Non-stationary operation of gas pipeline based on selections of travel

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Abstract. A technique for calculating the nonstationary regime for the movement of natural gas along a multi-stranded gas main with allowance for travel selections is proposed. On the total flow of transported gas, gas flows are determined at all sections of the pipeline, taking into account the pressure in the controlled areas. When compiling the calculation formula for ф non-stationary mode, the formulas for calculating travel selections were used. .

1. Purpose of study

In the operation of gas mains, the flow of natural gas is carried out in a single hydraulic mode, which is achieved by equalizing the gas pressure at the crane sites, inputs and outputs of compressor stations. Therefore, when determining the regime parameters, it is necessary to calculate the flow of natural gas in parallel sections of the pipeline, taking into account the stationary and non-stationary conditions.

The calculation of engineering networks by common methods is presented in the Code of Regulations for the design and construction of SR 42-101-2003 [1]. There are numerical solution methods based on the construction of iterative algorithms. The construction of the algorithm with the help of a mathematical model leads to the solution of the task of controlling the operation of the pipeline, taking into account nonstationarity [2].

2. Carrying out the research

During operation of the main gas pipeline, a non-stationary non-isometric flow of natural gas, characterized by the equation for section X_{12} is:

$$P_{11}^2 - P_{12}^2 = G_{12}^2 c_{12} x_{12} \tag{1}$$

where c_{12} is the coefficient determined by the parameters of the transported natural gas and the gas pipeline, formulas for calculation are given in [3-5]. Fig. 1 shows the operation of two parallel gas pipelines.
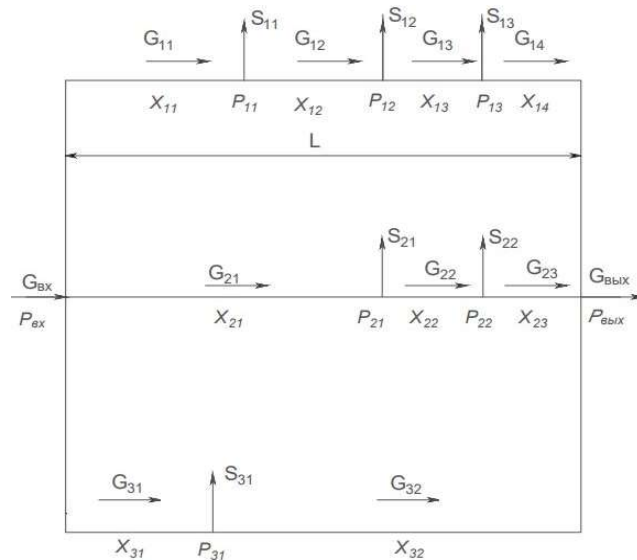
Figure 1. A scheme of operation of two parallel gas pipelines

where i - the number of the pipeline; j - plot number; S_{ij} - travel selections; X_{ij} - distance of linear sections between trackings; P_{ij} - gas pressure in the gas pipeline; G_{ij} - gas flows.

Using equation (1), unknown gas parameters are determined and a new value of the coefficient is found. The iterative process is repeated until the required calculation accuracy is achieved [6, 7, 8].

To calculate the operation of parallel gas pipelines, it is necessary to determine the gas flows at all sections of the pipeline, the pressure at the points under investigation at a known pressure and gas flow at the gas pipeline inlet, gas extraction values, coefficients c. The gas flow corresponds to selection with a negative sign [9, 10, 11] Fig 2.

$$P_{in}^2 - P_{out}^2 = G_{11}^2 c_{11} x_{11} + (G_{11} - S_{11})^2 c_{12} x_{12} + (G_{11} - S_{11} - S_{12})^2 c_{13} x_{13} + (G_{11} - S_{11} - S12 -- S132 c14 x14.$$
(2)

Let us transform expression (2) in the case of nonstationarity into the form:

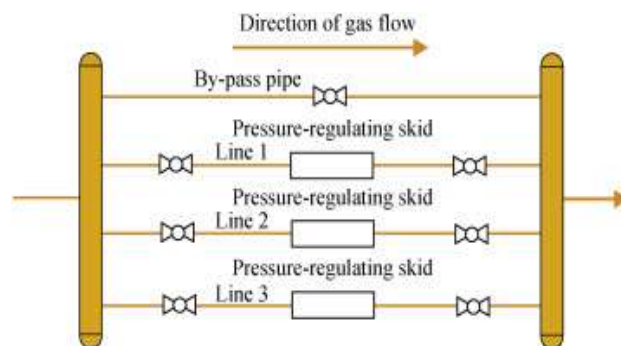$$P_{in}^2 - P_{out}^2 = G_{11}^2 a_1 - 2G_{11}\beta_1 + \gamma_1. \tag{3}$$

Figure 2. A flow chart for parallel pipelines in gas-transmission stations

where β₁ - coefficient determined by the parameters of the transported natural gas under non-stationary conditions [12,13,14]; γ₁- coefficient determined by the parameters of the transported natural gas under steady-state conditions [15,16]. Fig. 3 shows the operation of the gas pipeline during the non-stationary regime.
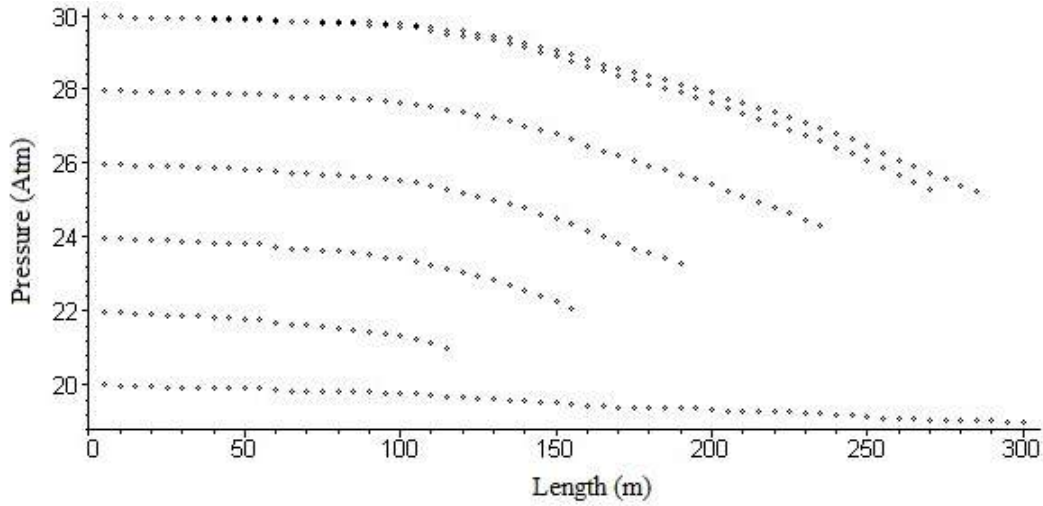

Figure 3. Pressure along the gas pipeline

Equation (3) can also be written as:

$$P_{in}^2 - P_{out}^2 = a_1 + \left(G_{11} - 2G_{11}\frac{\beta_1}{a_1} + \frac{\gamma_1}{a_1} \right)^2 = a_1 \left[\left(G_{11} - \frac{\beta_1}{a_1} \right)^2 + \frac{\gamma_1}{a_1} - \frac{\beta_1^2}{a_1^2} \right].$$ (4)

Since $\frac{\gamma_1}{a_1} - \frac{\beta_1^2}{a_1^2} \leq \left(G_{11} - \frac{\beta_1}{a_1} \right)^2$, the path selections are small compared to the gas flow, equation (4) can be written as:

$$P_{in}^2 - P_{out}^2 = a_1 \left(G_{11} - \frac{\beta_1}{a_1} \right)^2.$$ (5)

Let us calculate the input streams for the parallel pipeline:

$$P_{in}^2 - P_{out}^2 = a_2 \left(G_{21} - \frac{\beta_2}{a_2} \right)^2.$$ (6)

Equation (6) calculates input flows for three or more parallel pipelines:

$$P_{in}^2 - P_{out}^2 = a_n \left(G_n - \frac{\beta_n}{a_n} \right)^2.$$

Subtracting $P_{in}^2 - P_{out}^2$ from equation (6), one can write:

$$a_2 \left(G_{21} - \frac{\beta_2}{a_2} \right)^2 = \sqrt{a_2} \left(G_{11} - \frac{\beta_1}{a_1} \right)^2,$$ (7)

let us find:

$$G_{11} = \frac{\beta_2}{a_2} + \sqrt{\frac{a_1}{a_2}} \left(G_{11} - \frac{\beta_1}{a_1} \right)^2.$$ (8)

Taking into account that gas input stream $G_{in} = G_{11} + G_{21}$, the sum of equation (8) can be written as:

$$G_{in} - G_{11} = \frac{\beta_1}{a_1} + \frac{\beta_2}{a_2} + \left(\sqrt{\frac{\beta_1}{a_1}} + \sqrt{\frac{\beta_2}{a_2}} \right)^2 \times \left(G_{11} - \frac{\beta_1}{a_1} \right). \tag{9}$$

Equation (9) with respect to gas flow G_{11} has the form:

$$G_{11} = \frac{G_{in} - \frac{\beta_1}{a_1} - \frac{\beta_2}{a_2} - \frac{\beta_n}{a_n}}{1 + \sqrt{\frac{a_1}{a_2}} + \sqrt{\frac{a_2}{a_n}}} + \frac{\beta_1}{a_1}. \tag{10}$$

Input streams of natural gas for other threads of the parallel pipeline are determined by formula (8). When the diameter pipe does not differ from the parallel pipeline, taking into account the same coefficient c, it is possible to write down the form:

$$G_{11} = \frac{G_{in} - \beta_1` - \beta_2` - \beta_n`}{2} + \beta_1`;$$

$$\beta_2` = S_{21} \frac{l_{22}}{L} + S_{22} \frac{l_{23}}{L}. \tag{11}$$

For intermediate sections, gas flows are determined by the formulas:

$$G_{12} = G_{11} - S_{11}; \; G_{13} = G_{11} - S_{11} - S_{12};$$
$$G_{14} = G_{11} - S_{11} - S_{12} - S_{13};$$
$$G_{22} = G_{21} - S_{22};$$
$$G_{23} = G_{22} - S_{23}.$$

Similarly, the formulation of the problem is solved with output values of pressure and gas flow.

3. Conclusions
The proposed methodology can be used not only to calculate the operation of two parallel gas mains, but also for other gas pipelines.

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