Research of stress-deformed state of main gas-pipeline section in loose soil settlement

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Abstract. The article represents the analysis of a main gas-pipeline section in loose soil settlement using ANSYS software.

The objective characteristics of the Russian gas network are difficult climatic conditions that have negative impact on gas pipe lines operation, which may increase risk of ecological or technical disasters. The forces that are not provided by pipeline specifications can cause significant deviations of stress-deformed state (SDS) of gas pipelines. These deviations can result in changes of gas pipeline spatial positions [1]. It can be attributed to ground settlement which appears as a result of soil consolidation due to moisture draining; weight of soil and the vibrations of gas pipe line. These forces lead to greater pipe curvature, its excessive strain and, as a result, to pipe line damage (weld joint ruptures and wormholes in the pipe walls). The repair of such damage requires repair works with temporary gas transmission shutdown. Besides, each damage, depending on its character, can lead to great gas losses [2]. Such failures more often occur in the so called loose grounds [3]. The SDS calculation of an underground main gas pipeline should be carried out taking into account both pipeline specifications and foundation soil properties as well as their interaction [4].

The purpose of this work is to study main gas pipeline behavior in loose ground settlement and its stress-deformed state.

Let us consider the section of an underground straight gas pipeline. Suppose that it is buried in dry ground which won't be encroached during the operation period. In this case vertical displacement (ground settlement) will appear as a result of soil packing under the pipe. This packing, according to the design parameters, is insignificant because the pressure of the pipe on the ground is no greater than 0.5 N/cm2 and there is no need to take it into account.

Let us suppose that the pipeline is buried in the loose water-saturated ground or the ground is periodically flooded. The water-saturated ground settlement is supposed to be soil packing under the pipe. It is known from the mechanics of soil that fully water-saturated ground can be considered as a two-phase system, and its compaction is conditioned by filtering out water from the cavities of the soil skeleton under the pressure of compaction load [3].
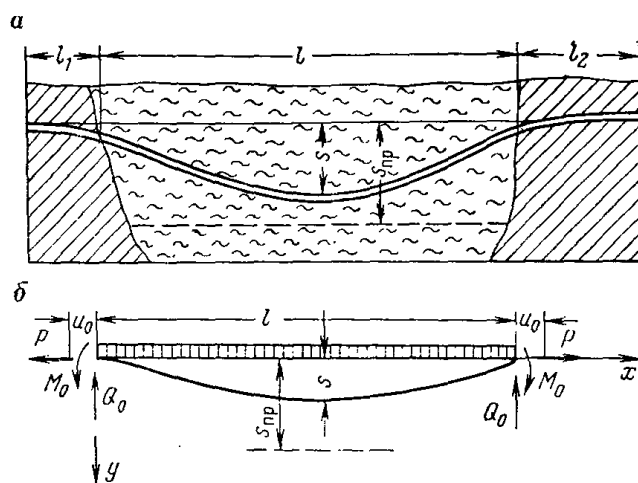
Figure 1. Motion of settlement type: a – general view; b – scheme.

Let the ultimate settlement be S_u. This settlement is called stabilized. S_u along the pipe line is drawn with the dashed line in figure 1. If the loose ground would spread proportionally throughout the length of pipeline, the settlement would be equal throughout the length. However, in practice we can see alteration of the loose grounds and grounds with greater bearing capacity. The last ones can have no settlement. In the middle of the loose ground section settlement could reach the ultimate value S_u. The gas pipeline on section 1 curves, as shown in figure 1. Since the pipe elongation can occur only at the expense of its stretching at section 1 and neighboring sections l_1 and l_2, there appears a stretching lateral force P, and section l begins to work as a hard thread. The real settlement S appears to be substantially less then S_u [3]. There emerge lateral force stresses, bending stresses from the overlaying ground, and stresses resulted from the weight of the pipe itself, the inner pressure and pipe walls temperature drop [5].

The software ANSYS is used for analysis of stresses caused by ground settlement to determine the stresses inside the pipe that exceed acceptable values and the variation range of numerical characteristics of the processes.

The scheme of lowering of a pipeline section with the following parameters is studied: outer diameter 530 mm, wall thickness 11 mm, length 12 m, operating pressure 9.0 MPa. Pipe line is made of steel 17G1S with following mechanical characteristics: short-term strength limit σ_s – 490 MPa, residual deformation fluctuation limit σ_r – 350 МПа. Apart from the operating pressure there are following loads on the pipeline: distributed load caused by the weight of pipe with insulation, the gas and the pressure of overlaying ground – q_{gen}, ground pressure on the pipe from underneath– q_r.

The loads, affecting the pipe line, are estimated due to Construction Norm and Rules 2.05.06-85* «Main pipelines» [6].

There are assumptions that correspond to the easiest option of pipe-ground interactions: in the beginning and in the end of the pipeline there are no X-movements, the ground pressure is 20% from the overlaying load, the pipe wall temperature rate is not considered.

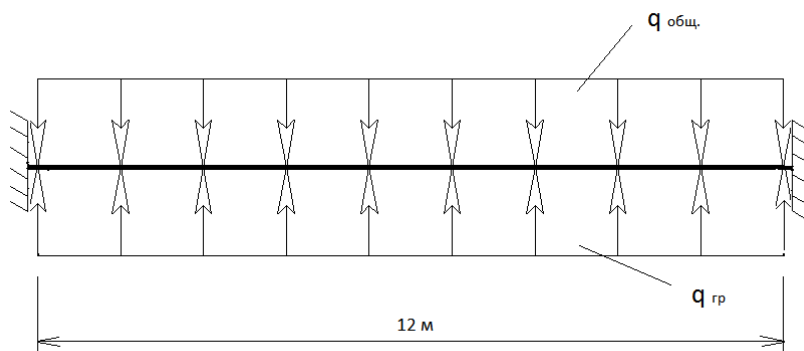Considering this hypothesis and the scheme in figure 1, the following model is shown in

Figure 2. Pipeline model of structure.

Figures 3 and 5 show the pipe line section calculation made with the ANSYS, and figures 4 and 6 show the graphic data interpretation.
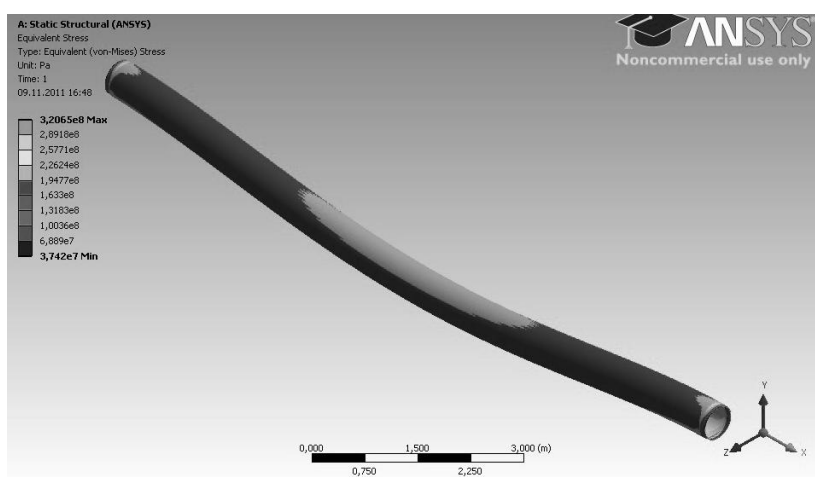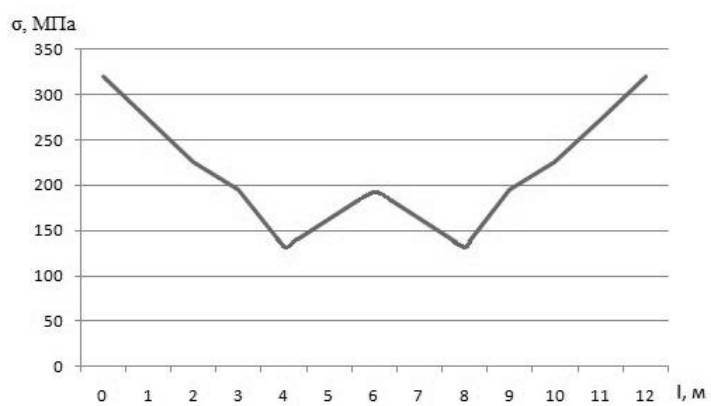

Figure 3. Stresses caused by ground settlement.

Figure 4. Distribution of stresses (σ) lengthwise (l) of the pipeline section.

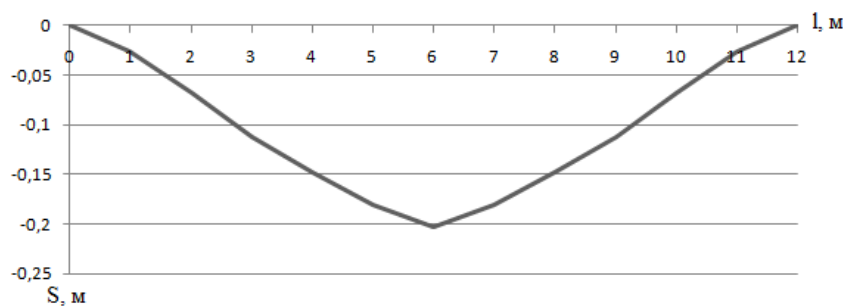**Figure 5.** Deformations of a pipeline caused by ground settlement.

Figure 6. Stress distribution (S) lengthwise (l) in the pipeline section.

Conclusion

The obtained results allow us to make the following conclusions:

- changing of the stress values, which occur during the pipeline settlement, can reach the values which are close to steel flow limit. It decreases the pipe line safety level;
- intensity of stress is changeable lengthwise the pipeline. The sections of pipeline that are situated in the zone of transition from loose grounds to the grounds with greater load bearing capacity, is characterized with great stress level;
- these results are not sufficient for making the design decision. It is necessary to conduct more detailed study of stress deformed state of pipeline, taking into account the physical and mechanical soil properties.

References

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