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STATIC AND DYNAMIC CALCULATION OF STRENGTH OF PIPELINES

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Abstract

The paper deals with the solution of static and dynamic problems of the mechanics of a deformable solid (MDTT) by the finite element method. Various approaches to solving the MDTT problem for modern finite element methods (FEM) are given.

Keywords: Solid mechanics, static, dynamic, rigidity, stability, matrix formulation, stiffness matrix, discretization.

Аннотация

В статье рассматривается решение статических и динамических задач механики деформируемого твердого тела (МДТТ) методом конечных элементов. Приведены различные подходы к решению задачи MDTT для современных методов конечных элементов (МКЭ).

Ключевые слова: Механика твердого тела, статических, динамических, жесткость, устойчивость, матричная формулировка, матрица жесткости, дискретизация.

Introduction

The principles of pipeline calculation are the choice of the design scheme for various loads and impacts, their accounting, as well as the assignment of limit states, i.e. the permissible level of stress-strain state, taking into account the accepted hypotheses and assumptions in the calculation. There are two types of limit conditions in which further operation of the pipeline is impossible: The first limit state is in terms of bearing capacity (strength and stability of structures, fatigue of the material). Having reached this state, the structure is no longer able to resist external influences. The second condition is the maximum permissible deformations caused by static and dynamic loads, upon reaching which deformations and vibrations occur in a structure that retains strength and stability, excluding the possibility of its further operation. The possibility of achieving one or another limiting state of the structure depends on many factors, of which the most important are:

1) External loads and other impacts;
2) The quality and properties of the materials from which the structure is made;

3) General working conditions of the structure, the conditions of its manufacture, etc. The calculation of the pipeline is important for predicting the operability and durability of the structure in real conditions. In many ways, this is important not only from the technical side, but also from the economic side. The pipeline design should not be unreasonably bulky and expensive. The calculation allows you to reduce the costs of the manufacturer. The purpose of this work is to study static and dynamic stress-strain the state of the pipe and support structure by the finite element method under the influence of loads. The finite element method is the main method of modern structural mechanics, which underlies the vast majority of modern software systems designed to perform calculations of building structures on a computer. But the range of its application is extremely wide: construction and mechanical engineering, hydro and aerodynamics, mining and the latest technology, as well as various problems of mathematical physics - thermal conductivity, filtration, wave propagation, etc. The finite element method was first applied in engineering practice in the early 50s of the XX century. At an early stage, the formulations of the FEM were based on the principles of structural mechanics, which limited the scope of its application. And only when the basics of the method were formulated in a variational form, it became possible to extend it to many other tasks. The rapid development of the FEM went in parallel with the progress of modern computer technology and its application in various fields of science and engineering practice .

A significant contribution to the development of the FEM was made by Ioannis Argyris. For the first time, he gave a general matrix formulation for calculating core systems based on fundamental energy principles, defined the compliance matrix, and introduced the concept of the stiffness matrix (as the inverse of the compliance matrix). Argyris is one of the founders of the finite element method. In 1956, his theoretical developments were used in the construction of the Boeing-747. The works of Argyris and his collaborators, published in the period 1954-1960, provided a starting point for the matrix formulation of known numerical methods and the use of computers in the calculations of structures. The first work in which the modern concept of FEM was outlined dates back to 1956. American scientists M. Turner, R. Cluff, G. Martin and L. Topp, solving a planar problem of elasticity theory, introduced a triangular element, for which a stiffness matrix and a vector of nodal forces were formed. The name – the finite element method was introduced in 1960 by R. Cluff. The appearance of the mathematical theory of finite elements dates back to the seventies. Scientists have made a significant contribution to the development of the theoretical foundations of the FEM.

The period of the last decades is especially characteristic for the development and application of FEM in such areas of continuum mechanics as optimal design, consideration of nonlinear behavior, structural dynamics, etc. The complexity of shapes and dimensions of structures make it difficult to carry out a full-scale experiment. Thanks to the development of computers, modeling of complex physical phenomena has become possible. Among all numerical methods, the finite element method has become the most widely used. This method is the most effective and universal. Today, FEM is a generally recognized method of structural analysis in a number of fields of science and technology. There are several reasons for this:
Ability to set local boundary conditions.
Simple interpretation of computational operations.
Geometric flexibility and applicability to a wide class of partial differential equations.
Ensuring the uniqueness of the resulting solution at all points of the considered area.
Efficiency and cost-effectiveness in its machine implementation compared to other methods.
The material properties of adjacent elements do not necessarily have to be the same. This allows the method to be applied to bodies made up of several materials A curved area can be approximated using rectilinear elements or described exactly using curved elements. Thus, the method can be used not only for areas with a "good" border shape. Element sizes can be variable. This allows you to enlarge.

It is worth noting that the finite element method, of course, is an approximate numerical method, and thus has some degree of error. However, it contains a large number of parameters with which it is possible to control the degree of accuracy of the results obtained (the shredding of the grid, loading parameters and methods for obtaining a solution). A separate issue is the degree of adequacy of the solved mathematical model to its physical prototype. All this is placed on the shoulders of the calculation engineer, only he is responsible for the result. But it should be said that the FEM allows you to explore constructions of almost unlimited degree of complexity. While this is objectively impossible using analytical methods. The principle of FEM is to divide the studied area into elementary subdomains of finite dimensions (finite elements). In each such element, the unknown function is approximated by a polynomial, the degree of which varies depending on the problem, but usually remains low (from 1 to 6). For each element, the approximating polynomial is determined by its coefficients. The coefficients can be determined by the values of the function at particular points called element nodes. If the function is known at each node, then it is possible to approximate it over the entire region. To describe the stressed and deformed state of a deformable body divided into finite

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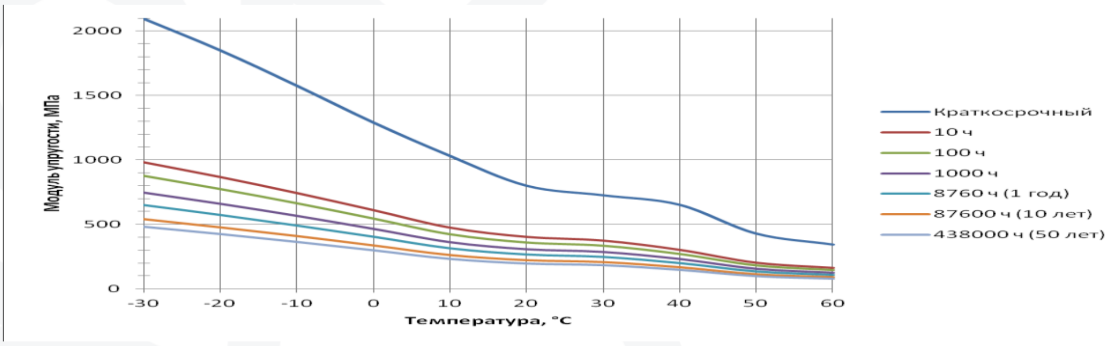
elements, the stiffness matrices for which are known, it is necessary to combine all the elements into a single system approximating the calculated one, i.e. to satisfy the conditions of static and kinematic compatibility for the structure as a whole. At the same time, it should be taken into account that the design is represented by a set of elements interacting in a finite number of nodal points, and therefore the specified conditions must be set for these points of the system. Most often, these issues are solved on the basis of the energy principles of the mechanics of deformable media, based mainly on the fact that the energy of the system is equal to the sum of the energy, each of which relates to the corresponding finite element.

Polyethylene Pipelines and Their Properties

Today, an urgent task is to expand the scope of application of polymer pipelines. The materials of plastic pipes are quite diverse, they are divided into three main groups: thermoplastics, including reinforced; fibrous thermosets and their combinations. To choose a pipe that would be operable in certain climatic conditions, it is necessary to know the whole range of operational properties. In the future, all this should become valuable information for determining the reliability of these materials. The main advantage of polymer pipes is the almost complete absence of corrosion damage and adhesive overgrowth of the inner surface. For example, one of the most important properties when introducing polyethylene pipes in gas supply systems is throughput. A comparison of the throughput capacity of steel and polyethylene pipes with similar values of internal diameters shows that in gas pipelines made of PE pipes, it turns out to be greater than that of steel pipes, due to an increase in the roughness of the steel pipe during operation. Also, the advantage of PE pipes is the speed of installation work. No heavy machinery is required for pipe welding. Polyethylene pipes can be welded by a team of 1-2 people. In addition, plastic pipes are several times lighter than steel pipes, as a result of which one vehicle is able to carry a larger number of pipes.
The properties of polyethylene pipelines largely depend on the temperature and operatingtime.



Here is a table of the dependence of the modulus of elasticity on the temperature and duration of the load (values of the modulus of elasticity in Mpa). Exposure period, h.					PE 100* pipe according to GOST 18599 with change 1					
Период воздействия, ч.					PE 100* pipe according to GOST 18599 with change 1					
Temperature, oC										
-30	**-20**	**-10**	**0**	**10**	**20**	**30**	**40**	**50**	**60**	
Short-term	2095	1850	1576	1291	1032	801	727	653	430	
10 ок	983	868	744	611	475	403	374	302	202	
100 ок	876	773	663	544	422	358	333	269	180	
1000 ок	747	660	566	465	361	306	285	230	154	
8760 ок (1 год)	650	573	491	404	314	266	247	199	134	
87600 ок(10 лет)	541	477	409	336	261	221	206	166	111	
4380000к (50 к)	483	426	365	300	233	197	184	148	99	

Graphical view of the dependence of the modulus of elasticity on the temperature and duration of the load. From the graph, it is obvious that the temperature has a significant effect on the properties of the polyethylene pipe.

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