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Sources of alternative types of energy in system of hydro-engineering structures of angrenskaya mine of brown coal

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Abstract. Along with the development of traditional energy in Uzbekistan, much attention is paid to alternative and renewable energy. The Angren Special Economic Zone, on the one hand, is a catalyst for the development of industrial production, the creation of new innovative technological enterprises, the strengthening of logistics processes, and the improvement of the city's living standards. All this requires the search for new sources of energy resources along with an increase in coal production. Unique hydraulic structures currently serve to ensure the functioning of the Angrenskaya coal mine. Analysis of individual technological hydrotechnical facilities made it possible to determine the availability of alternative energy sources. The paper provides some considerations on using these sources for energy generation using small hydropower plants. The average calculated indicators and energy potentials of alternative energy sources are presented. Some hydraulic turbines are considered within the framework of the hydraulic engineering systems.

1 Introduction

The Angren lignite deposit is the unique mining and ore enterprise for the extraction of solid organic fuel, using three methods of extraction: mining, open pit, and underground coal gasification [1]. In addition, a system of hydraulic structures (HTS) has been developed and implemented to organize open-pit coal mining. The main components of the GTS system are a dam, an underground reinforced concrete tunnel, a bypass channel for the water flows of the Akhangaran River, flow energy dampeners, drainage wells with water-lifting submersible pumps, a quarry water intake, a quarry pumping station with six units, water conduits with a total length of more than 13 km, a spillway for quarry wastewater - a hydraulic dump.

An exaggerated system of hydraulic structures in the form of a simple technological block diagram of the Angrenskaya section is shown in Figure 1.

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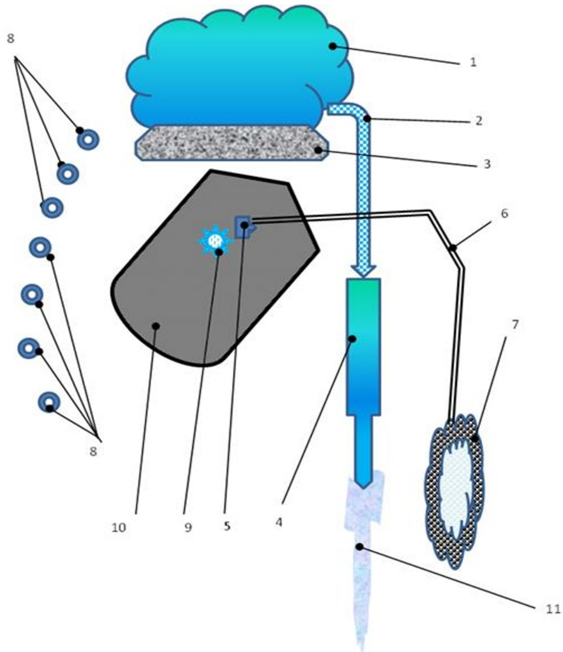

Fig. 1. Schematization of dislocation of main hydraulic structures in peripheral and internal space of Angrenskaya mine

1 is reservoir on the bed of the Akhangaran river,
2 is underground bypass tunnel of water flows of the Akhangaran river,
3 is security dam between the reservoir and the coal mine,
4 is bypass channel (by water-damping energy absorbers) of the water flows of the Akhangaran River,
5 is pumping station for quarry wastewater,
6 is pipeline transport of quarry wastewater,
7 is spillway facilities for quarry wastewater - hydro dump,
8 is water-reducing drainage wells with water-lifting pumps,
9 is catchment facility for quarry wastewater of the Angrensky mine,
10 is technological area of the Angrensky coal mine,
11 is natural course of the Akhangaran river.

2 Object and methods of research

The objects of research are technological hydraulic structures built more than sixty years ago. Calculation-analytical, literary-informational, and prior-visual research methods of the considered objects and functioning processes are used.

Traditionally, hydraulic structures are dams; buildings of hydroelectric power plants; spillways; drainage and water outlet structures; tunnels and channels; pumping stations, shipping locks, and ship lifts; structures designed to protect against floods and destruction of the banks of reservoirs, banks and bottoms of river channels [2,3,4,5,6]. Typically, hydraulic structures are designed to use water resources (rivers, lakes, seas, groundwater) or combat the water element's destructive effects.

In a particular case, using the example of the Angrenskaya coal mine, hydraulic structures are used as nature-protective, production-technological, temporary-localizing

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structures for strategically important objects of the coal industry.

3 Discussion of the obtained results

The main hydraulic structure - the dam was built at an altitude of 932 meters above sea level. Type of dam: earthen, length 1933 m, width (at the top) 12 m, and maximum height 100 m. The Akhangaran River has an average water flow of 22.8 m^3 / s; its source is at an altitude of 2710 m above sea level.

The dam (Fig. 2) serves to hold the water pressure and protects the coal mine and other objects from flooding; the underground tunnel allows you to bypass part of the water of the Akhangaran River without causing damage to the built-on production facilities, and the bypass channel is used to remove the water flow from the underground tunnel and reduce the energy of the water flow, the quarry pumping station pumps out sewage and atmospheric precipitation outside the Angrensky mine, the hydraulic dump is designed to drain quarry wastewater and atmospheric precipitation and to sediment suspended particles of coal, kaolin, sand, and other mineral inclusions.

a)

b)

Fig. 2. a) view of dam from side of reservoir, coal mine in perspective,
b) view of dam from Angrensky coal mine

The tasks solved by hydraulic structures are very diverse and strategically important. Analyzing the functioning of the work of hydraulic structures, it is necessary to note the special hydropower aspects of the underground tunnel and the bypass channel with water-jet energy absorbers.

The water level in the reservoir fluctuates widely, and discharges above the norm are carried out through a four-kilometer underground tunnel and further along a bypass channel with a length of more than 6.5 km, with water-cutting energy absorbers (Fig. 3).

Water-jet energy absorbers on the bypass channel are built at different distances depending on the level of water pressure, and a total 8 blocks

Each water-jet dampener of the water flow pressure has special design and hydraulic features depending on the speed of the water flow and the slope of the bypass channel, as well as the technological purpose.

Among the water-breaking energy absorbers, the third water-breaking energy absorber also performs the task of a mini-dam to withdraw part of the water resources to provide cooling water to the cooling tower of the Angren TPP.

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Fig. 3. Bypass channel with water-cutting energy absorbers of Angrenskaya mine
1) - water intake unit of the underground tunnel, 2) - a bypass tunnel with a dewatering energy absorber, 3) - the first water-breaking energy absorber, 4) - the second dewatering energy absorber, 5) - the third dewatering energy absorber, 6) - the fourth water-breaking energy absorber, 7) - the fifth water-breaking energy absorber, 8) - the sixth water-breaking energy absorber, 9) - the eighth water-breaking energy absorber

The difference in water levels in the water pressure absorbers of the water pressure is, on average, 5-8 m. But the difference in the water levels of the weir with the energy absorber is 10-12 m, and the difference in water levels in the bypass underground tunnel is, on average, 30-40 m.

As you know, one of the main factors determining the efficiency of using a hydroelectric power source is the water flow's local energy potential. When choosing a rational location for mini-micro HPPs, one has to solve a complex problem related to determining the amount of energy that can be obtained using a given watercourse and its sufficiency to meet the needs of consumers; the pressure or height of the fall, which a given source of water has; volume flow and speed; pressure pipeline dimensions; distances and powers transmitted through power lines from the impeller to the generator and from the generator to consumers, the availability of an energy backup system and flow control systems, etc.

The main design parameters in determining the power and type of a mini-micro hydroelectric power plant are head and volume flow, respectively, the potential and kinetic components of hydropower.

Figure 4 shows the main positions of the water pressure levels in the reservoir w^s; at the entrance and exit of the bypass underground tunnel -t^1, t^2; and on the bed of the river Akhangaran-w^r.

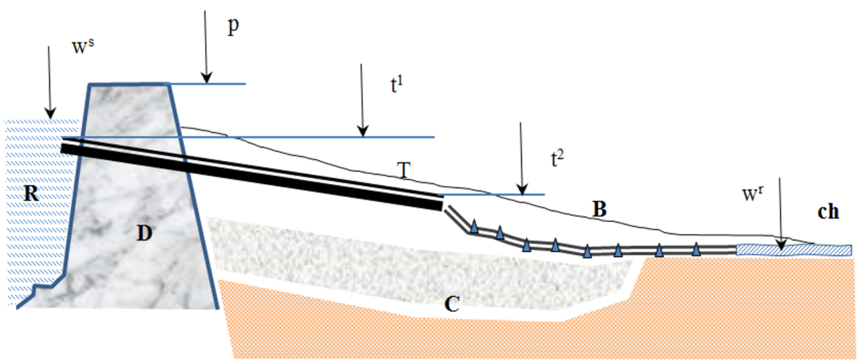

Fig. 4. Main positions of pressure levels of water of objects of study in GTS system of Angrenskaya open pit

where: w^s is the water level in the reservoir; t^1, t^2 are water levels at the inlet and outlet of the bypass underground tunnel, w^r is water level on the Akhangaran riverbed, p is dam level, R is reservoir, D is dam, C is coal pit, B is bypass channel, ch is old riverbed Akhangaran

Considering the above, a simplified calculation method can be applied to determine the hydropower parameters of the proposed energy-generating facilities in the available conditional nodes.

As an example, we can use the "calculations and selection of mini-micro HPPs" using the methodology proposed by the company - Weswen [7]:

In the presence of water pressure, the power of the hydroelectric power station can be determined from the expression

$$P = 9.81\eta \cdot Q \cdot H, \qquad \text{kW}$$

where P is power plant capacity; Q is water flow through a certain section, m^3/s; H is the head of water supplied to the hydraulic turbine, m; η is the Efficiency Factor of a hydroelectric power plant.

When determining the head, it is necessary to consider the total (static) head and the working (dynamic) head. The total head is the vertical distance between the top of the supply pipe (water intake mark) and the point where water is released from the turbine. The operating head is the total head minus pressure or hydraulic losses due to friction and turbulence in the pipeline. These losses depend on the type, material of the pipe, diameter, length of the pipe, number of bends, etc. To determine the actual power, it is recommended to calculate the working head «H».

$$H = H_{full} - H_{fric} - h_{add} \qquad m$$

where: H_{full} is full head, H_{fric} is friction losses in the conduit; h_{add} is additional or local losses associated with clogging of the water intake, bifurcation on constrictions and expansions, gate valves, valves, etc.
The magnitude of the pressure loss due to friction in the conduit can be determined by the expression:

$$H_{fric} = \mathrm{J} \cdot \mathrm{L} \qquad m$$

where J is the hydraulic gradient; L is the length of the conduit, m.
The following practical formula can be used to determine the hydraulic gradient:

$$\mathrm{J} = a \cdot \mathrm{V}^{m} \cdot \mathrm{D}^{n}$$

where V is the flow velocity, m; D is the diameter of the conduit, m; ***a, n, m*** are coefficients of the material from which the conduit is made (take into account the roughness of the wall surfaces and the protection of internal surfaces).
In water conduits of a closed type to calculate friction losses:
1. steel pipe 0.885 (a), 1.8 (n), 1.17 (m)
2. concrete pipe 0.917 (a), 2.0 (n), 1.25 (m)
In closed water conduits, it is recommended to use the Darcy-Weisbach equation to calculate friction losses:

$$H_{\mathrm{fric}} = f \cdot \frac{L}{4R} \cdot \frac{V^2}{2g} \qquad m$$

where: R is the hydraulic radius (in meters); V is the average flow velocity, m/s; f is dimensionless coefficient (given in hydrological tables, depending on the degree of roughness of the conduit and the Reynolds number).
Additional or local losses in the conduit are determined from the expression:

$$\mathrm{H}_{\mathrm{add}} = \varepsilon_x \frac{V^2}{2g} \qquad m$$

The values of the coefficient ε_x are given in the reference books of hydraulic resistance (losses at bends, narrowings, etc.).
When determining the capacity of a hydroelectric unit and designing a hydroelectric power plant, one should consider the region's climatic features and local legislation in the field of hydropower resources.
Projected HPPs are classified by power, MW: small up to 0.2; small up to 2 MW; average up to 20 MW; large over 20 MW and head, m: low-pressure up to 10 m; medium head up to 100 m; high-pressure over 100 m.
In addition, small hydroelectric power plants are divided into three groups based on water pressure: low-pressure - water pressure less than 20 m; medium-pressure - water pressure in the range of 20-75 m; high-pressure - water pressure exceeds 75 m.

Table 1 shows the average water flow pressure in the underground tunnel and in the water pressure absorbers of the water pressure energy of the bypass channel.

Table 1. Average calculated pressure indicators in the main power units of the bypass channel and bypass tunnel and calculated power capacities*

pressure Δh m, and node power N_e kW	Underground drainage tunnel	spillway tunnel node	Bypass channel energy dampenersa							
			first	second	third	fourth	fifth	sixth	seventh	eighth
Δh	30-40	10-12	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6
N_e	1500	500	250	250	250	250	250	250	250	250

**in calculations, η - the efficiency of the hydroelectric complex is taken in the order of 0.5*

It can be seen from the table that even with the values of the efficiency of the hydroelectric power station equal to 0.5 - rated power, all hydropower plants have significant energy resources that can be used as alternative energy sources for generating electricity. This issue is relevant along with other sources of alternative resources of a coal deposit [8-14].

In addition, the average annual water flow along the Akhangaran River was taken into account, considering the flow for the needs of the Angren TPP. Now, summing up the average potential new capacities, we get 6000.0 kW (i.e., 6.0 MW).

Calculations show that the energy potential of alternative energy sources is plentiful, and the energy of the pressure of the water flow is extinguished in vain by hydraulic waterworks and energy absorbers along the Akhangaran River.

The design and availability of technological capabilities of water-jet energy absorbers on the bypass channel allow us to consider these objects as hydropower facilities [15,16,1

Solving the problems of creating mini-cascades from small hydroelectric power plants allows you to create a unique system of hydraulic structures. This system can be considered a system of water jet energy absorbers and a system of small hydropower cascades.

In practice, many design and engineering companies are currently involved in designing and manufacturing various hydropower turbines for small and mini hydropower plants intended for a wide consumer market.

One of them is WESWEN, which offers hydro turbines from 3 kW to 1000 kW. The company can supply hydraulic turbines such as FRANCIS, TURGO, and KAPLAN. The main power ranges of hydraulic turbines are summarized in Table 2.

Table 2. Power capacities of micro HPPs of FRANCIS, TURGO, and KAPLAN firms [7]

Power of micro HPP with turbine, kW			
№	FRANCIS	TURGO	KAPLAN
1	3	3	5
2	5	5	
3	8	8	8
4	10	10	10
5	15	15	
6	20	20	
7	40		
8	100	100	
9	240	200	280
10	1000		

It can be seen from the table that FRANCIS hydraulic turbines are listed in ten items, TYURGO hydraulic turbines in eight items, and KAPLAN hydraulic turbines in only four items. According to the above calculations, for the objects under study - alternative energy sources- it is possible to offer hydraulic turbines with a capacity of 100 kW, 200 kW, 240 kW. The layout of the proposed hydraulic turbines during installation is based on the operating conditions and modes of operation of small, mini hydroelectric power plants and operational requirements.

Preliminarily, it is possible to recommend eight sources conventionally located in the sections of water-breaking energy absorbers, three 100 kW each, with one reserve, for the section of the drainage unit of the underground tunnel - three 240 kW, with one reserve. For a site located at the exit of an underground tunnel, it is appropriate to recommend four units: one with a capacity of 1000 kW and three with a capacity of 240 kW, with one standby. At the same time, some questions arise regarding the continuous provision of the rated power of the mini-CHP in cases of hydro turbine failure or shutdown for repair work and emergency cases. Therefore, it is acceptable to use hydro turbines with a capacity of 240 kW in the amount of 6 units and with two in reserve. Then a mini-hydro power plant can provide energy regularly with a rated power, and two units allow you to avoid large imbalances in energy production at the site.

Thus, in conclusion, it can be noted that the intended hydraulic structures at the Angren brown coal mine are of great importance in ensuring the functioning of coal mining processes and in the presence of sufficient reserves of alternative energy in certain sections of the system of hydraulic structures.

The total average design hydropower capacity of the considered sections is 6.0 MW, in particular, 1.5 MW, 0.5 MW, and six 0.25 MW each. Alternative energy sources distributed along the perimeter of the bypass channel are favorably reflected in the use of generated useful energy in the conditions of the development of this region since these territories are currently being developed and new production facilities are being created.

The positive side of the proposed idea in the difficult conditions of the operation of a coal mine is the use of sections of water-damping absorbers of water energy of the bypass channel as sources of alternative energy and the production of useful universal energy.

Implementing the proposed measures allows directing energy losses aimed at converting mechanical and thermal energy into useful electrical energy. In addition, in the future, to contribute to the development of alternative energy in Uzbekistan.

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