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Study of the variant of application of pressure type of derivation designed as a pipeline

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Abstract. Hydropower has become one of the most reliably functioning elements of the energy complex under the economic transformations taking place in Russia. Small hydropower has taken a stable position as a component of the energy sector in many countries of the world. Many small rivers in the Russian Federation form about half of the total volume of the country's river flow. Experts estimate the energy potential of Russia's small rivers at 380 billion kWh. Small hydropower plants have advantages, which make this equipment more and more popular. We note the environmental safety of mini hydropower plants - an important criterion considering environmental protection issues. Small hydropower plants have no harmful effect on the properties or quality of water. We can use water areas (where small hydroelectric power plants are installed) for both fishery activities and as a source of water supply for settlements. Small HPPs do not need large bodies of water to operate. They can operate using the energy of small rivers and even streams. The purpose of the article is to study the variant of application of pressure type of derivation designed as a pipeline.

1 Introduction

The Russian Federation has accumulated extensive experience in using hydropower resources of small rivers. In the 50-60s the country was at the forefront of the world in the construction of small hydropower plants. One of the most important economic factors is the renewability of hydropower resources. If we calculate the benefit of small hydropower plants, it turns out that such electricity is almost 4 times cheaper than electricity from thermal power plants. This is the reason power-consuming industries use HPPs more often today.

As for economic efficiency, both micro and mini hydroelectric power plants have many advantages. Plants designed with modern technology are easy to operate. Automated equipment does not require human presence. Mini hydropower plants can operate both autonomously and as a part of the power grid [1,2].

An effective direction for the development of SHPPs (small hydropower plants) is the reconstruction and rehabilitation of pre-existing ones. Subsequently decommissioned SHPPs, construction of SHPPs on existing reservoirs, which have overflows on canals, pipelines of water supply and diversion at the objects of various economic purposes, construction of SHPP under the construction of hydroelectric complexes [3].

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We determine the composition of structures, their design and layout, the number and type of main and auxiliary equipment based on the principles of integrated use of hydropower resources and environmental safety of operation of facilities.

Construction of small HPPs corresponds to three major schemes, which allow us to create a concentrated head: dam, derivative and combined schemes.

2 Research methodology

Natural, ecological and economic conditions, on the example of the studied section of the Halmeryu River, determine the variants of hydropower construction schemes.

Derivative hydropower plants are more often built in the upper and middle reaches of the rivers flowing in mountainous areas. Capital investments in such HPPs are small, and the duration of construction is short. The head of water supplied to the turbines of power plants depends on the peculiarities of the derivation facilities and amounts to several hundred meters [4].

The derivation scheme makes it possible to create a concentrated head by diverting water from the river into an artificial channel, which has a different route and slope than the natural channel.

Depending on the terrain and geological structure, derivation can be non-pressurized, pressurized, as well as a mixed type of non-pressurized and pressurized water body sections.

As the experience of designing small hydropower plants on the rivers of the North Caucasus and South Yakutia shows, the economically justified river gradient for diversions of tunnel type or as surface pressure pipelines is not less than 12-13 m/km. The river Halmeryu has relatively low water flow rates and slopes, for it we recommend a small HPP of derivative type.

We can determine the length of the diversion by the availability of convenient places for water intake, the routing of the diversion, the location of the small HPP building, and also by the possibilities of manufacturing and supplying the main hydro-power equipment [5].

When selecting the type of derivation, we consider the variant of pressure pipeline derivation as the main one. It ensures its operability and independence from laying conditions. This variant solves two problems related to engineering-hydrogeological conditions: prevention of filtration from the diversion route and protection against surface runoff, mudflows, and landslides.

The closed hermetic section of the derivation provides the greatest stability of the base of the derivation tract because of the absence of water leakage, giving pressure pipeline derivation advantages as compared to open-pipe derivation.

Collection of sediment in the sump, flushing and discharge of sediment in the downstream are in the structures of water intake hydroelectric complex to prevent abrasion of equipment and pressure pipes of small HPP derivation. The diversion structures of small HPPs ensure the flow of water taken from the Halmeryu River at the water intake facility to the station node [7,8].

The purpose of the study is to investigate the variant of application of the pressure type of derivation designed as a pipeline. Because of the presence of a small bend in the riverbed of the Halmeryu to the right side.

3 Results of the study

Construction works for laying of the small HPP derivation contain four stages: laying of the inspection road; excavation of the trench under the derivation pipeline; installation and backfilling of the derivation pipeline; installation of the station fork.

We carry out the laying by creating a 6.20 m wide horizontal terrace on the natural slope, where the cross slope of the land surface reaches 1:5. For the terrace profile, excavation of natural soils is carried out. Separate sections of the route require high-quality embankment fill works. The left terrace edge mainly requires backfilling.

Builders level and compact the terrace surface. The terrace surface is the basis for subsequent paving. The builders excavated a roadside ditch on the right side of the terrace. A 1:1.5 grade slope follows the ditch.

The road dressing is a gravel layer 130-200 m thick, compacted by rollers. The road bed has a one-sided cross slope of 0.02. The width of the roadbed is 3.50 m.

We have designed the pressure type of diversion as a pipeline. Because of the slight turn of the Halmeryu river channel to the right side, the pipeline is routed along the slope of the right bank of the river.

The designed diversion pressure pipeline comprises fiberglass pipes «Flowtech» [6] (Figure 1).

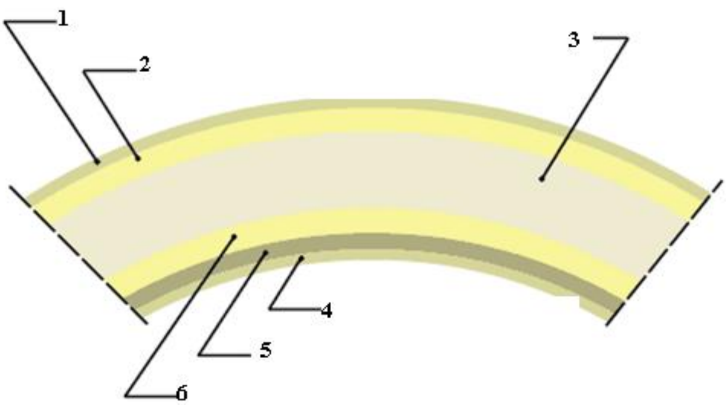

Fig. 1. «Flowtech» pipe structure (1 - outer surface; 2 - outer structural layer; 3 - core; 4 - inner coating; 5 - protective layer; 6 - outer structural layer).

The main loads of pressurized pipes, as for underground pipelines, are in the radial direction. Only the method of simultaneous reinforcement with continuous and chopped fiberglass strands allows us to achieve high-quality products and low cost [6].

Let's calculate the diameter and losses in the derivative pipeline.

We determine the diameter of the pipeline by applying the Formula 1:

$$D = \sqrt{\frac{4 \cdot Q}{\pi \cdot V}}; \tag{1}$$

where Q is the flow through the pipe, V is the velocity in the pipe.

Hydraulic losses ΔH are the sum of local head losses and friction losses along the length (2).

$$\Delta \mathrm{H} = h_l + h_{\mathrm{f}} \tag{2}$$

Formula 3 will help us determine the length loss in the derivation pipeline.

$$h_{\mathrm{l}} = \lambda \cdot \frac{l}{D} \cdot \frac{V^2}{2 \cdot g}; \tag{3}$$

where, D - pipe diameter, m, V - average velocity in the pipeline, m/s, l - pipeline length, λ - coefficient of friction resistance of a unit relative length depending on the roughness of the pipe walls, λ = 0.0102.

We accepted the grade of fiberglass pipes as PN4 (400 kN/m^2, 40 m/s) based on the value of the perceived internal pressure. We determined this grade based on the calculation of the actual maximum value of water pressure in the pipeline, considering the hydraulic impact occurring during transients at a small hydroelectric power plant. The wall thickness of the GRP pipeline is 20 mm. Figure 2 considers the structure of the «Flowtech» pipe [6].

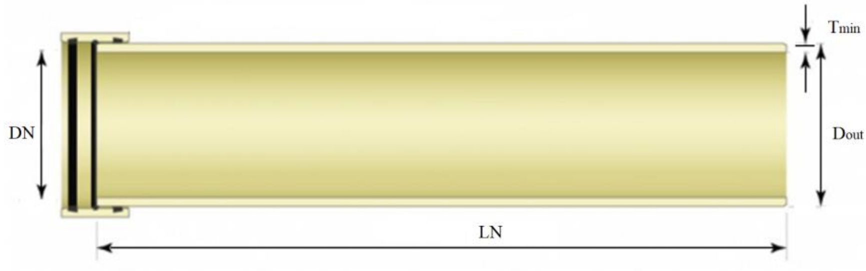

Fig. 2. «Flowtech» pipe structure (DN - nominal pipe diameter; LN - nominal pipe length; D_{out} - pipe outside diameter; T_{min} - minimum pipe wall thickness).

Each link is 6 m long. Fiberglass couplings connect the links.

Because of the possibility of longitudinal movement of the links in the couplings, the pipeline is of a continuous design. For 6.0 m long pipeline links with a diameter of 1.8 m, the maximum rotation at the joint between the links is 1.5°. Figure 3 shows «Flowtech» pipe coupling [6].

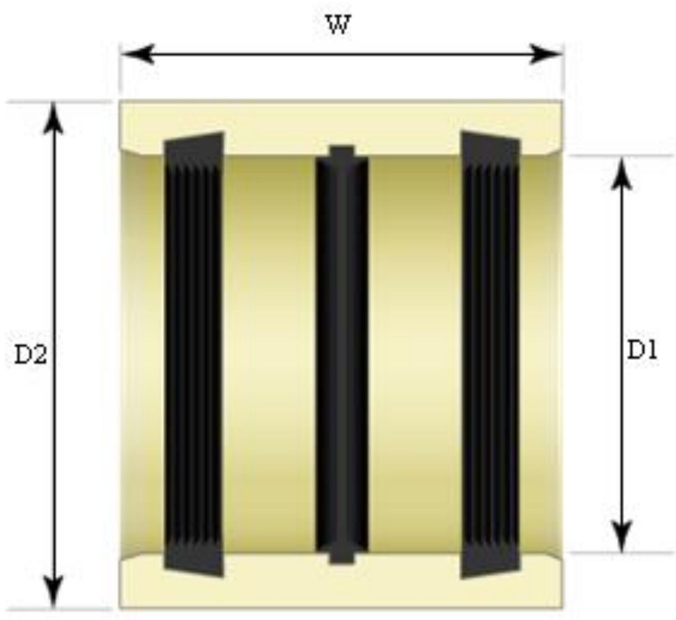

Fig. 3. «Flowtech» coupling (D1 - maximum inside diameter (D1 is the maximum inside diameter of the coupling, D2 is the maximum outside diameter of the coupling, W is the width of the coupling).

The middle of the coupling has a keeping ring, on the sides - sealing rings REKA made of EPDM rubber, or other material, depending on the type of transported liquid [6].

4 Discussion of results

There are no places of sharp turns and axis fractures because of the curvilinearity of the designed pipeline route. Considering the backfill of the pipeline, there is no need to install anchor supports, except fork near the building of the small hydroelectric power plant. The fork of the pipeline in front of the building of a small hydroelectric power station is of a cluster type with successive branches for each of the four hydroelectric units of a small hydroelectric power station. The workers concreted the pipeline at the junction of the branches. Figure 4 shows the scheme of the connection method of pipes with concrete [6].

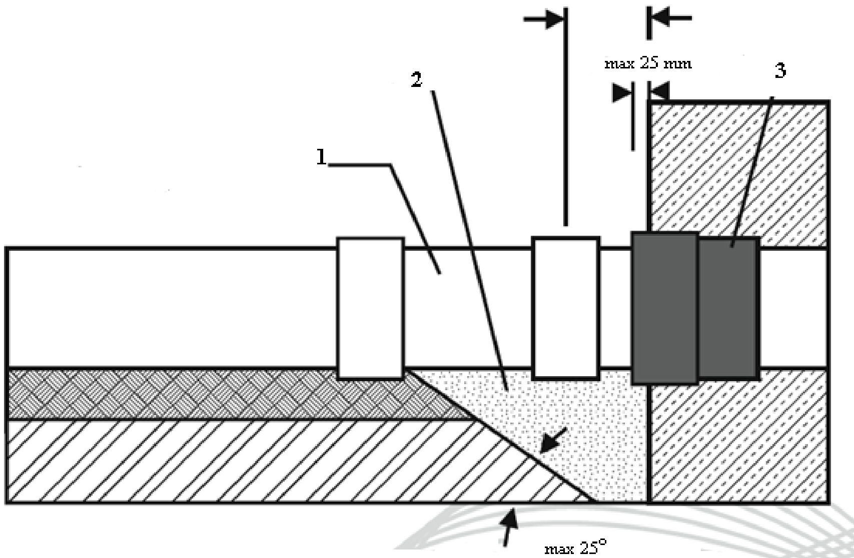

Fig. 4. Method of connecting the pipes to the concrete (1 - short pipe section (not over 2 m or 2 x DN, not less than 1 m 2 x DN); 2 - tamped backfill SC1 or SC2 (stabilized); 3 - elastomeric tape).

Laying of the pipeline under the bottom of this watercourse, with temporary drainage for the period of construction works, is envisaged in the area where the pipeline route crosses the channel of the left-bank tributary of the Halmeryu River. Reno mats, fixed at the crossing of the watercourse bed, prevent possible erosion of the backfill of the excavation [9,10].

5 Conclusion

Small HPPs are a complex of structures and equipment that provide power supply to various consumers, according to their requirements. Three major schemes of small HPP construction allow to create concentrated head: dam, derivative and combined ones.

Natural, environmental and economic conditions determine the variants of hydropower construction schemes.

When choosing the type of derivation, we consider the variant of pressure pipeline derivation as the main one. This type ensures its operability and independence from laying conditions. The aim of this study was to investigate a variant of application of pressure-type diversion designed as a pipeline made of fiberglass pipes «Flowtech». We carried out the study on the example of the Halmeryu river section.

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