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TESTING OF THE PROTOTYPE OF MINI-HYDRO POWER PLANTS OF HYDROCYCLONE TYPE IN PRODUCTION CONDITIONS

Abstract. The aim of the project is to develop and test a new technical solution to improve the technological scheme of mini hydroelectric power plants using the hydrocyclone effect of water treatment.

Method of research. Computer simulation of the process was carried out by SolidWorks (flow simulation). Additional software "Autodesk Simulation CFD" was used to verify the calculations. Initial industrial experiments were carried out with the water flow in the hydrocyclone through the pipe with diameter of 100mm., and then the pipe was disconnected and supplied with water through a quadrangular inlet size 240 x 167 mm. The Third variant of the experiments was conducted in the combined form, i.e. in the presence of a quadrangular pipe and the inlet pipe.

Research result. It is established that the manufactured sample is quite workable in production conditions. The range of tested and confirmed parameters is within the following limits: head H= 1.5-2.5 m, water flow-Q = = 45-120L/c. at the same time, power generation is provided within N = 0.5-2.0 kW. The obtained parameters on a specific test object require approbation in a wider range and testing them in order to establish a rational mode of operation of the mini HPP of the proposed design.

Key words: mini hydroelectric power station, hydro turbine, generator, computer simulation, experimental sample, production test.

Introduction. To calculate the expected energy parameters and computer modeling of the process in the manufactured experimental sample, according to the prepared technical documentation, their tasks and methods were adopted based on the size of the installation, possible technological parameters of the test and taking into account the experience of development and operation of small and mini HPPs [1-17].

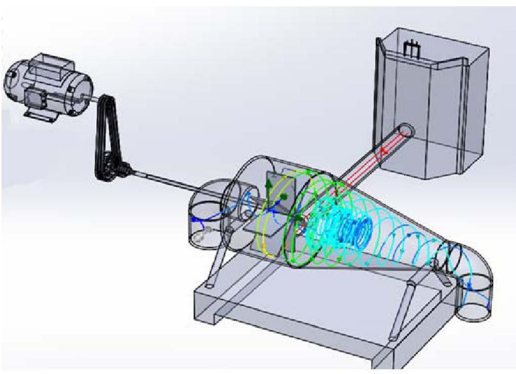


Figure 1 –
General design scheme of mini hydroelectric power station of hydrocyclone type

At the same time, the entry of water with mechanical impurities into the hydrocyclone body (figure 1) was carried out in two versions: through a pipe with a diameter of 124mm (mm) and through a quadrangular hole with a size of 240mm x 167mm. In the cone part, sediment removal through a sand hole with a diameter varying within 50-200mm (mm) by means of a valve was provided. The cleaned part of the flow is carried out through the drain pipe (diameter 200mm (mm), located at the end of the hydrocyclone. The total length of the hydrocyclone body to the gate of the sand hole is 1480mm. The diameter of the cylindrical part is 700mm [5].

In the calculations, two options were considered for the operation of the hydraulic turbine at pressures H=1, H=1.5 m, which can be provided at the selected site (range) of the branched part of the Turgen river.

Computer computational modeling [18,19] implemented by SolidWorks (flow simulation). Additional software "Autodesk Simulation CFD" was used to verify the calculations. When comparing these programs, errors were made in the range of 10-12%.

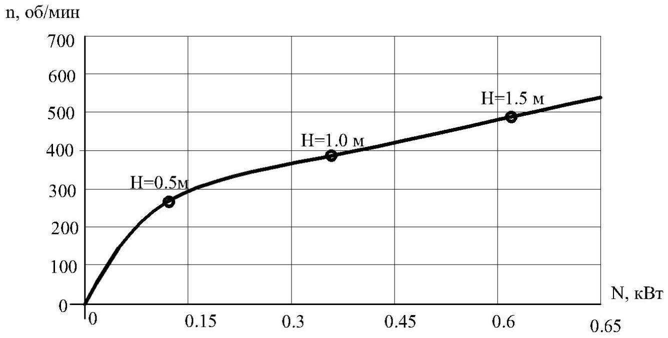
Result of calculation. In computer simulation according to the first variant, i.e. at a head H= 1.0 m, the speed of the generator rotor was within n=395 rpm. And in the next variant, i.e. at H=1.5 m, the speed was equal to n=490 rpm.

Calculations show that when the heads are opened, the torque generated by the water flow on the blades is M1=8.2 N*m and M2=12N*m.

Then, the generator power according to the variant - 1

M1=0,339 kW =339w, and according to the variant -2 M2 = 0.616 kW = 616w. Figure 2 shows a graph of the power dependence on the rotation of the hydraulic unit N=f (n)

Figure 2 –
Graph of power dependence
on hydraulic unit speed N=f (n)



There is some increase in unit power with increasing shaft speed of the turbine corresponding to the pressure of the incoming water.

Verification of the obtained data of the calculation program was carried out in an analytical way using well-known formulas.

Then, the power of the hydraulic unit

$$N=Q*g*H*h, вт \quad (1)$$

where Q – water consumption at the inlet of the unit, m^3/s.

$$Q=V*F=3,13*0,012=0,037\ m^3/s; \quad (2)$$

where V – water speed, m / s

$$V=\sqrt{(2*g*H)}=\sqrt{(2*9.81*0.5)}=3.13\ m/s \quad (3)$$

F – area cross-section of the inlet, m^2.

When the diameter of the inlet pipe D=0.124 m then F=0. 012m^2

g – acceleration of free fall, 9.81 m/s.

h=0.65-efficiency for two multiples (Crossfair) and simple active hydroturbines'.

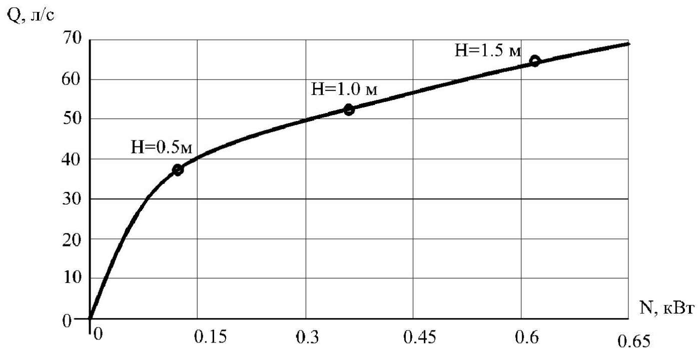
Then, under the first option

$$N=0,037*9,81*0,5*0.65=0.118\ kW=118\ W \quad (4)$$

Computational modeling and verification calculation showed minor errors of the results (121 W and 118 W). In other cases, the test calculations almost coincided with the original data.

Figure 3 shows a graph of the dependence of the flow rate on the power, which changes similarly to the previous case.

Figure 3 – A
graph of flow rate from power



To check the maximum possible capacity of the unit under consideration, the inlet section of the pipeline was increased to 240 x 167 mm, and the cross-section area F=0.04 m^2. Water pressure H=1.5 m.

Then, the speed and flow rate at the inlet of the pipeline

$$V=\sqrt{(2*g*H)} =\sqrt{(2*9.81*1.5)} =5.42 \ m / s \quad (5)$$

$$Q=5.42*0.04=0.217 \ m^3 / s$$

The generated power

$$N =0,217*9,81*1,5*0,65=2,076 \ kW= 2076 \ W;$$

If we take into account that for household and economic needs of a separate residential building, the required power on average is within 1200 W-1500 W, then we can consider the obtained power value to be quite sufficient for normal provision. If necessary, you can increase the power by increasing the initial pressure of the incoming water. For example, at a head of 3 m, the power of the hydraulic unit will increase to 5.87 kW.

For general clarity of the process under consideration, below are the isometries of velocities and pressure in a hydrocyclone with a hydraulic turbine at different pressures.

1) at the pressure (head) of the inlet flow H = 1.0 m.

In this case, there is a slight increase in the water velocity at the inlet to VVC = 4.5-5.5 m / s, and the pressure rvx = 8000-8500 PA (figure 4).

2) at the pressure (head) of the inlet flow H = 1.5 m.

As can be seen from the following figure, the required (working) speed and pressure to ensure normal operation of the hydraulic turbine and removal of impurities through the sand hole is achieved at H = 1.5 m.

In this case, the speed is equal to VVC = 5.5 – 6.5 m/s, and the inlet pressure rises to rvx = 10000-11000 PA.

Methods and results of production tests. The prototype of the hydrocyclone hull for processing the technological process was designed by the executors of project No. 7 and manufactured by the forces of IP "Originative" (Esik) [3-5].

The purpose of the test was to check the performance of the manufactured new sample of mini HPP in real conditions and to establish the expected technological parameters.

The tests were carried out on a branched section (fast current) of the Turgen river with a corresponding pressure-flow characteristic.

According to the results of R&D for 2019, the test considered the issues of establishing changes in the pressure-flow characteristics and the effect of these changes on the generated power is mainly when working on water without taking into account the degree of its purification in the hydrocyclone [1,2].

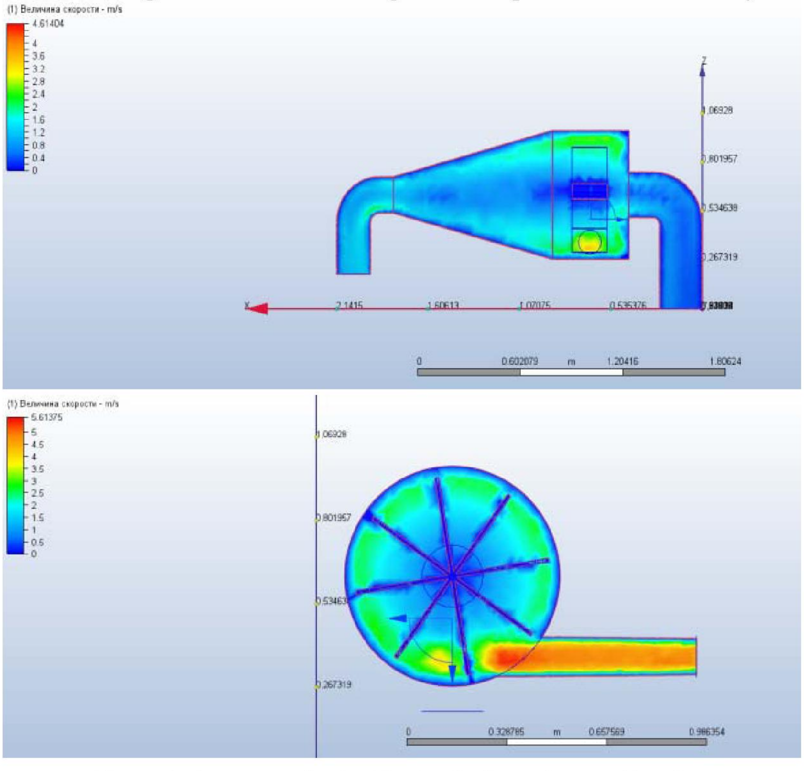


Figure 4 – Isometry of velocities in a hydrocyclone at H= 1.0 m

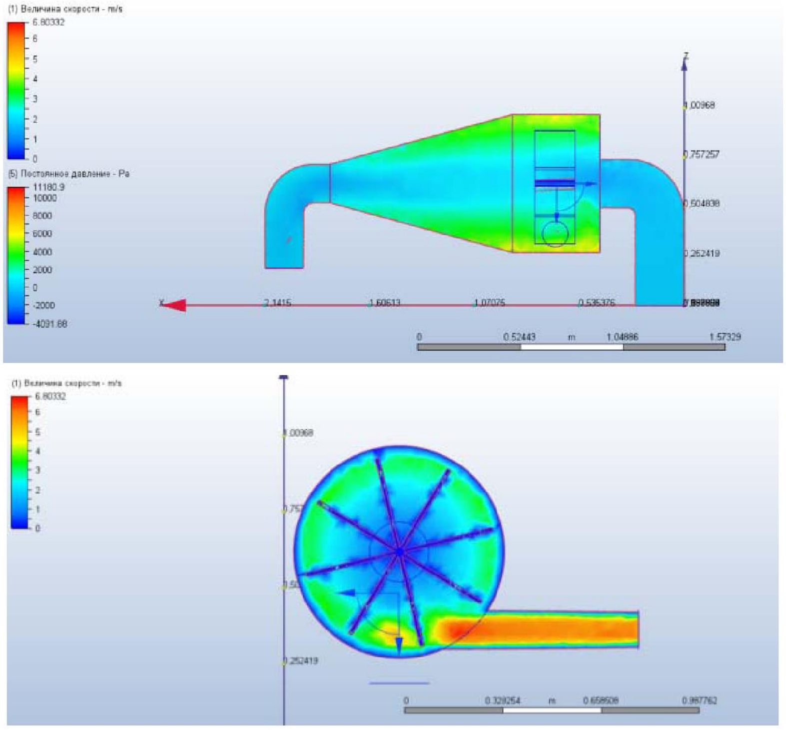


Figure 5 – Isometry of velocities (a) and pressure (b) in hydrocyclone at H= 1.5 m

The mode of operation on the alluvial mode, i.e. at different concentrations of sand in the water used, will be considered in 2020.

In order to study the changes in the main technological parameters of the mini hydroelectric power station (head, speed and flow rate, shaft speed, power) under different operating conditions of the installation, a water supply regulator in the form of a gate installed at the outlet of the camera was used. And the pressure of the supplied and used water in the three discharge holes (inlet, drain and sand hole) were determined by pressure gauges (accuracy class-2.5).

On the basis of the manometer reading, the speed was calculated by the formula, and then the flow rate of the supplied water-KV, m^3/s. The frequency of rotation of the shafts of the hydraulic turbine and generator was measured using a tachometer.

With the use of these experimental data, the power generated by the generator of the mini HPP was established.

If necessary, the water flow through the drain pipe QSL. and the sand hole Qpes were measured by volume method using a metal container with a volume of 20L, to establish the reliability of the measurement reading, they were compared with preliminary calculated data.

The first experiments were carried out when water was supplied to the hydrocyclone through a pipe with a diameter of 100 mm., and then the pipe was disconnected and water was supplied through a quadrangular inlet pipe with a size of 240 x 167 mm. The third version of the experiments was carried out with a combined version, i.e. in the presence of a pipe and a quadrangular inlet pipe.

In case of impossibility of direct measurement of the flow-pressure characteristic the pre-prepared curves of calibration of these indicators were used.

In General, the results of the test show that the developed design is quite workable and it allows to achieve the realization of the goal.

Confirming this conclusion, the operating mode of mini hydroelectric power station (figure 6) is achieved by using the combined version of the experiments, when the water supply to the hydrocyclone housing (DC = 700mm) is carried out through the pipe and partially through the inlet pipe (figure 6). In this case, the flow rate of the supplied water through the pipe from the camera was regulated by a paddle gate.

Based on this, the following is only the data obtained in the combined version, i.e. in the presence of a pipe and a quadrangular inlet pipe (table 2).

Figure 6 – Types of mini HPP when water is supplied to the hydrocyclone housing through the pipe and partially through the inlet pipe

Table 2 – Technological parameters of the prototype mini hydroelectric power station of hydrocyclone type obtained during the production test

Total area inlet, F, m^2	Pressure water on input, Hв, m	Speed water on input, Vв, m	Expenditure water on input, Q, m^3/s	Frequency rotations, п, turn/min	Torsional moment, M,H*m	Power hydraulic unit, Na, kWт
0,05	1,5	0,90	0,045	80	59,6	0,500
0,05	1,6	1,24	0,062	100	66,8	0,700
0,05	1,7	1,68	0,084	120	79,5	1,000
0,05	1,8	1,90	0,095	150	76,4	1,200
0,05	2,0	2,14	0,107	200	71,6	1,500
0,05	2,5	2,30	0,114	300	63,7	2,000

As can be seen from the table, with an increase in the water pressure at the inlet-HB increases the flow rate of the supplied water-QB. The maximum flow rate of the hydrocyclone is provided at a head of HB = 2.5 m. In this case, the shutter of the camera is open to the full cross-section.

It should be noted that the change in torque is not proportional to the straight line, but to the parabola, although in modeling its dependence on the speed was inversely proportional.

The achieved capacity of the hydraulic unit within the range of N = 0.5-2.0 kW is quite sufficient parameter for the selected test object, which is characterized by a low head of water flow due to the small difference in the river bed. This means that the considered mini hydroelectric power plant has additional opportunities to increase the power characteristics when using it in areas with a significant slope.

On the basis of the results of the tests and analysis of the data obtained, an act and a test report were drawn up, which indicated the proposals and conclusions of the Commission. In them, in particular, it is noted that the presence of a pulley of a significant diameter (d=0.4 m) contributes to steady rotation and its frequency increases to a certain extent due to the inertia force up to 300 rpm or more.

The act specifies the efficiency of directed water supply to the surface of the blades of the hydraulic turbine with the help of a pipe (nozzles) than the use for this purpose of 4 coal nozzles located relative to the outer surface of the hydrocyclone.

It was noted that in the future it is necessary to make the following improvements of a constructive nature:

- the conical part of the hydrocyclone body should be performed in a shortened form and provide for the removal of trapped solids from the side with a significant diameter (about 200-250mm).

This is due to the fact that the delay of the swirling liquid in the hydrocyclone creates resistance in the body and thereby slows down the rotation of the hydro turbine.

Conclusion. 1. The manufactured sample is quite workable and can be used in production conditions. The range of tested and confirmed parameters is within the following limits: head H = 1.5-2.5 m, water flow-Q = 45-120L/c. At the same time, power generation is provided within N = 0.5-2.0 kW.

2. The achieved capacity of the hydraulic unit within the range of N = 0.5-2.0 kW is quite sufficient parameter for the selected test object, which is characterized by a low head of water flow due to the small difference in the river bed. This means that the mini HPP under consideration has an additional technological opportunity to increase the power characteristics when used in areas with a significant slope.

3. The obtained parameters on a specific test object require approbation in a wider range and testing them in order to establish a rational mode of operation of the mini HPP of the proposed design and protection of the hydraulic unit from abrasive wear, based on our experience [20-22].

The specified design of mini hydroelectric power station of hydrocyclone type is developed under the target program "Creation of bases of serial production of the Kazakhstan sources of renewable energy of the world level" (BR05236263, NAS RK, 2018-2020).

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ГИДРОЦИКЛОНДЫҚ ТИПТЕГІ МИНИ ГЭС-тің ТӘЖІРИБЕЛІК ҮЛГІСІН ӨНДІРІСТІК ЖАҒДАЙДА СЫНАҚТАН ӨТКІЗУ

Аннотация. Гидроэлектрстанцияларда электр энергиясын өндіруге байланысты шығындардың аса төмен болуы мен оның бәсекеге қабілетті бағасына сай атқарылуы инвесторлар үшін тартымды бизнес екендігі белгілі.

Сонымен қатар, шағын немесе мини ГЭС-терді салған аймақты аса су баспайды және жылу электростанцияларымен салыстырғанда ауаға CO2 таралуы мүлдем орын алмайды.

Тиісті ақпараттық және патенттік іздеулер нәтижесінде, оның техникалық-экономикалық негіздемесін ескере отырып, ҚР Ұлттық ғылым академиясында цилиндрлі-конусты гидроциклонмен жабдықталған гидроэлектрстанциясының шағын (микро) нұсқасы жасалды. Бұл техникалық шешім жеке ғимарат пен тұрғын үй-жайларды өз алдына дербес түрде электр энергиясымен жабдықтауға және көптеп зауыттан шығаруға мүмкіндік туғызады.

Сынақтан өткерудің мақсаты – жасалған жаңа мини ГЭС моделінің өндіріс жағдайындағы жұмыс қабілеттілігін тексеру және күтілетін технологиялық параметрлерді анықтау.

Сынақ барысында ағын тегеурінінің сипаттамаларында болатын өзгерістерді анықтау жағдайлары қарастырылды және гидроциклондағы су айналымы барысында бұл өзгерістердің өндірілетін қуатқа әсері қарастырылды.

Зерттеу әдістері. Процессордың компьютерлік модельдеуі SolidWorks (ағымды модельдеу) бағдарламасына сәйкес жүргізілді. Есептеулерді тексеру үшін «Autodesk Simulation CFD» қосымша бағдарламалық жасақтамасы пайдаланылған.

Бастапқы өндірістік сынақ гидроциклонға су диаметрі 100 мм болатын құбыр арқылы жеткізілген, ал содан кейін құбыр бекітіліп, қажетті су мөлшері 240х167 мм төртбұрышты құбыр арқылы берілген. Эксперименттің үшінші нұсқасы екі құбырдың бірге істеген жағдайында атқарылған.

Зерттеу нәтижелері. Сынақтан өткерілген ГЭС-тің тәжірибелік нұсқасының өндірістік жағдайда толықтай жұмыс істейтіні анықталған. Сынақ кезінде қарастырылған параметрлер диапазоны келесі өлшемдермен анықталады: тегеурін H = 1,5-2,5 м берілген су өтімі – Q = 45-120 л/с. Осы параметрлер жағдайында алынатын гидротурбина қуатының шамасы N = 0,5-2,0 кВт арасында қамтамасыз етілген.

Осы сынақтар кезінде анықталған параметрлер алдағы уақытта неғұрлым кең диапазонда сыналатын болады және су ағындары тегеурінді өзендерде мини ГЭС-тің ұтымды режимі қалыптастырылады.

Түйін сөздер: мини ГЭС, гидротурбина, генератор, компьютерлік моделдеу, тәжірибелік үлгі, өндірістік сынақ.

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ИСПЫТАНИЕ ОПЫТНОГО ОБРАЗЦА МИНИ ГЭС ГИДРОЦИКЛОННОГО ТИПА В ПРОИЗВОДСТВЕННЫХ УСЛОВИЯХ

Аннотация. Общеизвестно, что, благодаря относительно низким эксплуатационным затратам и конкурентоспособной цене за электроэнергию, выработанной на ГЭС, они представляют собой очень привлекательный бизнес для инвесторов. Кроме того, при строительстве малых и мини ГЭС не происходит затопления прилегающих территорий, сокращаются выбросы СО2 за счет замещения теплоэлектроцентралей, работающих на ископаемом топливе.

На основе информационного и патентного поиска в мировом масштабе и с учетом целесообразности, в АН РК разработан мини (микро) вариант ГЭС, снабженная цилиндроконическим гидроциклоном. Это позволяет обеспечить локальное энергообеспечение отдельных зданий и жилых помещений, а также облегчает организацию их серийного производства.

Целью испытания являлась проверка работоспособности изготовленного нового образца мини ГЭС в реальных условиях и установление предполагаемых технологических параметров.

При испытании рассматривались вопросы по установлению изменения напорно-расходной характеристики и влияние этих изменений на вырабатываемую мощность преимущественно при работе на воде без учета степени ее очистки в гидроциклоне.

Методы исследования. Компьютерное расчетное моделирование процесса осуществилось по программе SolidWorks (flow simulation). Для проверки произведенных расчетов было использовано дополнительное программное обеспечение «Autodesk Simulation CFD».

Первоначальные производственные опыты проводились при подаче воды в гидроциклон по трубе с диаметром 100 мм, а затем труба была отключена и обеспечена подача воды через четырехугольный входной патрубок размером 240х167 мм. Третий вариант опытов проводился при совмещенном варианте, т.е. при наличии трубы и четырехугольного входного патрубка.

Результаты исследований. Установлено, что изготовленный образец мини ГЭС вполне работоспособен для выработки электроэнергии в производственных условиях.

Диапазон апробированных и подтвержденных параметров составляют в следующих пределах: напор H = 1,5-2,5 м, расход воды – Q = 45-120 л/с. При этом обеспечивается выработка мощности в пределах N = 0,5-2,0 кВт. Полученные параметры в ходе этих испытаний будут апробированы в более широком диапазоне и отработаны рациональные режимы работы мини ГЭС предлагаемой конструкции в условиях эксплуатации в реках со значительным перепадом течение воды.

Ключевые слова: мини ГЭС, гидротурбина, генератор, компьютерное моделирование, опытный образец, производственное испытание.

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