Methods for calculating thermal fields using modern software products

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\textbf{Abstract.} The paper presents methods of mathematical modelling of buried multilayer oil pipelines laid in areas of Western Siberia and the Arctic zone of the Russian Federation. Modelling was carried out on the basis of data from several sections of oil pipelines under various burying conditions. In the work, we also used a wide range of different software programs for modelling in order to identify a software product suitable for the goals and objectives of this work.

1. \textbf{Introduction}
Currently, the development of the north is the basis of the “Energy Strategy of Russia for the period until 2030” and the order of the Government of the Russian Federation of November 13, 2009 No. 1715-r, therefore, ensuring the reliability and safety of pipeline transport facilities is a priority in the design, construction and the operation of the oil transportation system. Modern software products allow the engineer-designer to predict thermal processes at the stage of the project development, and to prevent further behaviour of the pipe-soil system and emergency situations during operation. [1]

The selection of reliable and economical thermally insulated pipeline structures when designing linear sections is carried out considering operating conditions, types of laying and conditions on site.

Thermal design of such structures often takes a lot of time due to many changing conditions along the length of the pipeline and looks rather cumbersome.

Mathematical modelling of these processes on modern computers allows you to set many changing parameters over time, and to predict the behaviour of nearby engineering structures over a long period of time.

2. \textbf{Objects and methods of research}
The first stage of modelling is to search for a specific object for modelling and processing field data which include the main characteristics of the studied area. In this work, we took a section of the pipeline laid in difficult geocryological conditions of the Yarudeyskoye field. This section is indicative of the large geological diversity of frozen rocks and many cases of displacement of pipelines from the design position (Figure 1). [2]
There are many programs that allow you to create a two-dimensional model of the area under consideration, among which Autodesk products such as AutoCAD, and built-in CAD packages (computer-aided design and drawing tools) have proven themselves. [3]

Two-dimensional modelling has the following advantages:

- does not require large computing power;
- simplicity of model building.

Another option is to create a three-dimensional model of the area under consideration, giving a visual representation of nearby engineering objects and structures that are part of the general system. The most widely known CAD programs are Inventor, Fusion 360, 3ds Max (Figures 3,4,5). [4]
Figure 3. A model developed in Autodesk Inventor

Figure 4. A model developed in Fusion 360

Figure 5. A model developed in 3ds Max
The second stage is mathematical modelling of heat transfer processes, if we know most of the required parameters. Currently, the following programs provide modelling of thermal processes as close to real conditions as possible: a universal software system for finite element modelling - ANSYS, a system for modelling fluid flows, gases and heat transfer processes - Autodesk CFD and Frost 3D Universal - a software package for modelling thermal processes in soil. [5,6]

At the modelling stage, in the ANSYS system and the Transient Thermal package for a preloaded model, triangles are created and set up for more correct calculation of heat fluxes. The boundary conditions are also determined, and the parameters of insulating materials and soil are set. For soil, the parameters of the phase transition from the frozen state to the thawed state and vice versa are set. After completing the calculation in this software package, you can display not only a graphic image of the temperature halo, but also graphs and various dependencies (Figures 6,7).

Figure 6. Modelling results in ANSYS

Figure 7. Modelling results in ANSYS
Modelling of thermal processes in Autodesk CFD differs markedly from the previous one in fewer functions and less accurate results.

When creating a 3D body in the first stages, you can specify unnecessary small elements and objects that the program will not take into account in the calculations, which positively affects the processing speed, but negatively affects the accuracy of the final result. [7,8]

Next, it is necessary to refine the primary model, to exclude microvoids and structural defects from the calculation in order to avoid errors in the calculations, each insulation layer here is taken as a continuous medium. After finishing work with geometry, each design layer is given a specific parameter of density and temperature. These parameters are set only from predefined materials, which is a significant drawback (Figure 8).

Figure 8. Determination of the model parameters.

After determining the material of each of the elements of the model, constructing a cloud of points and a grid for calculation, the grid is calculated automatically, only the size can be adjusted (Figure 9).

Figure 9. Creating a grid for calculation in Autodesk CFD
At the last stage, the simulation of the movement of heat fluxes and data output are performed. Calculations are performed for a certain number of iterations, and it does not allow calculating the thermal effect of the pipeline in the long term (Figure 10).

![Figure 10. Modelling results in CFD](image)

**Figure 10.** Modelling results in CFD

**Figure 11.** An example of modelling in Frost 3D Universal

3. Conclusion
Mathematical modelling, as a research method, allows you to get an idea of the physicochemical processes taking place in the places of the experiment without directly interfering with the transport of
the oil product, or evaluate the degree of reliability of structures at the design and construction stages. The mathematical model, in contrast to the actual experiment, has several advantages:
- it saves the material resources required for the formulation and conduct of a physical experiment;
- performance assessment of systems with long technological cycles (weeks, months, years) occurs in a much shorter time.

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