turbine itself
   D turbine

D turbine = 0,5m
D turbine = 0,3m
D turbine = 0,2m

Why do we take these dimensions?

From the previously obtained research and the experiment conducted, there are limits to the dimensions of the design that can be investigated.

After the results obtained, having chosen the optimal size, we will consider the view of the structure from above and thereby investigate the angles for the direction of water into the turbine[22-24].

1) H water head

Depending on the capacity of the water inside the turbine, its velocity changes.

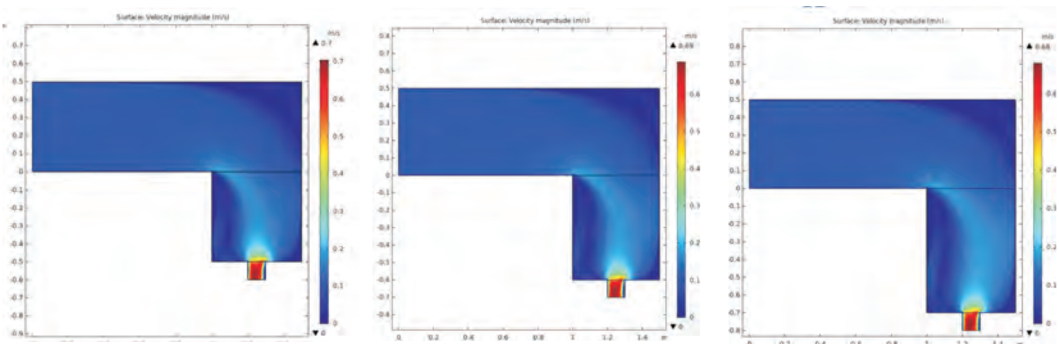


Figure 4 – The case when H1=0.5m and H2=0.6m, H3=0,7m

Now that we have the data for the cylindrical type of turbine, we can build a graph for a visual study of the process:

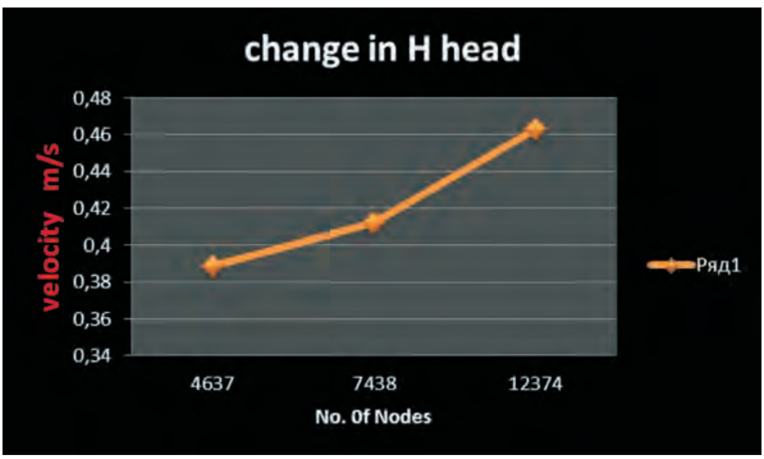


Figure 5 – Example of a case when we change the water pressure

2) D diameter of the orifice at the outlet

Depending on the diameter of the outlet hole, its velocity also changes.

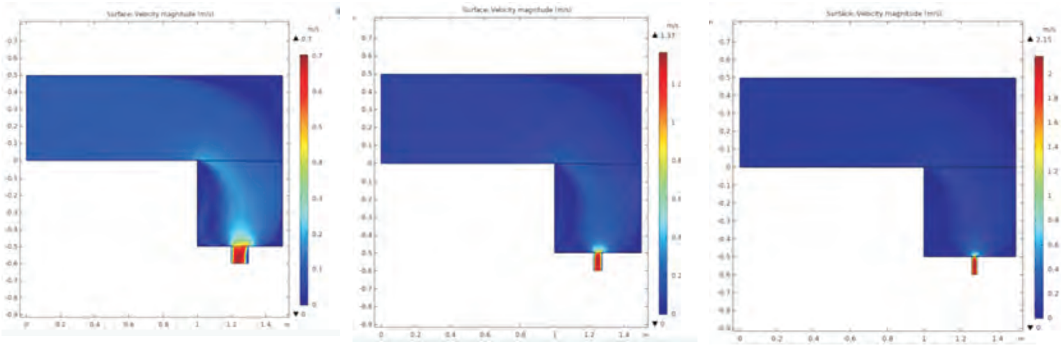
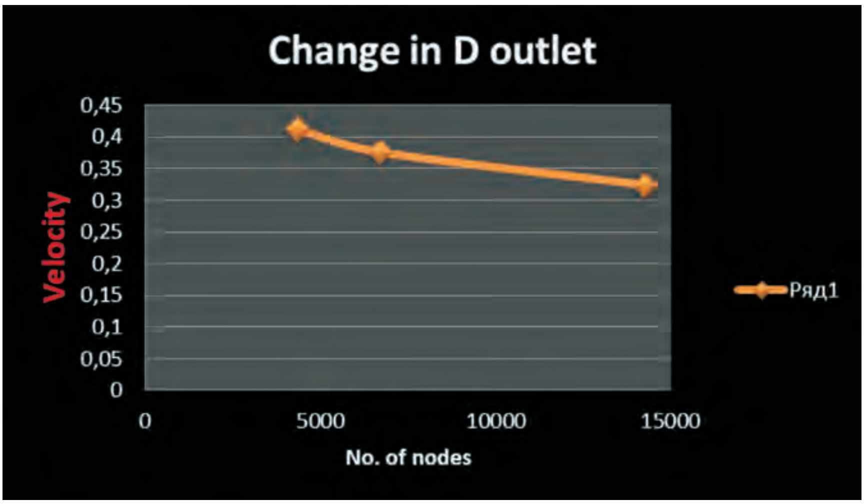


Figure 6 – The case when D1=0.1m and D2=0.05, D2=0.03m



Figur 7 – Example of a case when we change the diameter of a hole

3) D diameter of the turbine itself

Depending on the diameter of the turbine itself, its speed also changes:

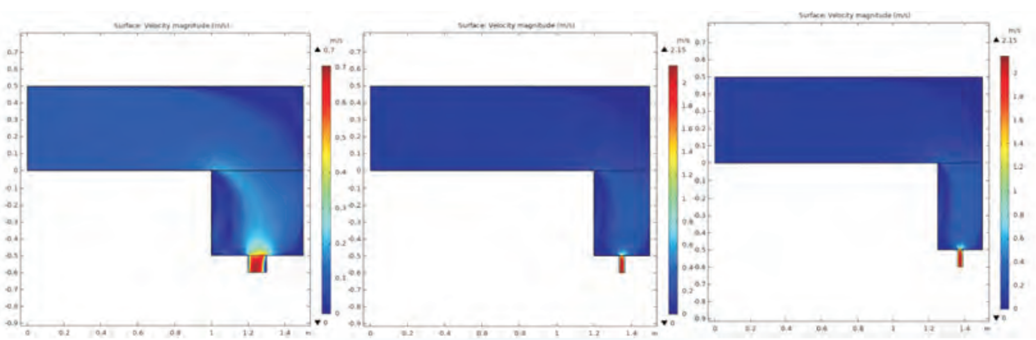


Figure 8 – Case when D turbine = 0.5m and D turbine = 0.3, D turbine = 0,2m

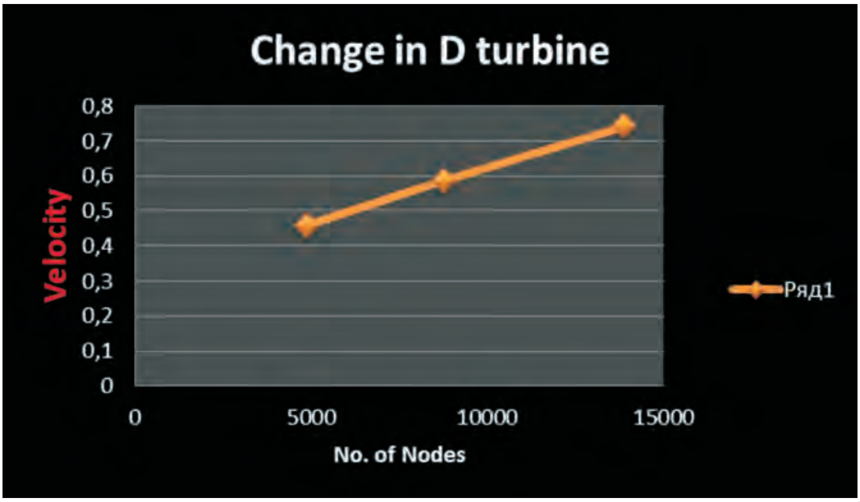


Figure 9 – Example of the case when we change the turbine diameter

Changing the dimensions of this cylindrical view of the turbine and examining it in Comsol multiphysics, it is easily possible to determine which parameters will be optimal for further research, i.e. by changing certain parameters we can see how the flow rate changes, thus we can say that the efficiency of this mini power plant directly depends on its speed, the more speed, the more it is optimum. And it will be possible to modulate the top 2D view of the mini-HPP when we already know the optimal dimensions and in this case we will already consider the angular velocity of the flow, and it in turn directly depends on the turbine inlet throat from the channel. And so from the above data we can say that the best option for a cylindrical turbine is:

H head > 0, 5m, D outlet = 0,1m, D turbine = 0,2m

Using this data, we will consider the top view. To do this we change:

H neck = 0,1m, H neck = 0,05m, H neck = 0,03m

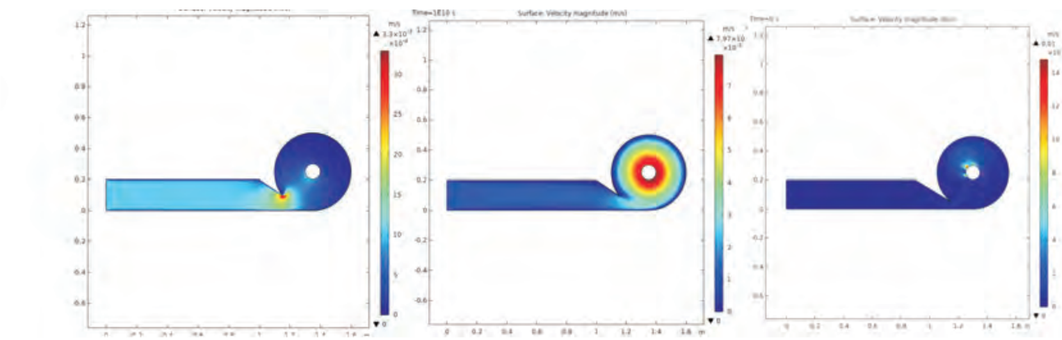


Figure 10 – Turbine cylindrical view module, top view

In the next turn we will consider the conical view of the turbine and exactly the same change of parameters such as:

D turbine, H head (with the same dimensions as in the cylindrical form)

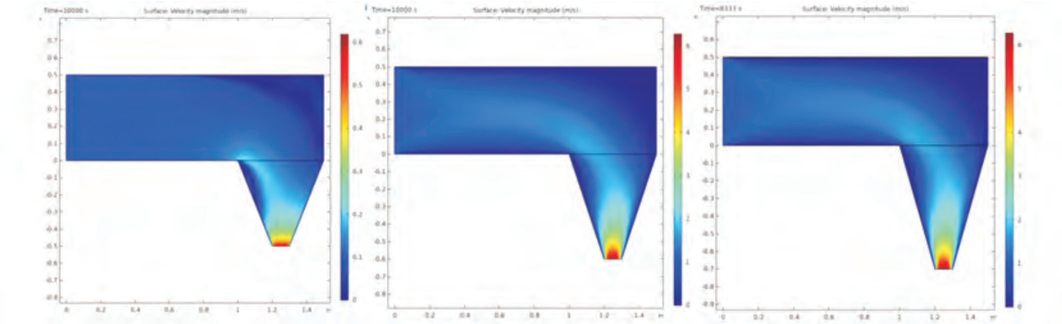


Figure 11 – The case when H1=0.5m and H2=0.6m, H3=0.7m

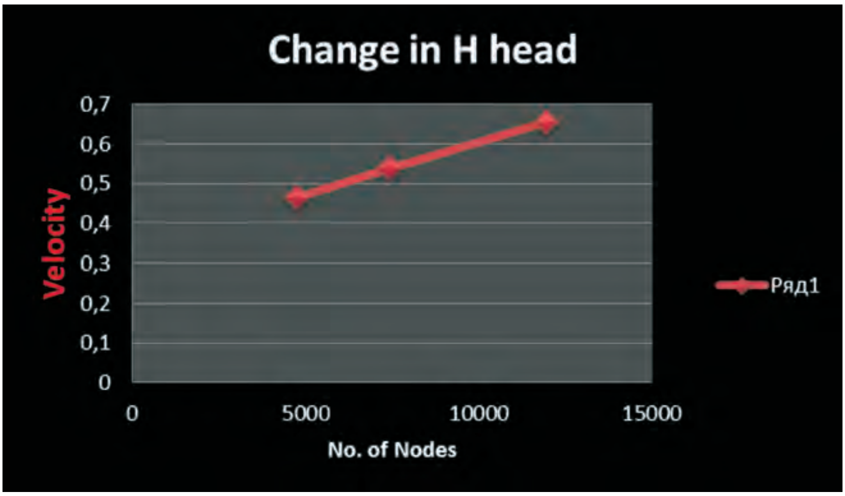


Figure 12 – Example of the case when we change the water pressure

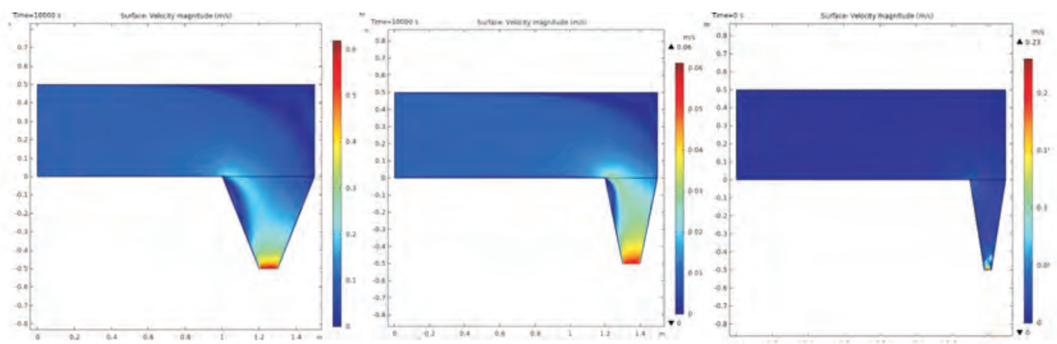


Figure 13 – Case when D turbine = 0.5m and D turbine = 0.3, D turbine = 0.2m

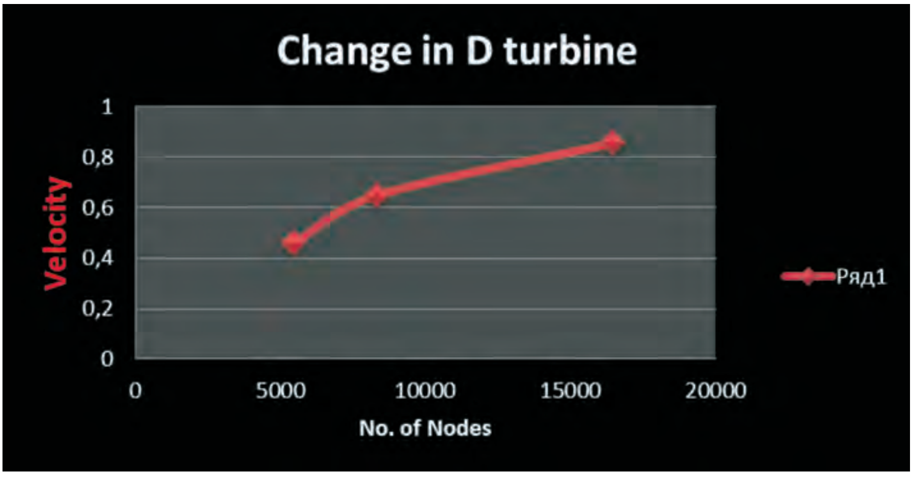


Figure 14 – Example of the case when we change the turbine diameter

But it should be noted that for the real design of this mini-HPP we can not take a very small turbine diameter because at high speed will be reverse flow of water, which will complicate the rotation of the turbine.

Also for the conical turbine type, change the H neck as shown in Figure-10:

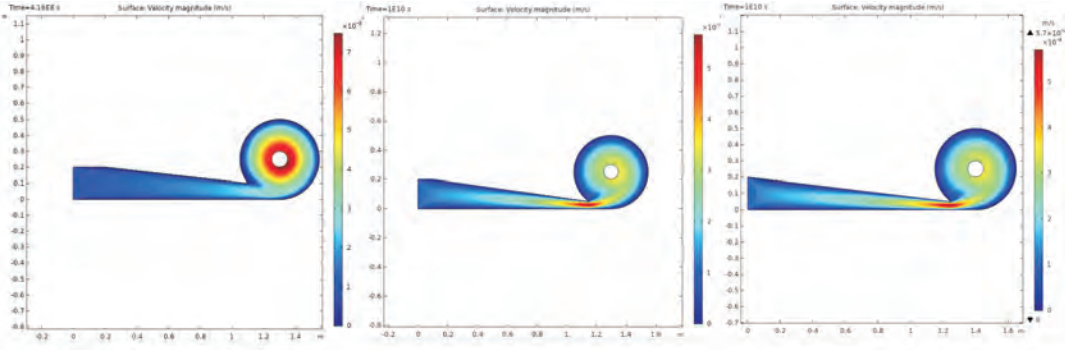


Figure 15 – Module of the conical turbine view, top view

Conclusion. In this paper, considering two kinds of turbine and with different size parameters, we have a sense of how the design should look like. If we look at the difference between the two kinds of turbine, the most optimal will be the conical kind of turbine, in this case we can note that the flow rate will be much higher and this kind of turbine will be conveniently streamlined and there will not be considered obstacles and reverse chaotic flow. It is possible to see the difference between the cylindrical and conical type of turbine on the figure-16, 17, 18:

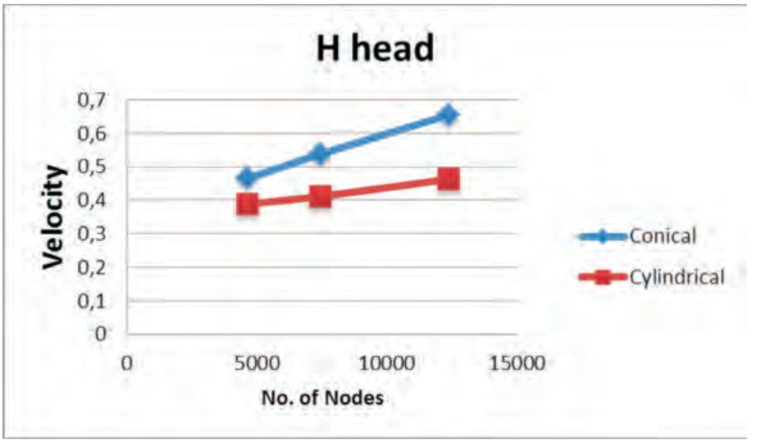


Figure 16 – Difference between the two types of turbine in water head

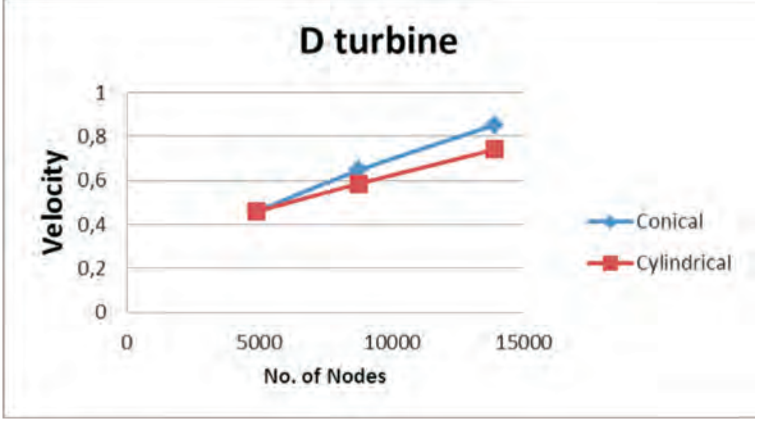


Figure 17 – Difference between the two types of turbine in diameter

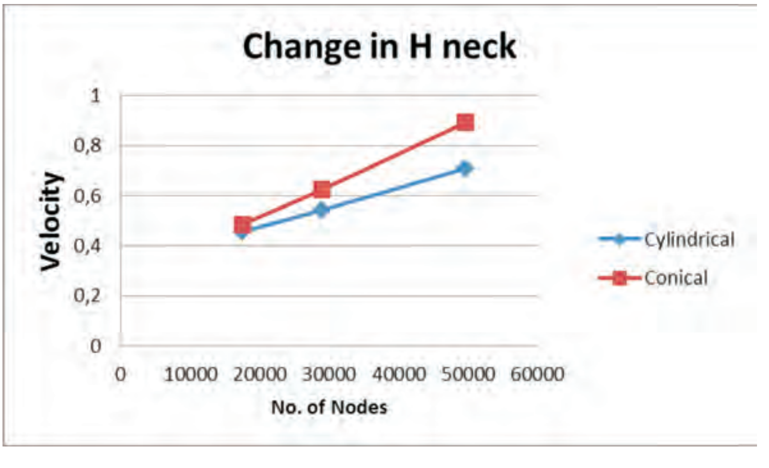


Figure 18 – Difference between the two types of turbine in the inlet throat from the canal

Optimal position of the turbine H head>0,5 m from the pool height, turbine diameter D turbine = 0,2m, also outlet diameter D outlet = 0,1m. Moreover, if we consider the top view, then the optimal solution for the inlet size from the canal would be in the conical shape of the turbine H neck=0.03m. The maximum efficiency varies from 30% to 50% depending on the number and size of the blades. The study also showed that a conical shaped basin has a better performance than a cylindrical shaped basin.

Kazakhstan has significant hydropower potential. On the territory along with 6 large rivers, there are also about 27 thousand small rivers and tributaries, the length of which exceeds 10 km mark. Developed by scientists of the Republic some designs of small and mini HPPs were presented at the exhibition EXPO 2017 (Astana) and received the approval of experts[6].

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COMSOL MULTIPHYSICS ПАКЕТІНДЕ CFD МОДУЛІН ПАЙДАЛАНЫП АЙНАЛМА ШАҒЫН ГЭС-ТІ ЗЕРТТЕУ

Бұл мақалада энергия көзі тапшы аймақтар мен үлкен ГЭС (ГидроЭлектроСтанция) плотиналарынан кейінгі су каналдарына қойылатын шағын ГЭС қондырғысын зерттеу жұмысы қарастырылды, нақтырақ айтқанда COMSOL Multiphysics пакетінде CFD модулін пайдаланылып айналмалы шағын ГЭС зерттелді.

Бұл құрылғыны зерттеудің басты себебі біздің мемлекетіміздің электр көзі тапшы, орталық аудандардан шетте орналасқан аймақтарды қуат көзімен қамтамасыздандыру мәселесі болып табылады, сонымен қатар ТМД мемлекеттерінде бұл ГЭС-тің түрі аз зерттелген, оның бірден-бір себебі отандық осындай құрылғыларды құратын орындардың аздығы мен баламалы энергия көзінің аз қолданылуы, тек айтатын болсақ соңғы жылдары ғана осы баламалы энер-

гия тақырыбын сөз етіп, ұлттық қордан қаражат бөлінуде. Ал мысалы Батыс Еуропа, Япония, Қытай мемлекетінде дәл осы шағын ГЭС құрылғысын шығаратын бірнеше компаниялар бар.

***Түйін сөздер**: ГЭС(ГидроЭлектроСтанция), баламалы энергия, цилиндр пішінді турбина, конустық пішінді турбина.*

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ИССЛЕДОВАНИЕ ВОДОВОРОТНОЙ МИНИ-ГЭС С ПОМОЩЬЮ МОДУЛЯ CFD В СРЕДЕ COMSOL MULTIPHYSICS

В данной статье рассматриваются исследования оборудования малой ГЭС (ГидроЭлектроСтанция) для водных каналов после крупных плотин и энергодефицитных территорий, в частности, исследование водоворотной Мини ГЭС с помощью модуля CFD в среде COMSOL Multiphysics.

Основная причина изучения данного устройства – проблема электроснабжения в районах нашей страны с дефицитом электроэнергии, расположенных за пределами центральных районов, а в странах СНГ этот тип ГЭС изучен слабо из-за отсутствия конструкционной техники и сравнительна малое использование альтернативных источников энергии в целом. Лишь в последние годы из Национального фонда были выделены средства для решения этой проблемы альтернативной энергетики.

Например, в Западной Европе, Японии и Китае есть несколько компаний, которые производят эту малую ГЭС.

***Ключевые слова**: ГЭС(ГидроЭлектроСтанция), альтернативная энергия, турбина цилиндрической формы, турбина конической формы.*