Abstract. The article studies stress-strain behavior of the main oil-pipeline section Alexandrovskoye-Anzhero-Sudzhensk using software system Ansys. This method of examination and assessment of technical conditions of objects of pipeline transport studies the objects and the processes that affect the technical condition of these facilities, including the research on the basis of computer simulation. Such approach allows to develop the theory, methods of calculations and designing of objects of pipeline transport, units and parts of machines, regardless of their industry and destination with a view to improve the existing constructions and create new structures, machines of high performance, durability and reliability, maintainability, low material capacity and cost, which have competitiveness on the world market.

Development of oil and gas industry on the basis of heavy-duty pipelines and their operation in the areas with difficult natural conditions created the agenda of control and evaluation of strength and performance capability of these structures. In this case the theoretical strength calculations for main pipelines are tentative as they essentially cannot take into account all the operation factors.

In Russia the major amount of oil is produced in northern deposits of Western Siberia, Yamalo-Nenets Autonomous Okrug, the Republic of Komi, and their vast territories are swampy. Main pipelines delivering oil to the country’s central regions and for export, cross water courses of various length. Water courses crossing is mainly solved by building underwater crossings.

Underwater crossings of main oil-pipelines, although making up a relatively small part of the total construction volume, belong to the most critical sections of these structures. So there are high requirements to reliability of underwater crossings, as even minor damages cause heavy environmental aftermaths.

Increasing reliability of pipelines becomes a pressing issue at all stages: design, construction and operation of pipeline systems. It is very important to determine adequacy of behavior for the constructed pipeline under operational and environmental loads to the model calculation adopted by the rules and regulations.

The main oil-pipeline Alexandrovskoye-Anzhero-Sudzhensk crosses in general 98 water courses. The section is undeveloped, covered by mixed forest along the pipeline route situated at the 208th km of the oil-pipeline Alexandrovskoye-Anzhero-Sudzhensk. The flood plain is wide, even and swampy. It consists of stretched interchanging low ridges and swaps covered by ledum and osier shrubs and birch trees of medium density, with shrub and sedge complex along the river bed. The river bed bogginess makes up 20%; its forest coverage is 90%. The river bed at the underwater crossing area is meandering, one-armed and sandy. The river bed width in low water period is 10-15 m the depth is 1.5-2 m.
The aim of this work is to research the stress-strain behavior (SSB) of the underwater crossing at the swampy pipeline area.

The calculation of the SSB pipeline structures based on material resistance factors and structural mechanics does not allow making an adequate analysis of fuel and energy sector pipelines strength with the required accuracy and in some cases can give a wrong picture of SSB structures. Nowadays numerical methods are intensively developed, which allow extending considerably the class and statement of solved problems due to a more complete consideration of real loading conditions and the properties of used materials. The finite element analysis (FEA) method is the most widely-spread among these ones. The advantages of FEA are minimal requirements to the source data and optimal presentation of the results. Considering the temperature influence and structure operation does not create any major difficulties for implementing the method.

Using FEA in structural analysis is actually the world’s standard now for structure strength and other related types of calculations. This is based on FEA universality, which allows using a unified method for calculating different structures with different materials properties. The information obtained as a result of pipelines SSB evaluation allows determining sections in pre-emergency state (even before damages appear) and take all the necessary measures for eliminating them, thus increasing the pipeline system reliability. [2-3]

The diameter of the studied pipeline is 1,220 mm, the operating pressure is 3.7 MPa. The pipeline crosses a swampy area. The pipe material characteristics: 13GS steel with the following mechanical properties $\sigma_{wp} = 510 \text{ MPa}$, $\sigma_m = 335 \text{ MPa}$. [4-6] The pipeline is affected by the following loads except for the operating pressure: distributed load of the pipe with isolation and transportation oil – q, buoyancy in water – $q_w$, hydrostatic pressure – $q_{hyd}$. It is assumed in the calculations that there are no loads acting in winter period and temperature influence on the pipeline.

The calculation model is shown in figure 1 and represents the transition place of the pipeline from ground to water.

![Figure 1. Pipeline calculation model.](image1)

The calculation results are shown in figures 2 and 3.

![Figure 2. Von Mises design strains of the studied section.](image2)
Having calculated the studied pipeline section, we’ll check if the Ansys model corresponds to the conventional calculation method results. So we take the created pipeline section model, apply only the design pressure and make a calculation of circular strains. The calculation results are shown in figure 4.

Maximal circular strains of the pipeline section under design pressure by FEA method is \( \sigma_{\text{max}} = 191 \, \text{MPa} \).

Calculated circular strains are \( \sigma_{\text{calc}} = 180 \, \text{MPa} \).

The calculation error:

\[
\Delta = \frac{\sigma_{\text{max}} - \sigma_{\text{calc}}}{\sigma_{\text{max}}} \cdot 100\% = \frac{191 - 180}{191} \cdot 100\% = 5.7% \quad (1)
\]

This means the adopted model gives the adequate result.
Distribution of the total shifts and strains obtained by the calculation is shown in figures 5 and 6.

![Figure 5](image1.png)  
**Figure 5.** Distribution of strains along the pipeline.

![Figure 6](image2.png)  
**Figure 6.** Distribution of the total shifts along the pipeline.

The following conclusions can be made from the obtained and presented results:
- the most critical pipeline cross-section is situated at the place of transition from one environment to another; here we observe maximal strains decreasing the pipeline reliability level;
- total shifts are variable along the tube length, and they considerably depend on the effect of distributed loads from the weight of the tube and the transported oil, as well as hydrostatic pressure and water buoyancy. The most critical cross-section is situated in the middle of the pipeline.
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