Modernization of polyethylene pipelines for expanding application of them in gas transportation systems

M N Nazarova, M I Davydenko, Yu E Yaroslavova

St. Petersburg Mining University, 21st Line of the Vasilievsky Island

E-mail: nmn_oilrb@mail.ru

Abstract. In this paper, methods for expanding the scope of the polyethylene gas pipeline in gas transport systems are considered. The methods of improving the performance characteristics of polymer pipes due to reinforcement, the influence of various types of reinforcement (internal and external) on the possibility of using pipes in the above-ground gasket are presented. In the second part of the work, there is the method of modernizing the cross-section of polyethylene pipes, which improves the flow parameters, primarily its turbulence and velocity.

1. Introduction

Polyethylene pipes are used for transportation of combustible gaseous and liquid substances in the and industrial sector. Pipes for a gas pipeline are made from low-density polyethylene with high density. The classes of polyethylene are 80 and 100 (SDR 17.6 and 11), the diameter can vary from 20 to 400 mm [1].

Polyethylene is a reliable and durable material for the production of pipes for gas supply systems; they are awarded to most products of this kind - strength, corrosion resistance, ductility and ability to withstand rather high temperatures of the coolant.

But the disadvantage is that the sun's rays have a negative effect on the structure of the polymer. That is why polypropylene pipes can not be used in the open space. The linear expansion of polymer pipes is 2 times larger than the expansion of metal pipes [2]. In addition, the modernization of the cross-section of polyethylene gas pipelines makes it possible to extend their use in the underground gasket.

Thus, the problem of modernization of polyethylene gas pipelines in terms of their application and elimination of serious deficiencies is more urgent than ever.

2. Materials and methods

A comparison between polymer pipes reinforced with glass fiber and aluminum foil was made to study the effect of reinforcement on the performance. An assessment of the effect of various types of reinforcement on the resistance of polyethylene to ultraviolet rays and the increased pressure was made. Also, a comparison between the positive impact of external and internal reinforcement was made in this paper.

In the second part, the effect of the presence of rifled sections on the characteristics of the gas flow in a polyethylene gas pipeline was identified. The weapon barrel allows one to use the energy of the powder charge to inform the bullet of the forward and rotational movement, and to accelerate it at the
desired speed and throw it in the desired direction. It is this principle that underlies the idea of modifying the pipeline.

At present, the most common methods of reinforcing polyethylene pipes are reinforcement with glass fiber or aluminum foil. Reliability, strength, low wear even at high flow rates, are the reasons to be used in pipelines with high internal pressure and sharp temperature changes.

Aluminum-reinforced pipes have small thermal expansion. The coefficient of thermal expansion of reinforced pipes is 10-12 times less than for conventional plastic products. They are expanded at a temperature above 70 °C by 1 cm per 1 meter of pipe length, and unreinforced pipes expand at the same temperature by 10 cm per 1 m of the pipe. Aluminum-reinforced pipes begin to expand at a temperature of 175 °C, and even then the reinforced pipe will not burst only lose shape and hang on the fasteners [3].

The presence of aluminum between the layers of polyethylene increases the strength, the protection against possible leaks and damages, also it reduces the inflation of the tube in high temperatures and sunlight. Aluminum-reinforced polyethylene is able to withstand exposure to sunlight longer than conventional polyethylene.

In addition, the presence of aluminum foil in the layers of polyethylene leads to a significant increase of safety margin. Figure 1 shows the level of stress distribution in a PE pipe reinforced with aluminum foil [4].

![Figure 1](image1.png)

**Figure 1.** Distribution of voltages in the unit of the PE pipeline: a - circumferential stresses; b - axial stresses.

Stress distribution was in the polyethylene cell during 50 years and at an operating pressure of 1.2 MPa. The level of circumferential stresses does not exceed 2.1 MPa with a minimum long-term strength for PE80 - 8.0 MPa. The level of axial stresses does not exceed 1.0 MPa. The strength of the polyethylene sector of the pipe is: by circumferential stresses ≈ 4; on axial ≥ 8 [4].

Glass fiber reinforced polyethylene pipes also have a number of advantages. Thus, the diffusion barrier prevents the penetration of free oxygen through the walls of the pipes, does not settle and the walls of the boiler are not oxidized. Glass fiber reinforced pipes are more ductile than aluminum-reinforced pipes.

Glass fiber reinforced polyethylene pipes do not need to be cleaned and calibrated before installation; they have higher resistance to corrosion and mechanical strength [5] in contrast to aluminum-reinforced pipes.

In addition to internal reinforcement, there can be external reinforcement of pipes too. External reinforcement is a cord of metal wire outside the polyethylene pipe. External reinforcement of the polyethylene pipe is presented in Figure 2.
3. Modernization of the cross-section of a polyethylene gas pipeline

The barrel profile of the firearm with cuts was adopted as a prototype for the new cross section. The rifled portion of the barrel serves to give the pool a rotational motion. The notches are grooves curling along the surface of the barrel bore. The rectangular shape of the rifling is adopted in the section. Advantages of this form of rifling are reliability, durability and economy of manufacture [7].

For the analysis of the suitability pipes in gas transport, it is necessary to calculate how much the presence of the teeth will affect the nature of the flow of gas in the pipeline, and whether there is an increase in the resistance of the pipeline and as a consequence of the friction losses during gas pumping. Figure 3 shows a simplified image of the cross-section of the gas pipeline after the cutting of the teeth.

Figure 3. Cross-sectional profile of a cut section of a gas pipeline

We begin with the determining the quantitative change in the main characteristic of the flow of the fluid-the Reynolds number (Re). We will assume that the length of the circle enclosed between the lateral faces of the tooth differs from the tooth base by an infinitesimal amount, and the difference between them can be neglected [8]. The wetted perimeter value for external and internal teeth is determined by the formula:

$$
\chi_{\text{out}} = \pi \cdot D_m - n \cdot a + n \cdot (2 \cdot b + a) = \pi \cdot D_m + 2nb, \tag{1}
$$

where $a, b$ - the parameters of the teeth, $m$; $D_m$ - internal diameter of the pipeline, taking into account the height of the teeth, $m$; $n$ is the number of teeth along the circumference.

The value of the hydraulic radius will be determined by expression:

$$
R_{\text{t, out}}^* = \frac{S_{\text{out}}}{\chi_{\text{out}}} = \frac{S_{\text{out}}}{\pi \cdot D_m + 2nb}, \tag{2}
$$

where $S_{\text{out}}$ - the area of the tooth section.
where \( S_{\text{nap}} \) is the cross-sectional area of the gas pipeline, m\(^2\).

The Reynolds number \( Re \) for the threaded section:

\[
Re_{\text{out}} = \frac{\nu \cdot D_h}{\nu} = \frac{Q}{\rho \cdot S_{\text{out}}} \cdot 4 \cdot R_{\text{t, out}} = \frac{Q \cdot 4}{\pi \cdot D_{\text{m}} + 2nb} \cdot \frac{S_{\text{out}}}{\mu \cdot S_{\text{out}}} = \frac{4 \cdot Q}{\mu} \cdot \frac{1}{\pi \cdot D_{\text{m}} + 2nb}.
\]

(3)

Based on the results of calculations, the following conclusion can be drawn: the turbulent nature of the gas flow in the gas pipeline is observed (\( Re \) is in all cases greater than the critical value: 2300 for the circular section and 300 for the channels of non-circular sections), the optimal number of threaded channels for any diameter is 2 [9].

To determine the success of riveted sections on gas pipelines, it is also necessary to assess how the presence of the teeth will affect the friction that occurs when the gas moves through the gas pipeline. To calculate the main friction factor in the gas pipeline - the coefficient of hydraulic friction, we will use the basic formula for the turbulent regime - the Altshul formula. The equivalent roughness is taken in accordance with GOST 0.002 [10, 11].

The calculation of the coefficient of hydraulic friction and gas velocity for the threaded section of the gas pipeline was carried out. A comparative analysis of the values of the hydraulic resistance coefficient for a rifled and circular section of a gas pipeline was carried out. The coefficient of hydraulic friction for a threaded section is less than for a section of circular cross-section for both steel and polyethylene gas pipelines. Values for a rifled and circular gas pipeline differ by 9.2% on average for steel and 9.4% for polyethylene gas pipelines. At the same time, there was a 2.17-time increase in the velocity of the gas flow in the gas pipeline for all diameters.

4. Conclusion

It can be concluded that the use of reinforced both externally and internally polyethylene pipes can solve the problems of ground laying of this type of pipes, use polymer pipelines as intra-house or in-site. Reinforcement of all types contributes to the enhancement of the most important properties of the material and pipe, internal reinforcement reduces the coefficient of expansion of the pipes, and also increases the resistance of the material to high pressure.

Thus, it is possible to draw a final conclusion about the possibility of using threaded pipes in the construction of the gas pipeline: the presence of a rifled part significantly affects the turbulence of the gas flow, in addition, it increases the gas velocity (2.2 times on average). The main disadvantage of using this technology will be a noticeable increase in friction losses along the length of the gas pipeline, but it is necessary to find out whether it is possible to compensate for these losses by a sufficiently large increase in the gas flow rate. In the future, it is planned to estimate the gas erosion wear of the teeth under the influence of the gas flow.

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