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Energy-saving as an integral part of technical and economic efficiency

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Abstract

The technical and economic aspects of the pipeline rehabilitation of water supply systems by various methods are presented and the mechanism for choosing the optimal technology for the minimum energy costs is determined. Based on the results of the calculated data, it was found that the influence of resistivity has a decisive role in energy saving during water transportation through pipelines of a water supply system. In conclusion, as a criterion for evaluating energy saving when implementing trenchless methods for pipeline rehabilitation that retain structural integrity and residual strength.

Keywords: Pipeline, Rehabilitation, Water, Supply System, Trenchless.

Ahorro de energía como parte integral de la eficiencia técnica y económica

Resumen

Se presentan los aspectos técnicos y económicos de la rehabilitación de tuberías de los sistemas de suministro de agua mediante diversos métodos y se determina el mecanismo para elegir la tecnología óptima para los costos mínimos de energía. Con base en los resultados de los datos calculados, se encontró que la influencia de la

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resistividad tiene un papel decisivo en el ahorro de energía durante el transporte de agua a través de tuberías de un sistema de suministro de agua. En conclusión, como criterio para evaluar el ahorro de energía al implementar métodos sin zanjas para la rehabilitación de tuberías que conservan la integridad estructural y la resistencia residual.

Palabras clave: tubería, rehabilitación, agua, sistema de suministro, sin zanjas.

1. INTRODUCTION

In the practice of restoring pipelines of water supply systems, a large number of methods find application, the choice of which is made according to various criteria: technical, technological, cost, energy-saving, etc. Recently, when choosing the optimal method for pipeline rehabilitation, the most acute questions are related to energy conservation, as an integral part of technical and economic efficiency. When conducting a comprehensive analysis of the benefits of rehabilitation of pressure pipelines of water supply systems using trenchless methods, the calculation of technical and economic efficiency can be performed according to the following options (HRAMENKOV, 2005):

-Comparison with the laying of a new pipeline to replace the old one in an open way (with earthworks);

-Changing (increasing) the capacity of the rehabilitated pipeline compared to the old one;

-Reducing the cost of energy consumption for water supply (OTSTAVNOV, USTYUGOV & PRIMIN, 2010);

-Decrease in the real volume of leaks (hidden water consumption) on water supply networks due to the exclusion from consideration of problems associated with exfiltration (ORLOV, 2009);

-Comparison with laying a new backup pipeline and treating the existing pipeline.

A comprehensive analysis of the advantages of trenchless rehabilitation of pipeline water supply systems in terms of technical and economic efficiency can be carried out according to the following options (PRIMIN & HRAMENKOV, 2003):

-Comparison with the laying of a new pipeline to replace the old open method (using earthworks);

-Changing (increasing) the capacity of the rehabilitated pipeline compared to the old one;

-Reducing the cost of energy consumption for water supply (SHEVELEV & SHEVELEV, 1984);

-Decrease in the real volume of leaks (hidden water consumption) on water supply networks due to the exclusion from consideration of problems associated with exfiltration (HRAMENKOV, PRIMIN & ORLOV, 2008);

-Comparison with laying a new backup pipeline and cleaning the existing pipeline (DOBROMYSLOV, 2005).

2. METHODOLOGY

Calculation of the effectiveness of rehabilitation work on utility networks to actually reduce the cost of electricity for water supply is a very difficult task in the conditions of an extended and extensive pipeline network of the city. The reason is that after changing the hydraulic resistance in certain sections of the network where work was done to restore it, the direction of flows may change. In this case, it becomes difficult to prove the real effect of rehabilitation work (ORLOV, 2010). In addition, during the rehabilitation of network sections, obvious jumps in changes in pressure or flow at pumping stations are not always noticeable, and the estimated pressure growth in network nodes can be smoothed out due to increased costs in nodes (ensuring growth is also the effect of rehabilitation work), but it is very difficult to measure and prove its presence (BASS, 1977; SOMOV, 1988).

The following path is proposed to determine the actual effect of the engineering facilities rehabilitation by trenchless methods. It is based on the determination of energy savings during water transportation through a rehabilitated pipeline compared to the old one with constant flow parameters along the line before and after repair and rehabilitation works (HRAMENKOV, PRIMIN & ORLOV, 2002).

The annual energy savings ΔE (kW • h) due to the reduction of hydraulic resistance after operations to restore the pipeline and, consequently, the reduction of pressure losses along the length of the pipeline, is determined by the following basic formula (1.1):

$$\Delta Э = \frac{\rho g Q \Delta H}{1000 \cdot \eta_{нас.} \cdot \eta_{двиг.}} \cdot 24 \cdot 365 \ \left[\frac{кг \cdot м^2}{с^3} \cdot ч = кВт \cdot ч \right] \qquad (1.1)$$

where ρ is the fluid density, kg/m^3; g is the acceleration of gravity, m/s^2; Q - flow rate of water supplied by the pipeline, m^3/s; ηn., and ηmot. - efficiency factors respectively of the pump and electric motor; 24 - the number of operation hours of the pump per day, h; 365 - the number of days in a year; 1000 is the conversion factor from W to kW.

ΔH - reduction of pressure losses along the length of the pipeline, m water column (1.2):

$$\Delta H = Hold - Hnew \qquad (1.2)$$

where H1 and H2 are the pressure losses in the pipeline before recovery (old pipeline) and after recovery, m w.c. In the case of water transportation, i.e. with values ρ = 1000 kg/m^3, g = 9.81 m/s^2 and mathematical operations of transformation, formula (1.1) will be transformed into formula (1.3):

$$\Delta Э = \frac{9{,}81 \cdot Q \Delta H}{\eta_{нас.} \cdot \eta_{двиг.}} \cdot 24 \cdot 365 \qquad (1.3)$$

For the purpose of the universality of the approach to determining economic parameters, the concept of annual energy saving per unit length of the pipeline ΔE1m should be introduced. In this case, the pressure loss H1 and H2 will be calculated per unit length of the pipeline, i.e. on 1 m. The form of the general formulas for determining the pressure loss through the specific hydraulic resistance will be as follows:

Hold = Aold·l·Q2 (1.4)

Hnew= **A**new·l·Q2 (1.5)

where l is the length of the pipeline (according to the conditions of the problem 1 m); Aold and Anew - respectively, the resistance coefficients of the old and new pipelines, s2/m6; Q - flow rate of transported water, m^3/s.

Taking into account the unit length, the formulas (1.4 and 1.5) are transformed to the form (1.6 and 1.7):

Hold= Aold·Q2 (1.6)

Hnew = Anew·Q2 (1.7)

Substituting formulas (1.6 and 5.7) into (1.3) and making the transformations, by outlining the square of the flow rate Q2, we obtain the basic formula for determining the annual energy savings per unit length of the old pipeline after its rehabilitation (1.8):

$$\Delta Э_{1м} = \frac{9,81 \cdot Q^3 (A_{стар.} - A_{нов.})}{\eta_{нас.} \cdot \eta_{двиг.}} \cdot 24 \cdot 365 \quad (1.8)$$

3. RESULTS AND DISCUSSION

The following is a calculation of energy savings after the rehabilitation of old steel water pipelines with internal diameters of 800, 600, 400 and 200 mm, which allow flow rates of 0.51, 0.296, 0.132 and 0.034 m^3/s, respectively, which in turn corresponds to the flow rate of water in steel pipelines 1.0 m/s for the entire range of diameters listed in two ways:

- The technology of pulling a plastic pipe deformed in the profile;
- Applying a cement-sand coating by centrifugal spraying.

The calculation of the annual energy saving ΔE1m (kW•h) per unit length of the pipeline was calculated according to formula (1.8). The calculation results are presented in summary table 1.

Table 1: Summary calculated data on annual energy savings ΔE1m depending on the trenchless rehabilitation method and pipeline diameter

Rehabilitation method	Old pipeline's inner diameter, m	Value of ΔE_{1m}, kW·h
Pulling a deformed polymer pipe	1,0	68,7426
	0,8	49,3853
	0,6	38,4467
	0,4	20,6902
	0,2	2,9214
Cement-sand coating	1,0	60,3373
	0,8	50,3047
	0,6	42,1841
	0,4	27,5611
	0,2	13,8871

Based on the data in Table 5.2, for greater clarity, as well as to identify and describe the mathematical dependence of the annual energy savings ΔE1m per unit length of the pipeline on the diameter d, i.e. ΔE1m = f (d), graphs are plotted (Figure 1.).

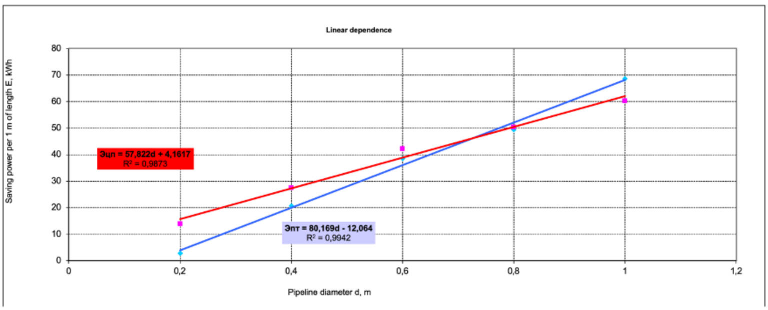

Fig.1: Graphs of the dependence of annual energy savings per unit length of the pipeline on the diameter:

CSC - for the case of cement-sand coating;

PPP - for the case of pulling a polyethylene pipe.

An analysis of the two graphs obtained in Figure 1 indicates the identical linear nature of the dependences of annual energy savings per unit length of the pipeline on the diameter. Moreover, the larger the diameter of the rehabilitated pipeline, the greater the economic effect can be achieved as a result of recovery, regardless of the method. Given various values of the diameters d of the pipeline to be rehabilitated, the obtained dependences CSC = 57.822 d + 4.1617 and PPP = 80.169d-12.064 can be used for a rough estimate of the economic effect when implementing the corresponding trenchless pipeline rehabilitation technologies. A detailed analysis of the curves presented in Fig. 1 suggests the following characteristic conclusions:

- On large diameters, i.e. more than 800 mm with the corresponding pipeline defects, it is more economical to apply the technology of pulling deformed polyethylene pipes into the old pipeline, and for smaller 600 mm - apply a cement-sand coating by centrifugal spraying;

- When restoring an old pipeline with a diameter of about 700 mm, the annual energy savings per unit length of the pipeline are almost the same for two trenchless technologies.

4. CONCLUSIONS

Mathematical dependencies are given and substantiated, which make it possible to perform feasibility calculations, which are based on the determination of the electricity cost for water supply and its savings when implementing trenchless technologies for water pipelines rehabilitation. As a criterion for evaluating energy saving when implementing trenchless methods for the pipeline rehabilitation that retain structural integrity and residual strength, as well as for the universality of the approach to determining the economic parameters of rehabilitation, the concept of annual energy savings per unit length of the pipeline ΔE1m is introduced and specific examples are calculated and the values of this parameter are compared for various pipeline rehabilitation technologies.

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