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Two-phase Flow in Pipes Calculation of Transportation Capacity

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ABSTRACT: This article presents the general concept of two-phase liquid flows, types of two-phase flows, basic definitions, terminology and characteristics, the problem of transporting two-phase liquids and ways to solve them.

I. INTRODUCTION

A characteristic feature of two-phase flows is the pressure pulsation in the pipe. This leads to disruption of the normal operation of pumping equipment, tools, etc.

Also, under the conditions of real operation of pipes transferred from the Earth's field, the forces of gravity, together with the forces of friction, affect the gas-liquid flow. As a result, the liquid phase accumulates in the elevated parts, and the gas phase accumulates in the descending parts of the pipeline track. For example, during the operation of the pipe system, complications arise due to a decrease in the flow area or complete clogging of the pipes as a result of the accumulation of stable gas probes and liquid (water or condensate).

II. METHODOLOGY

The oil pumped through the trunk pipelines almost always contains dissolved petroleum gases, which can accumulate in local compounds of the gas released from the liquid when the pressure drops.

In addition, the formation of water plugs associated with the driving of oil with the addition of water in oil pipelines is possible. The accumulation of water and gas reduces the working cross section of the pipes and increases their hydraulic resistance.

Similar difficulties arise when transporting unstable liquids through pipelines, especially in winter or during the start-up period.

The presence of moisture in the composition of the product being transported during the operation of gas pipelines also makes it difficult for them to function normally, in addition to increasing the corrosion of hydrogen sulfide, it causes various operational complications. Water vapor can thicken, disrupting the normal flow of gas through the pipeline.

In the horizontal and descending sections of the track, the liquid moves along the pipe walls in the form of a film. The presence of a liquid film significantly increases the hydraulic resistance of the gas flow. The largest amount of liquid accumulates in the elevated parts of the gas pipeline, forming a hydraulic seal, partially or completely covering the pipeline.

In addition, the presence of the former hydrate (gas, condensate) and free water (liquid water, ice, water dispersed in the volume of gas or liquid hydrate, water film on the surface of the pipeline, etc.) under appropriate temperature and pressure conditions contributes to the formation of hydrates. These reasons lead to a decrease in hydraulic resistance and hydrostatic pressure.

It is clear that the presence of operational complications in the use of pipelines has a negative effect on their hydrodynamic regimes, which is especially common in the current operating conditions of pipeline transport facilities, at pressures lower than the designed pressure.

Therefore, in order to reduce energy costs for transport, in particular, the effect of the multi-phase nature of the transport and the convenient presence of operational complications, the implementation of effective operational control and management of pumping modes in pipeline sections. need

To solve this problem, first of all, methods of mathematical modeling of processes in the pipeline system and parametric analysis of hydrodynamic quantities, description of the behavior of hydrocarbon mixtures in the pipeline system taking into account the above-mentioned characteristics of their operation, and secondly, the use of modern methods of information monitoring of hydrocarbon pumping modes possible through

III. RESULTS AND DISCUSSION

The final goal of the general study of two-phase flows from an engineering point of view is to determine the characteristics of heat transfer and pressure losses. These problematic issues can be solved satisfactorily only with respect to a certain structure, together with experimental and theoretical methods. Therefore, knowing the structure of a two-phase flow is as important as knowing whether a single-phase flow is laminar or turbulent.

K. A. Rakhmatullin, F. I. Frankl, G. I. Barenblatt, V. M. Makkaveyev, M. A. Velikanov, A. V. Karaushev, I. I. Levi, Yu. A. Buyevich, A. N. Krayko, D. F. Fayzullayev, K. Sh. Latipov, S. I. Kril, A. I. Umarov, A. A. Shakirov. , A.M. Arifjanov, S. Sou, G. Wallis, A. Fortye and others made a great contribution to the creation of a mathematical model of two-phase flows.

Due to the complexity of the processes that occur during the hydraulic transportation of solid materials through horizontal pipes, theoretical works on the distribution of the concentration of solid particles along the vertical diameter of the pipe are very limited. It is very difficult to study the process of hydrotransport of solid materials in order to distribute the calculation dependences noted in the scientific works of scientists [1,2,7,8] equally to the flow depth.

The analysis of existing formulas for determining the main parameters of hydraulic conductivity shows that the specific hydraulic resistance is determined by many researchers based on the specific hydraulic resistance in a uniform fluid flow, taking into account corrections based on experimental data and specific physical conditions. Thus, the calculated dependencies differ in their composition and often do not take into account the relationship of hydraulic resistance with the kinematic structure of the gravity flow. As for the important hydraulic transport rate formulas, they are usually empirical.

$$\left.\begin{array}{l} f_n\dfrac{\partial p}{\partial z}=\dfrac{\mu_n}{r}\dfrac{\partial}{r}\left(rf_n\dfrac{\partial u_n}{\partial r}\right)+\dfrac{\mu_n}{r^2}\dfrac{\partial}{\partial\varphi}\left(f_n\dfrac{\partial u_n}{\partial\varphi}\right)+K\left(u_{2n}-u_n\right)+\rho_nF_n \\ f_n\dfrac{\partial p}{\partial r}=0 \\ f_n\dfrac{\partial p}{\partial\varphi}=0 \end{array}\right\} \qquad (1.1)$$

From equation (1.1) [3,4,5,6] for a one-dimensional steady drag flow, we have:

$$\frac{dP}{dz}=\rho gi-\frac{\lambda_{см}\rho Q^2}{2d\omega^2}-\frac{s\pi d}{\omega}\tau_0 \qquad (1.2)$$

When deriving the equation of motion, the following signs were adopted for the density and velocity of the hydro-mixture:

$$\rho = (1-s)\rho_1 + s\rho_2 \tag{1.3}$$

$$\vartheta = \frac{(1-s)\rho_1\vartheta_1 + s\rho_2\vartheta_2}{(1-s)\rho_1 + s\rho_2} \tag{1.4}$$

Here: s is the volume concentration of the solid component; ρ_1 and ρ_2 liquid and density of solid particles; Q - consumption of hydromixing; ω - cross-sectional area of the pipe; ϑ_1 and ϑ_2 - average velocities of liquid and solid particles along the pipe cross-section; i- stream slope; P- hydrodynamic stress, pressure; χ – pipe perimeter; τ_0 - initial resistance of the mixture; λ_{mix} is the coefficient of hydraulic friction of the mixture.

Taking equation (1.2) into account for the boundary conditions (at z=0 P=P_1 and z=L, p =P_2), we get:

$$\frac{\lambda_{\text{см}}\rho}{2d\omega^2}Q^2 = \frac{P_2 - P_1}{L} + \rho g i - \frac{s\pi d}{\omega}\tau_0 \tag{1.5}$$

Current consumption is determined by the following expression:

$$Q = \sqrt{\frac{2d\omega^2}{\lambda_{\text{см}}\rho}\left(\frac{P_1 - P_2}{L} + \rho g i - \frac{s\pi d}{\omega}\tau_0\right)} \tag{1.6}$$

Here: P_1–P_2=ΔP is the pressure drop created by the pumping system taking into account $i=0$:

$$Q = \sqrt{\frac{2d\omega^2}{\lambda_{\text{см}}\rho}\left(\frac{\Delta P}{L} - \frac{s\pi d}{\omega}\tau_0\right)} \tag{1.7}$$

The state in which the action of the mixture begins is written in the following form:

$$\frac{P_1 - P_2}{L} > \frac{s}{R}\tau_0 \tag{1.8}$$

Thus, it is necessary to create a pressure difference ΔP that exceeds the value $(s/R)\tau_0$.

For this case, that is. For drag flow in negatively sloped pipes, we get:

$$Q = \sqrt{\frac{2d\omega^2}{\lambda_{\text{см}}\rho}\left(\frac{P_1 - P_2}{L} - \rho g i - \frac{s\pi d}{\omega}\tau_0\right)} \tag{1.9}$$

Then, the state at which the mixture begins to move is written in the following form:

$$\frac{P_1 - P_2}{L} > \rho g i + \frac{s}{R}\tau_0 \tag{1.10}$$

The peculiarity of the approach is that, in addition to the main factors characterizing the movement of the drag flow, the influence of the pipe slope is also taken into account:

$$\Delta P > \rho g i + \frac{s}{R}\tau_0 . \qquad (1.11)$$

Thus, the single-speed model of the movement of the mixture is used as a mathematical model, i.e. hydromixture in its movement is determined by an imaginary one-speed constant of variable density.

IV. CONCLUSION

In conclusion, it can be said that the calculated resistances recommended by many researchers to determine the main parameters of hydrotransport often represent the results of the experiments in which they were determined, and therefore the areas of application of these relationships are very limited.

Based on the model of H.A. Rakhmatullin, K.Sh. Latipov, A. Arifzhanov and other scientists are further developed in their scientific work, a model of the movement of a two-phase mixture in a circular cylindrical pipe is proposed, taking into account the flow gradient. That is, it is a one-speed model of mixture motion, that is, the liquid mixture in its motion is defined by an imaginary one-speed constant of variable density.

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