ESTUDO DO PROCESSO DE EROÇÃO DE TURBINAS DE UMA MICRO USINA HIDRELÉTRICA (UHE) NA FORMA DE UM HIDROCICLONE**STUDY OF THE PROCESS OF EROSION OF A MICRO HYDROELECTRIC POWER PLANT (HPP) TURBINES IN THE FORM OF A HYDROCYCLONE****ИССЛЕДОВАНИЕ ПРОЦЕССА ЭРОЗИИ ТУРБИН МИКРОГИДРОЭЛЕКТРОСТАНЦИИ (ГЭС) В ФОРМЕ ГИДРОЦИКЛОНА**ZHUZBAY, Kassymbekov^{1*}, KULYASH, Alimova², GALIMZHAN, Kassymbekov³^{1,2} Satbayev University, Republic of Kazakhstan.³ Kasgidro Almaty, Republic of Kazakhstan.

* Corresponding author
e-mail: jkk2004@mail.ru

Received 22 July 2020; received in revised form 28 September 2020; accepted 15 October 2020

RESUMO

Um dos graves problemas de uma usina hidrelétrica (UHE) é abastecer uma unidade hidrelétrica com água purificada com a pressão necessária. Caso contrário, os corpos de trabalho centrais - turbinas hidráulicas - estão sujeitos a desgaste abrasivo e falham rapidamente. O desgaste abrasivo não apenas reduz a eficiência e a vida útil da turbina, mas também causa problemas na operação e manutenção. Esta pesquisa teve como objetivo estudar o grau de desgaste abrasivo (taxa de erosão) da superfície de uma turbina hidráulica de pás de uma micro UHE durante a purificação da água por meio de um hidrociclone e garantir seu layout racional com base nos estudos. A investigação de danos à superfície da turbina com o impacto dinâmico foi realizada por modelagem computacional do processo usando o programa Autodesk Simulation CFD, com diferentes versões do corpo do hidrociclone e teste de uma amostra experimental. O software adicional SolidWorks (simulação de fluxo) foi usado para verificar os cálculos. Verificou-se que as formas de dureza das partículas na água afetam significativamente a taxa e a magnitude da erosão, e um projeto diferente do corpo de tratamento na forma de um hidrociclone de maneiras diferentes garante a separação do fluxo em fases. Foi selecionado um esquema racional para a instalação de uma turbina hidráulica dentro de um hidrociclone, que fornece a característica de potência necessária de uma mini central hidrelétrica e outros parâmetros necessários. O maior grau de purificação de água de impurezas sólidas (94%) foi alcançado usando a opção de configuração em um design cilíndrico-cônico com uma entrada de água rotativa no hidrociclone. A localização da turbina hidráulica dentro de um hidrociclone de determinado desenho e o fornecimento tangencial de água às lâminas da turbina hidráulica protegem significativamente a superfície da unidade dos efeitos das partículas sólidas. Sua vida útil pode ser aumentada sem investimento adicional na restauração da unidade.

Palavras-chave: *Micro HPP, hidrociclone, hidroturbina, desgaste abrasivo, grau de purificação da água.*

ABSTRACT

One of the severe problems of a hydroelectric power plant (HPP) is providing a hydroelectric unit with purified water with the required pressure. Otherwise, the central working bodies - hydraulic turbines - are subjected to abrasive wear and quickly fail. Abrasive wear reduces the efficiency and life of the turbine and causes problems in operation and maintenance. This research aimed to study the degree of abrasive wear (erosion rate) of the surface of a blade hydraulic turbine of a micro HPP during water purification using a hydrocyclone and to ensure its rational layout based on the studies. Investigation of damage to the turbine surface from the dynamic impact was carried out by computer modeling of the process using the Autodesk Simulation CFD program, with different versions of the hydrocyclone body and testing of an experimental sample. Additional software SolidWorks (flow simulation) was used to check the calculations. It was found that the forms of particle hardness in water significantly affect the rate and magnitude of erosion, and a different design of the treatment body in the form of a hydrocyclone in different ways ensures the separation of the flow into phases. A rational scheme for installing a hydraulic turbine inside a hydrocyclone was selected, which provides the required power characteristic of a mini hydroelectric power station and other necessary parameters. The highest degree of water purification from solid impurities (94%) was achieved using the configuration option in a cylindrical-conical design with a rotational water

inlet into the hydrocyclone. The location of the hydraulic turbine inside a hydrocyclone of a certain design and the tangential supply of water to the blades of the hydraulic turbine significantly protects the surface of the unit from the effects of solid particles. Their service life can be increased without additional investment in the restoration of the unit.

Keywords: *micro HPP, hydrocyclone, hydro turbine, abrasive wear, degree of water purification.*

АННОТАЦИЯ

Одна из серьезных проблем гидроэлектростанции (ГЭС) - обеспечение гидроагрегата очищенной водой с необходимым давлением. В ином случае основные рабочие органы - гидротурбины подвергаются абразивному износу и быстро выходят из строя. Абразивный износ не только уменьшает эффективность и срок службы турбины, но также вызывает проблемы в эксплуатации и техническом обслуживании. Целью данного исследования было изучение степени абразивного износа (скорости эрозии) поверхности лопастной гидротурбины микроГЭС при очистке воды с помощью гидроциклона и обеспечение ее рациональной компоновки на основе проведенных исследований. Исследование повреждений поверхности турбины от динамического воздействия проводилось путем компьютерного моделирования процесса с использованием программы Autodesk Simulation CFD с различными вариантами корпуса гидроциклона и испытания экспериментального образца. Для проверки расчетов был использовано дополнительное программное обеспечение SolidWorks (flow simulation). Установлено, что формы твердости частиц в воде, существенно влияют на скорость и величину эрозии, а также различное исполнение очистного корпуса в виде гидроциклона по разному обеспечивает разделения потока по фазам. Выбрана рациональная схема установки гидротурбины внутри гидроциклона, которая обеспечивает требуемую энергетическую характеристику мини ГЭС и другие необходимые параметры. Наибольшая степень очистки воды от твердых примесей (94%) было достигнута при использовании варианта компоновки в виде цилиндрико-конического исполнения с вращательным входом воды в гидроциклон. Расположение гидротурбины внутри гидроциклона определенной конструкции и тангенциальная подача воды в лопасти гидротурбины значительно защищает поверхность агрегата от воздействия твердых частиц. Срок их службы можно увеличить без дополнительных вложений в восстановление агрегата.

Ключевые слова: *микроГЭС, гидроциклон, гидротурбина, абразивный износ, степень очистки воды*

1. INTRODUCTION:

The global hydropower capacity worldwide amounted to almost 1,292 GW of which more than a quarter are located in China (352 GW), followed by Brazil (104 GW), USA (103 GW), and Canada (81 GW). In 2018, the global hydropower generated approximately 4,200 TWh of electricity (Hydropower Status Report, 2019). In recent years, small hydropower has received notable development, i.e., constructing mini and micro-hydroelectric power plants (Ghumman *et al.*, 2020). This is because they have some advantages. They do not require the construction of dams and large flooded areas, proximity to consumers, the absence of expensive transporting power lines, the prostate in regulating operating modes, and ecological balance maintenance. It has been established that when compared with other unconventional energy sources, the minimum level of pollution occurs when using mini hydroelectric power plants (Yumaev, 2018).

One of the disadvantages of small and mini hydroelectric power plants is that they require additional construction of outstanding facilities for

preliminary treatment (purification) of water in the form of sedimentation tanks, which lead to an increase in construction costs and operating costs up to 25-30% (Oliver Peysh, 2002). Deterioration of the working bodies' performance due to wear by mechanical impurities sharply reduces the HPP's technological and energy parameters. Therefore, many scientific and practical works are devoted to studying the erosion of hydraulic turbines and technology development for their protection (Padhy, 2008; Kumar, 2015). They noted that the wear of the surface of the turbine blades by solid particles is directly proportional to the duration of exposure, the concentration of impurities, and the granulometric composition of river sediments.

It is indicated that only those particles whose hardness exceeds the hardness of the manufacture material represent a real danger to a hydraulic turbine, i.e., erosion resistance of structural material (Bhola and Hermod, 2004). Two areas are used to study the processes of abrasive wear of various materials — the theoretical and experimental modeling of processes in laboratory conditions (Tkhabisimov, 2019). Erosion analysis of Francis turbine sediments provides insight into the relative intensity of erosion and critical areas of erosion

damage to turbine components (Neopane, 2010). Simultaneously, the highest speeds and accelerations were achieved at the exit from the runner blade and had significant erosion. Besides, unexpected sludge erosion was found on the suction side of the guide vane, where the concept of critical diameter can be used.

To improve the study of the process, a computer 3D model has been developed to describe the movement of solid particles in the flow paths of axial and radial-axial turbomachines (Tabakoff, 1990). The proposed model can be used to visualize the expected nature of the movement of solid particles. A discrete computer simulation of the motion of one particle can be performed using instantaneous values of velocities versus time (Tsuji, 2000). Further computer simulation of moving spherical particles was developed in the works of Joseph (Joseph, 2001). However, this model, like the previous one, does not take into account the real shapes of particles, which are random.

Overall, the review of the study shows that current knowledge and research results are not enough to address this problem entirely. The work performed primarily examines the erosion of operating hydraulic turbines based on the actual technical condition and issues recommendations for their elimination. Practically few studies are studying the abrasive wear of the surfaces of hydraulic turbine blades when working together with a hydrocyclone water treatment device.

Consequently, this research aimed to study the degree of abrasive wear (erosion rate) of the surface of a blade hydro-turbine of a micro HPP during water purification using a hydrocyclone and to ensure its rational layout based on the studies performed.

2. MATERIALS AND METHODS:

The designs of micro-hydroelectric power plants developed differing from the existing ones to protect them from abrasive wear, the hydro-turbines are located inside the cylindrical part of the hydro-cyclone and rotate due to the centrifugal force of the water flow formed at the tangential entrance to the hydro-cyclone body (Petrov, 2013). This ensures the separation of the water composition into liquid and solid phases, i.e., water purification before it reaches the flow part of the hydro turbine (Pezzini, 2016). This arrangement is associated with the need to simplify the construction of the device, downsize the loss of capacity and power generation, and, most notably

to preserve the efficiency and increase the service life of the hydro turbine. For a comparative analysis of the spread of the erosion rate on the blades of the hydro turbine, the following four configuration options of micro-hydroelectric power plants of the hydro-cyclone type were considered (Figures 1 and 2).

The first version (Figure 1a) is made in the form of a classic cylindrical-conical hydro-cyclone. Here the water supply is tangent to the cylindrical part, along a straight pipe. Therefore, the impact of the jet from the pipe with the turbine blade is carried out along its upper part directly, i.e., until the solid particles are entirely separated from the water. The second variant (Figure 1b) differs from the first in the form of the final branch pipe of the water supply pipe in a bent shape. And, the end of the pipe is provided with a flat nozzle, which allows the initial free passage of the jet through the space between the wall of the hydro-cyclone and the turbine blade. Thus, the impact of the jet with the blade occurs after water purification, i.e., from the second approach of the twist. The third variant (Figure 2a) is made in the form of a shortened cylindrical hydro-cyclone. The water supply is made as in the second variant using a pipe with a curved end. For removing captured particles to the dump, a relatively located pipe is provided in the lower part of the unit. The fourth option (Figure 2b) is a structurally inappropriate connection of the bent pipe branch with an uneven surface of the cone. Otherwise, this option is not remarkably different from the others.

To predict the degree of separation of a two-phase liquid in a hydro-cyclone during combined operation with a hydraulic turbine in various versions and study surface damage due to abrasive wear, the processes were subjected to computer modeling (Buldygerov, 2004; Evtyushkin, 2007). A computer simulation was carried out using the Autodesk Simulation CFD program using the Computational Fluid Dynamics model based on the Reynolds Navier-Stokes equation (Autodesk Simulation CFD, 2019). To check the calculations, the additional software "SolidWorks (flow simulation)" was used (Rakhimzhanova, I.B. *et al.*, 2019). When comparing these programs, errors were allowed within 10-12%. The advantage of studying using computer modeling is that the main factors affecting wear can be reduced to a single equivalent (Klunk, M. A. *et al.*, 2019; Buldygerov D.S. 2004). The granulometric composition of the used sediments entering the inlet of the hydrocyclone body is almost half (44.6%) of dusty particles, and 34.4% of particles with diameters of

0.05-0.50 mm (Table 1).

The reduced composition of sediments in water during field tests was determined by hourly taking water samples from the drain and sand pipes of the hydrocyclone. Then they were dried and passed through calibrated meshes to establish the division gradation and analysis according to GOST 12536-2014 (Russia). In this case, sieves with 10 holes were used; five; 2; 1; 0.5; 0.25; 0.1 mm; technical scales with a relative weighing error of no more than 0.1% and a drying cabinet. Separation of soil into fractions without washing with water (size from 10 to 0.5 mm), according to the specified standard, was carried. The sieves of the appropriate dimensions were installed in the column in order of increasing hole sizes. The selected sample was transferred to the top sieve, and it was closed with a lid. Sifting of the soil until complete sorting was carried out by light side blows of the palm of the hand. Fractions of grun, which lingered on the sieves, poured into the dishes, starting from the upper sieve. The completeness of the sieve was checked by shaking each sieve over a sheet of paper. If some particles fall on the sheet, then sieving was repeated until the particles stop falling on the paper. Then the sieve fractions were weighed on a balance.

When separating the soil into fractions with rinsing with water (with a particle size of up to 0.1 mm), the initially moistened sample was thoroughly ground with a pestle. The weighed portion was transferred in parts onto a sieve with a hole diameter of 0.1 mm and elutriated under a stream of water until the sieve flows out clear water. The fractions were dried in an oven at 105 °C, and the dish with soil was weighed. The analysis results were recorded. Since tiny particles do not pose a particular risk of wear, a more in-depth study was mainly subjected to particles with a size of 0.25-0.5 mm. The hardness of the metal of the carbon steel hydraulic turbine on the Mohs scale was 5.0 - 5.5. Some results of a qualitative and quantitative assessment of the abrasive ability of particles entrained with water and predicting abrasive wear for various layouts of mini hydroelectric power plants are presented in the modeling graphs using the above-described method (Figures 3-11).

Bearing in mind that the abrasive wear of the turbine is proportional to the cube of the relative velocity of the mixture of water and solid particles, when modeling the process, the main initial parameters were the velocity heads at the inlet and outlet of the hydrocyclone body. Here, the discharge pipe of the hydrocyclone, through which

the purified water is discharged, plays the role of a suction pipe of a mini HPP. The relative input speed is described by the following formulas:

$$V_1 = k_1 \sqrt{2gH_1}, \text{ m/s} \quad (1)$$

and at the exit

$$V_2 = k_2 \sqrt{2gH_2}, \text{ m/s} \quad (2)$$

where k_1 and k_2 are the speed coefficients, depending on the shape of the turbine blades; H_1 - working head of the turbine, m; g is the acceleration of gravity. Based on existing experience, if $V_2 > V_1$, the greatest abrasive wear should occur at the outlet of the turbine in the direction of the water discharge pipe. As can be seen from Figure 4, this position is confirmed by the results of the simulation.

Preliminary analytical assessment of technological parameters of the adopted mini hydroelectric power plant designs was carried out using the following formulas:

1. Water flow rate at the inlet or in the discharge branch pipe of the hydrocyclone, m^3/s .

$$Q = V * F, \text{ m}^3/\text{s} \quad (3)$$

where V is the speed of water supplied to the hydrocyclone through the pipe from the river, m/s
 F - area cross-section of the inlet or drain pipe, m^2 .

2. Power of the hydraulic unit

$$N = Q * g * H * \eta_g, \text{ W} \quad (4)$$

where $\eta_g = 0.65$ is the efficiency for double (Crossfair) and simple active hydro turbines.

3. Torque, $\text{N} * \text{m}$

$$M = 9550 * N / n, \text{ N} * \text{m} \quad (5)$$

4. Hydroelectric power plant efficiency

$$\eta_g = N / p_{gQH}. 100\% \quad (6)$$

5. Hydraulic unit efficiency

$$P = N * \eta_g - \text{electric power of the hydraulic unit, kW} \quad (7)$$

6. The degree of water purification in a

hydrocyclone

$$S_v = 100 - q_p \quad (8)$$

where q_p - is the percentage of sand through the drain pipe, m^3/s

Thus, it is possible to select (for the considered pressure range at the inlet H) the correct inter-position of the turbine and the hydro-cyclone, ensuring normal functioning with a given water saturation with solid particles.

3. RESULTS AND DISCUSSION:

Initial materials for modeling the process and analyzing the studied parameters were the following data: the diameters of solid fractions of 0.25-0.50 mm, the head of the supplied water $H = 1.5$ m, the flow rate of the supplied water $Q = 0.266$ m^3/s and the concentration of the hydro mixture 5-10%. As shown in Figures 3 and 4, when mechanical impurities enter the hydro-cyclone with water, their main effect occurs along the upper edges of the blades. Then these particles scatter randomly over the areas of contact (red) surfaces. Simultaneously, the maximum rate of erosion is in the range of 8-10 mm/year. Suppose a graphical characteristic based on these indicators $n = f(t)$ is constructed. In that case, the dependence of the rotation frequency (n) on the acceleration time (T) of the hydraulic unit is presented in the following form (Figure 5). It follows that in all versions of the micro HPP operation mode, the hydraulic unit acceleration is set when $t = 3$ s is reached.

It was found that 58 of the 100 particles received directly contact the surface of the hydro-turbine, and the rest (42) are removed through the sand hole and the drain pipe to the outside without touching the blades. In the second variant, as can be seen from Figure 6, the area of erosion on the surface of the blades is much smaller. This shows that with such water supply with mechanical impurities, the flow has time to be cleaned of particles at the first twist, and therefore wear of the surface is insignificant. This is confirmed by the high percentage of particles carried out through the sand hole into the dump (94%). The erosion rate is only 0-1.1 mm/year.

The speed characteristic along the perimeter of the hydro turbine after entering (Figure 7) is improved due to centrifugal forces (up to 6-7 m/s) and in the areas of discharge openings (sand hole and drain pipe) are reduced to 2-3 m/s, which is quite enough for the removal of particles and purified water to the outside. In this mode of

operation, the speed of the turbine shaft was 234 rpm. With a cylindrical design of the micro hydroelectric power station housing of the hydro-cyclone type (3rd variant, Figure 8) with a rotational water outlet, it turned out that the wear area of the blade surface does not change much. This indicates that the absence of the cone part in this case does not negatively affect the cleaning capacity of the unit.

A characteristic feature is that most of the turbine blades are not subject to wear. This is probably due to an increase in the gap between the blades of the hydro turbine and the inner surface of the hydro-cyclone. The speed of the shaft is slightly reduced (up to 170 rpm) in comparison with the second option. During purification, 88% of particles fall into the sand hole of the hydro-cyclone, which shows the permissible degree of water purification with abrasives solid impurities (88%). The trajectory of the swirling jet (stream) in a cylindrical hydro-cyclone with a turbine, due to the limited height of the hydro-cyclone, has a more compressed form. The values of the speeds at the inlet, inside the device, do not differ much (within 4-5 m/s) from each other, and on the drain pipe slightly decreases to 2.5-3.0 m/s (Figure 9). Isolines of the propagation of the flow velocity and pressure inside the cylindrical hydrocyclone fully correspond to the parameters of the established flow path.

Calculations have shown that an average of 15-20 particles out of 100 come into contact with the turbine, which shows the normal cleaning capacity of such a technical design. With a head at the inlet of 1.51 m, the head at the drain pipe was 1.25 m. These losses are considered insignificant and do not adversely affect the required operating mode. The volume flow rate at the drain is 0.206 m^3/s , and at the outlet of the sand hole – 0.06 m^3/s .

The fourth version of the design of a hydro-cyclone with a turbine in the form of a cone (Figure 11) was not the best technical solution to protect the surface of the blades from abrasive wear. This is seen from the Figure and therefore requires a separate particular study in the future. As can be seen from the Figure, the technological feature of wear from others is that the erosion process occurs mainly on the end of the blades, especially on the side of the drain pipe. There is a negative effect of the too-close location of the conical hydro-cyclone (only 4-5 mm) to the end part of the blades. This restricts the free removal of particles through the drainpipe, as in other variants. During the modeling of the process, it turned out that 53 particles out of 100 come into contact with the

turbine, and 74 particles get into the sand trap. The pressure loss at the drain is 10-15%.

The trajectory of the flow with particles, with a diameter of 0.25 mm, in a cone-shaped hydro-cyclone does not differ much from the trajectory of the second option. In order to assess the technological capability of the cylinder-conical version of the micro-hydroelectric power plant layout with the least abrasive wear, an experimental sample was tested in natural conditions at $H = 1.5 - 3.0$ m (Figure 11). The obtained technological parameters are shown in Table 2.

In general, the results of the tests carried out show that the developed design is quite workable, and it allows you to achieve the set goal. As shown in Table 2, with an increase in the water pressure at the inlet - H_B , the supplied water flow rate - Q_B increases. The maximum flow rate for testing is provided at a head of $H_B = 2.5 - 3.0$ m. In this case, the front chamber shutter was opened to the full section. It is also possible to note the efficiency of directed water supply to the surface of the hydro-turbine blades using a pipe (nozzles), rather than using for this purpose 4-carbon branch pipes located tangentially to the outer surface of the hydrocyclone.

4. CONCLUSIONS:

It was found that the value of erosion damage to the surface of the turbine blades in the cases under consideration depends on the degree of water purification from solid impurities in the hydrocyclone body and the dynamic effect of the swirling flow. Simultaneously, the highest degree of water purification from solid impurities (94%) is achieved when using the cylindrical-conical version of the hydrocyclone, and the erosion rate is the lowest and is only 0-1.1 mm/year. It is revealed that the modeling of erosive wear processes using modern software systems makes it possible to predict the rate of possible burial at the stage of designing a hydraulic unit. The effectiveness of this technical solution is confirmed by the achieved capacity of the hydroelectric unit within the range of $N_a = 2.5 - 3.4$ kW, which is quite a good indicator for the individual use of energy at the selected test object, characterized by a low head of water flow due to the small drop in the river bed. This means that the mini hydroelectric power station under consideration has additional opportunities for increasing the power characteristics when using it on areas with a significant slope.

5. ACKNOWLEDGEMENTS:

We are thankful for the target program of the Ministry of Education and Science of the Republic of Kazakhstan, "Creation of a base for serial production of world-class Kazakhstani renewable energy sources" (BR 05236263, NAS RK), which made it possible to carry out this work

6. REFERENCES:

1. Autodesk Simulation CFD (2019). https://www.tadviser.ru/index.php%D0%9F%D1%80%D0%BE%D0%B4%D1%83%D0%BA%D1%82:Autodesk_Simulation_CFD
2. Belash I.G. (2010). Problems of Reliability and Efficiency of Hydraulic Turbine Equipment of Hydroelectric Power Stations. *Proceedings of the Conference "Improving Reliability and Efficiency of Operation of Power Stations and Power Systems"*, MEI [online]. www.energy2010.mpei.ru
3. Bukhtoyarov, V. V., Tynchenko, V. S., Petrovskiy, E. A.; Buryukin, F. A. (2019). Comparative analysis of modeling methods well operation using a submersible electric pump. *Periódico Tchê Química*, Vol. 16 N. 32: 621-632.
4. Buldygerov, D.S. (2004). Computer simulation: methods of statistical modeling.-M.
5. Brekke Hermod. (2002). Design of hydraulic machinery working in sand laden water. *Abrasive erosion and corrosion of hydraulic machinery*, London.
6. Experimental stand for studying the abrasive resistance of structural materials and protective coatings (2013)./ Tkhabisimov A.B., Kachalin G.V., Mednikov A.F. S.V. Sidorov // *Natural and technical sciences*. - No. 5 (67) : 234-238.
7. ETSAP (2010). Energy Technologies Systems Analysis Program. IEA ETSAP - *Technology Bulletin E12*. Available at www.etsap.org
8. European Renewable Energy Institute (2012). Renewable energy sources REN21. *Global Status Report* ". European Focus, Paris, France.

9. Evtushkin, E.V., Matvienko, O.V. (2004). Mathematical modeling of turbulent transfer of a dispersed phase in a turbulent flow. *Vestnik Tomsk State University*, 6 (43): 50 -53.
10. Ghuman, A.R, Haider, H., Yousuf, I (2020). Sustainable Development of Small Hydropower Plants: Multilevel decision making from site selection to optimal design. *Arab Science and Technology Journal*, 45: 4141 – 4159.
11. Global hydropower: development results in (2018).
<https://eenergy.media/2019/05/16/mirovaya-gidroenergetika-itogi-razvitiya-v-2018-godu/16.05.2019> - by Energy.media 451
12. GOST 12536 — 2014 (2015). SOILS. Methods for laboratory determination of particle size (grain) and micro-aggregate composition. M., *Standartinform*.
13. Grigorash, O.V., Kvitko, A.V., Popuchieva, M.A.(2015). Prospects of small hydropower Plants in the piedmont and mountain Streams/ *Scientific journal KubSAU*, 112 (08): 1-13.
14. Herbut, P., Rzepczyński, M., Angrecka, S. (2018). The Analysis of Efficiency and Investment Profitability of a Solar Water Heating System in a Multi-Family Building. *J. Ecol. Eng.*; 19(6):75– 80.
15. International Network on Small Hydro Power (IN-SHP) (2010), World Expo Special Edition Newsletter, *IN-SHP*, Vol. 1, issue 3.
16. Joseph, D.D (2001). Lift correlations from direct numerical simulation of solid-liquid flow. *Proc. Fourth International Conference on Multiphase Flow*. No. 385:1-11.
17. Kassymbekov, Zh.K., Ni, N.P., Botantseva, B.S. (2014). Testing of the water-pipe centrifugal vent valve-pressure damper in laboratory conditions, *Water and Ecology*. 2(58). Sankt – Peterburg: 39-44.
18. Klunk, M. A., Dasgupta, S., Das, M., Wander, P. R. (2019). Computer codes of geochemical modeling used to water-rock interaction simple and complex Systems. *Periódico Tchê Química*, Vol. 16 N. 32: 108 -118.
19. Lagerev, A. (2006). Probabilistic Forecast of Erosion of Steam Turbines, *Moscow. Mechanical engineering*.
20. Lipkin, V.I., Bogombaev, E.S. (2007). Microhydroelectric power plants: a guide to application: Bishkek. LLC "M Maxima".
21. Mini hydropower plants for water supply systems and sewage (2019). [online] .Available at: <http://www.alterenergy.info/hydropower/28-notes/343-mini-hydro-water-supply-sewerage-drains>
22. Neopane, H.P. (2010). Erosion of sediments in hydroturbines. *Dissertation. Norwegian University of Science and Technology*: 201-223.
23. Neopane, H.P., Cervantes, M., Dahlhaug, O. G.(2012). The effect of sediment characteristics for predicting erosion on Francis turbines blades. *Article in International Journal on Hydropower and Dams* 19(1):79-83 .
24. Neopane, H. P., Ole G. Dahlhaug, and Thapa Bhola. (2009). Experimental examination of the effect of particle size and shape in hydraulic turbines. *Waterpower XVI, Spokane*, Washington, USA.
25. Oliver Paish (2002). Small hydro power: Technology and current status. *Article in Renewable and Sustainable Energy Reviews* 6(6):537-556 . DOI: 10.1016/S1364-0321(02)00006-0
26. Ole G. Dahlhaug and Thapa Bhola (2004). Sand erosion in a Francis turbine: a case study at a power plant in Yimruk, Nepal. *22nd IAHR Symposium on Hydraulic Machinery and Systems*, Stockholm, Sweden.
27. Ovchinnikov, V.V., Uchevatkina N.V., Kurbatova I.A., Lukyanenko E.V., Yakutina S.V (2019). Titanium alloy wearability increase via implantation of copper and aluminum ions. *Periódico Tchê Química*, Vol. 16 N. 32.: 945-966.
28. Padhy, M. K. and Saini, R. P. (2008). A review on silt erosion in hydro turbines. *Renewable and Sustainable Energy Reviews* 12(7): 1974 - 1987.
29. Pezzini, Alessandra; Briao, Vandré B.; De Boni, Luis A. B.(2016). Preliminary study for a cleaning and water reuse System. *Tchê Química*, Vol. 13 – No. 26: 127 – 132.

30. Petrov, V.I., Sizov, A.G., Fatikhov, I.F. (2013). Analysis of the efficiency of hydrocyclones *KNITU*, 16 (22):255-257.
31. Rakhimzhanova, I.B., Issabaeva, S. N., Zhumartov M.; Nazarbekova, K..T; Turganbay,K.(2019). Modeling in studying computer graphics in the fundamentalization of computer science. *Periódico Tchê Química*, Vol. 16 N. 32: 755-767.
32. Sandeep Kumar, Brajesh Varshney (2015). Estimation of Silt Erosion in Hydro Turbine. *International Journal of Engineering Research & Technology (IJERT)*, Vol. 4.
33. Stakhoviyak, G.V., Batchelor, A.V. (2006). Abrasive, erosional and cavitation wear. *Tribology Engineering*, 3., Burlington, Butterworth-Heinemann: 501–551.
34. Shuyushbayeva, N. N., Sagimbaeva, S. Zh., Mussenova, E.K., Bizhanova, K.B., Zhanturina, N.N.(2020). Reduction of defective conditions of the wind power plant operation at reserving the operation modes of alternative energy. *Periódico Tchê Química*, Vol.17 N. 34: 976-997
35. Tabakoff, W. (1990). Effect of environmental particles on a radial compressor proc. on corrosion-erosion-wear of materials at elevated temperatures / Berkeley. : 261–268.
36. Thapa Bhola. (2007). Erosion Coatings for Hydraulic Turbines and Measurement of Erosion Resistance of Selected Coating Materials. *Journal of the Physical Society of Nepal*, 23 (1):1-6.
37. The current state and prospects for the development of small hydropower in the CIS countries / *Eurasian Development Bank (EDB)*. - Almaty, 2011.: 21-25.
38. Tsuji, Y. (2000). Activities in discrete particle simulation in Japan/*Powder Technology*. - No 113: 278–286.
39. Vinicius de Freitas, Trevisan Lisiane, Reguly Afonso. (2016). Tool steel wear resistance evaluation produced By powder metallurgy, heat treated vacuum. *Tchê Química*, Vol. 13 – N. 26: 97-104.
40. Wang, G. (2013). Current state and development of the research on solid particle erosion and repair of turbomachine. *20th CIRP International conference on life cycle engineering, No room*: 633-638.
41. Yumaev, N.R.(2018). Environmental aspects of the use of renewable energy sources / *Modern trends in technical sciences. Materials of the International Conference* (Kazan): 16-21.
42. Zhurinov, M., Kassymbekov, Zh.K., Kassymbekov, G. Zh. (2019). Mastering and development hydropower in Kazakhstan // *Of the national academy of sciences of the republic of Kazakhstan series of geology and technical sciences*. 3 (435): 219 – 224.

(a)

(b)

Figure 1. Layout diagrams of micro-hydroelectric power plants in the form of a cylindrical-conical (a) and hydro-cyclone (b).

(a)

(b)

Figure 2. Layout diagrams of micro electric power plants in the form of a cylindrical (a) and conical (b) hydro-cyclone.

Figure 3. A general picture of hydro turbine blade erosion with the direct flow of water from mechanical admixtures (1st version).

Figure 4. Areas of impact and spread of erosion along with the blades of a hydro turbine

Figure 5. Graphical dependence of the speed (n) on the acceleration time (t).

Figure 6. Picture of hydro turbine blade erosion when rotating water supply with mechanical mixtures (2nd option).

Figure 7. Trajectory and flow rates in a hydro-cyclone with a turbine.

Figure 8. Picture of erosion of the turbine blades in the cylindrical form of the micro-hydroelectric power station (3rd version).

Figure 9. Trajectory and flow rates in a cylindrical hydro-cyclone with a turbine.

Figure 10. Area of the spread of erosion on the blades of a hydro turbine.

Figure 11. Types of an experimental model of a cylinder-conical version of a hydrocyclone of a micro HPP. a) type of test piece; b) the type of work of the sample in the river.

Table 1. Granulometric composition of sediments.

Name of water source	Fraction of sediment, mm						
	< 0,01	0,01-0,05	0,05 -0,10	0,10-0,25	0,25-0,50	> 0,50	Dcp (mm)
The Turgen river	44,6	16,54	16,3	18,1	3,3	1,1	0,06

Table 2. Technological parameters of an experimental model of a mini hydrocyclone hydroelectric power station

Area inlet, F, m ²	Heads water at the inlet and in the drain pipe, H1 / H2, m	Speed water on entrance, V1, m / s	Flow rates water through the inlet and drain pipe, Q1 / Q2, m ³ / s	Frequenc y rotation, rp/min	Torque moment, M, N * m	Power hydro-regatta, Na, kW
0,03	1,5/1,34	5,42	0,17/0,14	210	54,1	1,19
0,03	2,0/1,78	6,26	0,19/0,17	243	75,8	1,93
0,03	3,0/2,66	7,67	0,24/0,20	293	110,5	3,39