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Research of the Dependence of the Pipeline Ends Displacement Value When Cutting Out Its Defective Section on the Elastic Stresses in the Pipe Body

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Abstract. In the process of repairing main oil and gas pipelines with cutting out defective sections, due to the elastic stresses in the body of the pipeline at the end of the first cut, there is a sharp displacement of the pipeline ends on both sides of the cutting site. This sharp displacement poses a threat to the lives of workers, and also complicates the further process of welding a new section of the pipeline due to the need to center its ends relative to each other. At the same time, to reduce the displacement of the ends of the pipeline, it is often pressed down with an excavator bucket before cutting, which contradicts the safety rules for conducting repair work. This article examines the dependence of the displacement value of the ends of the pipeline on the existing elastic stresses in it in order to substantiate the need to take into account the elastic stresses in the body of the pipeline in the used repair methods, as well as the need to develop safe and technologically efficient equipment for fixing the position of the pipeline before cutting and further centering its ends relative to each other.

1. Introduction

One of the main methods of repairing defective sections of main pipelines is cutting them out. During the repair work with cutting out a defective section, often at the end of the first cut, there is a sharp displacement of the ends of the pipeline, located on both sides of the cut, in an unpredictable direction by tens, and sometimes hundreds of centimeters, which poses a threat to the health of workers located close to the work area and may damage the cutting tool. In addition, to weld a new section of the pipeline, it is necessary to further center its ends relative to each other after cutting, for which expensive and heavy pipelayers are used.

The displacement of the pipeline ends after cutting when pressing the pipeline with an excavator bucket is shown in Figure 1.



Figure 1. The displacement of the pipeline ends after cutting when pressing the pipeline with an excavator bucket.

At the same time, the existing method for cutting out the defective sections of main pipelines does not imply fixing of position of the pipeline before cutting it. [1]

Currently, there are no safe and technologically effective methods among the methods proposed by specialists for solving the problem of a sharp displacement of the pipeline ends during its cutting. The proposed methods either require the production of additional earthworks, or do not provide reliable fixing of the pipeline position before cutting and further centering of its ends. [2-5]

For this reason, it is relevant to study the dependence of the displacement value of the pipeline ends when cutting out its defective section on the existing elastic stresses in the pipe body and, as a consequence, substantiate the need to take into account elastic stresses in the body of the pipeline and use special equipment for fixing of position of the pipeline before cutting, and also further centering its ends.

Before starting the calculation and analysis of the investigated dependence, it is necessary to understand the reasons for the elastic stresses arising during the operation of the pipeline.

The position of the buried pipeline during its operation is changed from the original, due to the action on the pipeline of the following types of loads [6-10]:

- standard loads that are in effect during the entire operation of the pipeline and are taken into account when designing the pipeline;

- abnormal loads arising from the impact of the environment on the pipeline and violations of the rules for the construction and operation of the pipeline. [11-15]

Among the standard loads, the following are distinguished:

- internal pressure inside the pipeline created by the transported product;
- temperature difference arising during the operation of the pipeline;
- dead weight of the pipeline, embankment soil and transported product;

- uneven resistance along the length of the pipeline from the side of the soil to pipeline movements;

- the difference in air temperatures during the laying of the pipeline and its further operation;

loads due to the pipeline design.

Abnormal loads include uncontrolled ground movements and mechanical impact of earthmoving equipment on the pipeline and the surrounding soil.

Under normal operating conditions of pipelines, the soil under the pipeline settles, and the voids that exist after the pipeline is laid and buried are filled. Also, soil settlement is observed during the outflow of excess moisture and during soil compaction under the influence of the pipeline's own weight and pipeline vibrations arising during operation. [16-20]

As for pipelines laid in permafrost soils, during their operation, thermokarsts, thermal erosion, solifluction, as well as cryogenic heaving of soils can be observed. As a result, there is a violation of the stability of the pipeline and the deterioration of physical and mechanical properties of its steel.

Thus, the surrounding soils have a great influence on the stress-strain state of the pipeline during its operation. In this case, the most common type of pipeline deformation is its bending due to subsidence or heaving of the soil. [25-31]

2. Problem statement

To determine the dependence of the elastic stresses in the pipe body on the magnitude of the sharp displacement of the pipeline ends when cutting out the defective section, we use the finite element method, which consists in subdividing the model into the set of elements, apply forces and restrictions to them to implement the selected case of loading the pipeline, whereby solving systems of equations describing the interaction of model elements. [32-37]

It is also necessary to investigate the influence of elastic stresses in the body of the pipeline on the displacement of its ends during cutting, depending on the geometric parameters of the pipeline. For this, modeling will be carried out for pipelines with two different geometric characteristics.

To solve this problem by the finite element method, we will use the tools of the ANSYS software, which makes it possible to simulate the static and dynamic loading of various structures.

Thus, in solving the problem, the following stages can be distinguished:

- creation of a volumetric model of the main pipeline of a certain length, diameter and with a certain wall thickness;

application of forces to the simulated pipeline, creating the case of its elastic bending;

- cutting the pipeline and determining the value of the displacement of the ends of the pipeline;

 determination of the displacement value of the ends of the simulated pipeline when changing the magnitude of the applied forces;

- plotting a graph of the dependence of the pipeline ends displacement on the value of the forces applied to it.

The parameters of the simulated pipelines are presented in Table 1. [38-39]

Parameters	Pipeline 1	Pipeline 2
Outer diameter, mm	1420	1020
Wall thickness, mm	33,4	12
Pipeline material	10G2FBJu (10% - carbon, 2% - manganese, <1% each - vanadium, niobium	09G2S (0,09% - carbon, 2% - manganese 1% - silicon)
	aluminum)	270 manganese, 170 smeony
Density, kg/m^3	7860	7850
Young's modulus, MPa	210	206
Poisson's ratio	0,3	0,3
Ultimate tensile strength, MPa	590	490
Yield strength, MPa	460	350

Table 1. Parameters of the simulated pipelines.

The length of each simulated pipeline is 36 m (three pipeline sections).

3. Modeling the displacement of the ends of the main pipeline when cutting out its defective section

During the process of simulation of cutting a pipeline in the ANSYS Transient structural calculation module, the following were carried out:

- fixing the left and right edges of the pipeline in the space before cutting the pipeline;

- static loading of the pipeline by applying bending moments from both of its edges to implement the case of its elastic bending, as well as by applying a distributed load from the weight of the pipeline itself;

- cutting the pipeline in the middle using the Element Birth and Death tool;

- recording data of the changing of the pipeline ends position from their initial position.

The pipeline ends displacement after cutting at the investigated values of bending moments is presented in Table 2.

Table 2. Values of the pipeline ends displacement after cutting at bending moments applied to the pipeline.

Magnitude of each bending	Value of the pipeline ends displacement, mm	
moment, MN·m	Pipeline 1 (1420x33,4)	Pipeline 2 (1020x12)
0	0	0
0,5	22,34	162,658
1	44,675	316,182
1,5	66,993	456,866
2	89,292	588,426

The graph plotted on the basis of the data obtained is shown in Figure 2.



Figure 2. Dependence of the pipeline ends displacement on the applied bending moments.

The change in the position of the pipeline before and after cutting on the example of a simulated pipeline with an outer diameter of 1020 mm and bending moments applied to it of 1 MN·m each, simulated in the ANSYS, is shown in Figure 3.



Figure 3. Changing the position of a pipeline with an outer diameter of 1020 mm with applied bending moments of 1 MN·m before and after cutting.

The proposed model for calculating the value of the displacement of the ends of the pipeline during its cutting is used to further study the dependence of the value of the displacement of the pipeline ends on the value of elastic stresses in the pipe body, the length of the repaired section, the geometric parameters of the pipeline, as well as the types of soils characterizing the value of the applied load.

4. Conclusion

As a result of the study, it can be concluded that a sharp displacement of the pipeline ends due to the elastic stresses in the pipe body significantly complicates the process of repair work, posing a threat to the health and life of workers, as well as technologically complicating the repair process due to the need to further center the pipeline ends after cutting out the defective section. At the same time, there are currently no safe and technologically effective ways of fixing the position of the pipeline before cutting out the defective section and further centering its ends.

Based on the results of modeling the displacement of the pipeline during its cutting, graphical dependences of this displacement on the bending moments applied along the edges of the repaired section were plotted. After the analysis of the obtained graphical dependencies, it can be concluded that the studied dependence is linear, while the displacement of the pipeline ends increases with a decrease in its outer diameter at a constant value of the applied bending moments. This is evidenced by the slope coefficient of the straight line, which in the case of a pipeline with an outer diameter of 1020 mm is 6.75 times greater than for a pipeline with an outer diameter of 1420 mm.

It follows that the problem of a sharp displacement of the pipeline ends during its cutting is relevant in the field of pipeline transportation of oil and gas. To solve it, it is necessary to develop repair methods taking into account the stress-strain state of the pipeline, as well as equipment for fixing the position of the pipeline before cutting it and further centering its ends relative to each other.

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