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Technological report of main oil pipelines under conditions of uncertainty of information

Aminaga SADIGOV, Ramin ZEYNALOV*
Institute of Control Systems, Baku, Azerbaijan
**Corresponding author.* E-mail: raminz.math@gmail.com

Abstract. In the work, the factors affecting the effective operation of main pipelines were investigated and a method was developed that allows to analytically assess the pressure losses spent on friction, taking into account the characteristics manifested in the given pipeline section for each time interval in conditions of information uncertainty.

Keywords: *main oil pipeline; coefficient of hydraulic resistance; volume consumption; interval arithmetic*

1. INTRODUCTION

Effective management of the main oil pipelines requires the solution of many related issues, one of which is distinguished by its importance is the issues related to the involvement in the comprehensive study of the characteristics of oil flow conditions in the pipeline during the transportation process. So far, a lot of research works have been carried out in this direction, the factors affecting the process of transportation of oil through pipelines have been considered, and along with the clarification of the mechanism of influence of these factors, it has been tried to determine the features of their influence on the technological indicators of the transportation process. Let's focus on some of these studies.

It has been established that the modern stage of development and exploitation of oil and gas fields is characterized by a deterioration in the structure of produced and pumped hydrocarbons [1]. As well as the cessation of the operation of industrial technological pipelines due to the occurrence of accidents not only leads to the loss of gas, oil and oil products, but also leads to an increase in the cost of repair and restoration work, which regularly leads to large economic costs [2,3]. In this regard, the rheological properties of high-viscosity oil before and after heat treatment were studied, and the effect of heat treatment of non-Newtonian oil on hydraulic losses in the main oil pipeline was determined [4].

The article [5] presents a brief analysis of the world experience of theoretical and experimental research in the field of increasing the throughput of the pipeline by reducing hydraulic resistance in the pipeline and methods aimed at reducing hydraulic friction losses in main oil pipelines in order to identify the main factors affecting the process of oil transportation by pipeline. Thus, a new method for reducing hydrodynamic friction losses in the pipeline was put forward by analytical research in the work. It has been established that in order to reduce the loss of hydraulic friction in the pipeline, it is necessary to develop recommendations for designing a spiral channel in the pipe in order to increase the efficiency of using vortex flow.

[6] in his work, it was noted that there is a need to develop theoretical foundations for effective management of the work of main oil pipelines. In full connection with this, [7] the effective management of a modern industrial company engaged in oil transportation in its work should be based on a scientifically substantiated, most accurate assessment of the production system in real time. Increasing the throughput of oil pipelines using Turbulent additives is the most economical and effective way today. However, the use of modern models, dependencies and research results to determine pressure losses in oil pipelines during the use of turbulent additives at real facilities leads to significant deviations from

actual prices. To solve this problem, it is proposed to use simulation based on machine learning models

At the same time, it has been established that cavitation effects have a significant impact on the technical and technological processes occurring in various systems, including the operation of pipelines. Thus, the flow regimes that allow the formation of cavitation in such systems lead to a violation of the general structure of the flow, which leads to the appearance of certain difficulties in the behavior of the system [8].

[9] The article notes that recently the frequency of low-probability events and their destructive power have increased dramatically. This is due to the fact that the number of natural and man-made disasters, financial and economic crises is gradually increasing sharply. Events that cause such situations are usually those that, as a result of small continuous impacts on the system, can cause sudden breakthrough changes in it. However, taking into account the fact that traditional methods for predicting the behavior of such systems are not effective enough, the work investigated the issues of high sensitivity to the initial conditions characterizing the state of the system against asymmetric threats, the possibility of a small violation leading to unforeseen technical, technological, economic, environmental and other consequences.

The problems of development of mathematical models of automated control systems and information technologies applied in connection with the elimination of complexities occurring in the work of main pipelines are considered to be of relevance both from a theoretical and practical point of view [10,11].

The above points make it necessary to continue research to improve the efficiency of technological calculations carried out taking into account the factors affecting the functioning of main oil pipelines, and as one of such research directions, consideration of the points related to the fact that some physical parameters used in making calculations cannot adequately correctly express the process can act.

2. ASSESSMENT OF HYDRAULIC LOSSES IN THE TECHNOLOGICAL CALCULATION OF OIL PIPELINES

It is known that the technological report in the design of oil pipelines provides for a complex of calculations describing the technological processes observed during the transportation of oil and oil products. These calculations, fundamentally, determine the cost-effective parameters of the belt (the diameter of the belt, the pressure at the pumping stations, the thickness of the wall of the Belt and the number of pumping stations, etc.).), is performed based on a complex of methods that allow solving such significant issues as determining the location of pumping stations in the pipeline and the mode of operation of the pipeline.

In order to make these calculations, it is required to give sufficiently certain values of such parameters as pipeline capacity (annual volume of oil transported), temperature dependence of oil viscosity and density, temperature at the depth at which the pipeline passes; mechanical properties and necessary technical and economic indicators of the pipe material. In addition, a drawing of the profile of the oil pipeline line, taking into account the relief features of the earth, should also be built. In addition, calculations on increasing the reliability of pipelines are of particular importance. Increasing the reliability of pipelines has an important role in ensuring uninterrupted accident-free operation of the transportation process. At the same time, the solution to the issue of increasing the reliability of pipelines should be aimed primarily at preventing damage to the environment caused by leakage of transported oil from the pipeline. In this regard, in ensuring the reliability of pipelines, to a greater extent, attention should be paid to the mechanical strength of the material of the pipeline, strict compliance with technical requirements and technological rules, and the good quality of the welding places. The mentioned factors directly express themselves in connection with the hydraulic calculation features of the belt during the transportation process.

Such calculations make it possible to predict pressure losses along the pipeline performing a hydraulic calculation of the main oil pipeline.

The average speed of movement of oil in the oil pipeline is found as follows:

$$V = \frac{4Q}{\pi D^2}, \tag{1}$$

where Q and D accordingly is the volume consumption of oil and the diameter of the pipe.

The loss of pressure spent on friction in a circular cross-section pipe is determined by The Darcy-Weisbach formula:

$$h = \lambda \frac{L}{D} \frac{V^2}{2g} \tag{2}$$

or taking into account (1)

$$h = \lambda \frac{8LQ^2}{g\pi^2 D^5}, \tag{3}$$

where λ - the coefficient of hydraulic resistance; g - is the momentum of free fall.

The coefficient of hydraulic resistance is set depending on the mode of flow. The flow regime is characterized by the Reynolds number (Re), which is defined as follows:

$$Re = \frac{VD}{\nu} = \frac{4Q}{\pi D \nu} \tag{4}$$

where ν -is the kinematic viscosity of oil.

In the case of laminar flow mode, the hydraulics coefficient of resistance is defined as $\lambda = \frac{64}{Re}$ and this mode manifests itself when $Re < 2300$. When $Re > 2300$ the turbulent flow regime is observed. In this interval of variation of the Reynolds number, the hydraulics coefficient of resistance is manifested in the variation zone, which has 3 types of characteristics: 1. Smooth friction zone: $\lambda = f(Re)$, 2300< $Re < Re_1$ ($Re_1 = \frac{10}{\varepsilon}$; ε -coefficient of ruggedness); 2. Mixed friction zone: $\lambda = f(Re, \varepsilon)$, $Re_1 < Re$ $< Re_2$ ($Re_2 = \frac{500}{\varepsilon}$); 3. Quadratic friction zone: $\lambda = f(\varepsilon)$, $Re_2 < Re$. The calculation formula for the coefficient of hydraulic resistance on the smooth friction zone: $\lambda = \frac{0{,}3164}{Re^{0{,}25}}$, for the mixed friction zone: $\lambda = 0{,}11\left(\frac{68}{Re} + \varepsilon\right)^{0{,}25}$, on the quadratic friction zone $\lambda = 0{,}1\varepsilon^{0{,}25}$.

3. ASSESSMENT OF HYDRAULIC PRESSURE LOSS TAKING INTO ACCOUNT INFORMATION UNCERTAINTY

Based on the mathematical relationships presented, it is possible to calculate the loss of pressure spent on hydraulic friction during the flow of oil in the oil pipeline by selecting the coefficient of hydraulic resistance in the above-mentioned forms, using the formulas (3) and (4). However, practice shows that usually the volume consumption of the belt can obtain variable values of different intervals for certain time intervals (Figure 1).

It should be noted that the change in the volume consumption of the belt in such dynamics may be due, first of all, to the occurrence of different nature and non-stationary nature situations occurring within the belt at each time interval. These circumstances, of course, first of all had an impact on the physical properties of the oil, as well as on the kinematic viscosity of the oil included in the calculation formulas. Under such conditions, uncertainties may occur due to the variability of the kinematic viscosity of the oil in the estimation of hydraulic resistance coefficients based on flow regimes when calculating pressure pressure losses. As a result, it can be assumed that when calculating the pressure pressure loss - it is advisable to include the hydraulic resistance coefficient λ in the form of an interval $[\lambda_1, \lambda_2]$. In general, it can be assumed that the increase in oil consumption in a certain period of time may be due to a decrease in oil viscosity, and a decrease in the coefficient of hydraulic resistance in this case can be observed due to the fact that the Reynolds number is inversely proportional to the kinematic viscosity of the oil. Therefore, as an interval $[\lambda_1, \lambda_2]$ for each time interval, interval values for the opposite dynamics can be taken in accordance with the nature of the dynamics described in Figure 1 of the indicator expressing oil volume consumption (Figure 2).

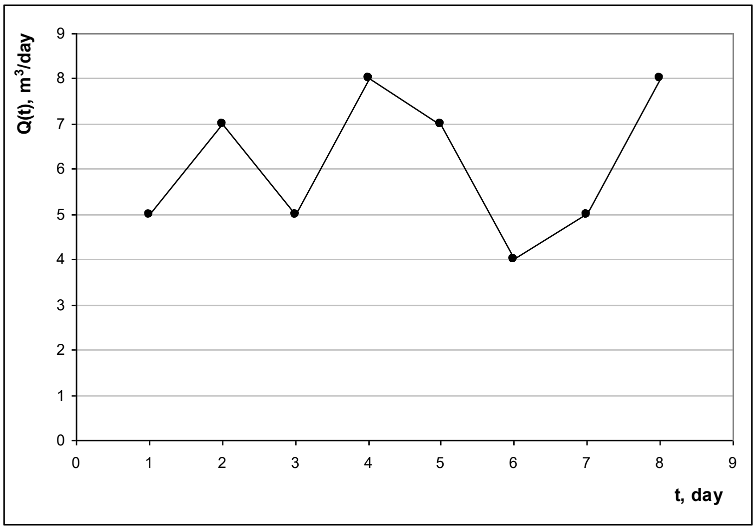

Fig. 1. Change of oil pipeline volume consumption in time

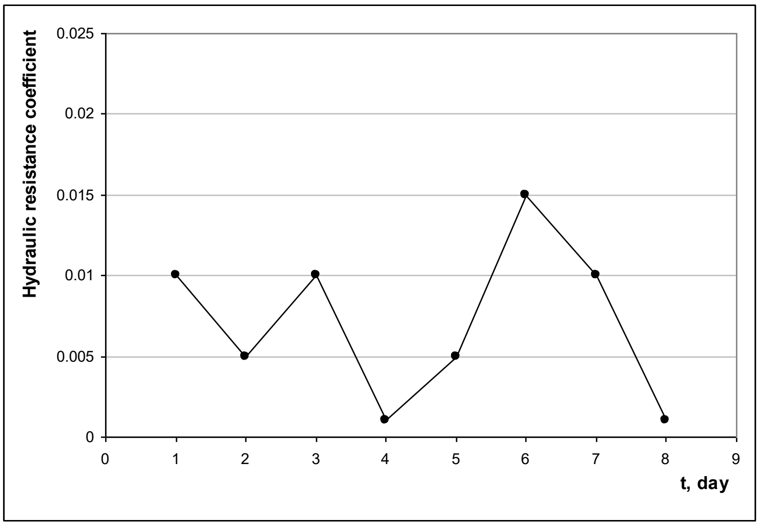

Fig. 2. Change of hydraulic resistance coefficient in time

Thus, based on the given dynamics, the calculation of the loss of hydraulic pressure during the flow of oil can be carried out according to the Formula (3) and the geometry of the intervals by the following formula [12]:

$$h_i = [\lambda_{1i}, \lambda_{2i}] \frac{8L \times [Q_{1i}, Q_{2i}] \times [Q_{1i}, Q_{2i}]}{g\pi^2 D^5},$$

where

$$[Q_{1i}, Q_{2i}]\times[Q_{1i}, Q_{2i}] = [\min\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\}, \max\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\}],$$

$$[\lambda_1, \lambda_2]\times[Q_1, Q_2]\times[Q_1, Q_2] = [\min\{\lambda_{1i}\min\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\},$$
$$\lambda_{1i}\max\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\}, \lambda_{2i}\min\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\}, \lambda_{2i}\max\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\}\},$$
$$\max\{\lambda_{1i}\min\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\}, \lambda_{1i}\max\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\}, \lambda_{2i}\min\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\},$$
$$\lambda_{2i}\max\{Q_{1i}^2, Q_{1i}Q_{2i}, Q_{2i}^2\}\}] \equiv A_i$$

λ_{1i} and λ_{2i}, Q_{1i} and Q_{2i} - accordingly to hydraulic friction coefficient and volume of oil are the starting and final values for each time interval of consumption.

Thus, in conditions of information uncertainty, the following formula is proposed, which allows you to estimate the pressure losses spent on friction, taking into account the characteristics that manifest themselves in a given pipeline section for each time interval:

$$h_i = \frac{8LA_i}{g\pi^2 D^5}.$$

4. CONCLUSION

In the work, the factors affecting the effective operation of main oil pipelines were investigated and a method was developed that allows calculating the pressure losses spent on friction, taking into account the characteristics manifested in the given pipeline section for each time interval in conditions of information uncertainty. Calculations carried out with the help of the developed method can effectively assess the performance of main oil pipelines and, on this basis, increase the reliability of operational control over the technical characteristics of the pipeline.

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