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IDENTIFICATION OF MECHANICAL SYSTEMS DEFECTS

Dissertation for the degree of Doctor of Philosophy (PhD)
in the specialty "6D060300 - Mechanics"

ANNOTATION

Relevance of the research topic:

The topic of the dissertation is the study of mechanical systems in the joints of rods, pipes and other thin, slightly curved structures. For a given set of specific frequencies, special attention is paid to determining the boundary fixings of these mechanical systems. Such problems are related to the problems of acoustic diagnostics and are of scientific interest both in theory and in practice.

Thin rods and their connections are everywhere. The theoretical foundations of the theory of rods were laid by A. Clebsch. An important role in the further development of the theory of rods was played by S. P. Timoshenko, A. I. Lurie, G. Yu. Dzhanelidze, S. G. Lekhnitsky, Yu. N. Rabotnov, and others. completed. Despite the fact that technical theories have long been used in engineering calculations, little is known about the conditions for their use, which is ensured by the accuracy of approximation, the relevance of calculation models for specific objects.

This thesis is devoted to the study of small vibrations of free rods from different parts. In this case, the problem arises of determining the natural frequencies and natural vibrations of such structures. It is known that natural frequencies depend not only on the initial geometric and physical characteristics of the structure under study. They are significantly influenced by both boundary restraints and restraints at nodes between several members. The issue of creating models of this type also plays an important role in such studies. The choice was made for elements of a thin rod or their fragmented parts at specified natural frequencies. The problem of determining the method of fixing the boundary with a set of natural frequencies relates to acoustic diagnostics.

Typically, technicians at a repair center can identify the part needed for repair by the noise of the engine without opening the car's engine. In other words, he "hears" the engine with his ears. Such tasks are related to acoustic diagnostics and are often used in various fields of technology.

The topic of the dissertation is directly related to the problems of acoustic diagnostics; in the simplest case, the task is to determine how the edges of the rod are fixed by the natural frequencies of the rod. This issue is split into two issues. First of all, how many natural frequencies does it take to find the value of the fixed edge of a rod? After determining the number of natural frequencies, it is necessary to develop a

method for fixing the edges of the rod. The rod attachment can be fixed in different ways: free support, free end, elastic attachment, rigid attachment. The number of natural frequencies required for different attachments may differ. In general, a structure can contain several rods. In this case, problems on one core are relevant.

Purpose of thesis: The dissertation examines small free vibrations of thin rods, consisting of different parts. In this case, it is important to determine the natural frequencies and natural vibrations of such structures. It is known that natural frequencies depend not only on the initial geometric and physical characteristics of the structure under study. The minimum number of natural frequencies has been determined for unambiguous restoration of the boundary fixation. An additional example is given. To achieve this goal, the dissertation posed the following research tasks.

1. Obtaining simple differential equations describing bending, transverse, torsional vibrations of a thin rod (a structure connected by thin rods);
2. Development of an algorithm for determining the natural frequency of free vibrations of a thin rod (a structure interconnected by thin rods);
3. Development of an algorithm for constructive reconstruction of the boundary fixing of a thin rod on the set of finite natural frequencies.

The object of research is thin rods, several rods tied into a knot, bridges, a bent pipe.

Subject of research: theory of rods, technical diagnostics, theory of elasticity, theoretical mechanics, technical mechanics, graph theory. Investigations are carried out in accordance with observations based on observational data in the mechanics of deformable solids and solids**.**

Research methods include the theory of Clebsch thin rods, Korn's estimate, Dirichlet condition, Kirchhoff conditions, the well-known Timoshenko equations for bending and transverse vibrations, Ilgamov inverse problems, inverse statics for the graph of rods.

Theoretical and practical significance of the research: reduction of three-dimensional equations of the theory of elasticity of bending of rods to one-dimensional models, in the arcs of the limiting graph of longitudinal vibrations of the rods, differential equations of the second order are given. Timoshenko, Love's theories were expanded. In the case of an unambiguous restoration of the fixing of the boundary, the minimum number of natural frequencies is determined. An additional example is given. The quantities influencing the critical wind speed on the lateral surface of the bridge have been determined. The internal pressure of a bent pipe is found and an algorithm for determining the natural frequencies is proposed.

The following new results were obtained in the dissertation:

1. Simple differential equations are obtained that describe bending, transverse, torsional vibrations of a thin rod (a structure connected to each other by thin rods);
2. An algorithm for determining the natural frequency of free vibrations of a thin rod (a structure connected by thin rods) has been developed.
3. An algorithm for constructive restoration of the boundary fixation of a thin rod at the set of finite specific frequencies has been developed.

The novelty of the first point is that the system of differential equations for bending and transverse vibrations of a thin rod are interconnected. It can be seen from the results obtained that for some hypotheses the Timoshenko equations of known bending and transverse vibrations are effective.

A new aspect of the third point is the determination of the minimum number of natural frequencies with an unambiguous restoration of the boundary fixation. An additional example is given.

Although research objects are often encountered in practice, the results of the dissertation are theoretical in nature.

The reliability of the results of the dissertation is confirmed by a comparison of the results with known results, as well as by the use of well-proven mathematical methods. The quality of publications is beyond doubt.

Practical value. In practice, rod structures are important - heterogeneous, slightly bent anisotropic rods, connected at random. The main goal of the problems on thin rods is to generalize the system of limit equations to the limit graph.

Approbation of the work. The main ideas and results of the dissertation are presented and discussed at the following scientific conferences and seminars:
scientific conferences:

1. Traditional international April scientific conference in honor of the Day of Science Workers of the Republic of Kazakhstan (06.04.2018-10.04.2018), p. 80-81, thesis
2. Conference "XIV International Scientific Conference of Students, Undergraduates and Young Scientists LOMONOSOV-2018" 20.05.2018-21.05.2018), p. 81-82, thesis
3. XVII All-Russian youth school-conference "Lobachev Readings - 2018", Kazan, RF, 23.11.2018-28.11.2018, p.138-140, abstracts of reports, Astana, 2018
4. "International Conference, Mathematics, Mechanics, Applied Questions" Karaganda, 12.06.2019-13.06.2019, p.186-187, thesis

Publications. Published 10 papers on the topic of the dissertation, including: 1 article published in the Scopus Eurasian Mathematical Journal, Q3, CiteScore - 37 percentile journal and 1 scientific journal included in the Web of Science database; 3 scientific articles in journals recommended by the KON MES RK; 2 theses were

published in the materials of foreign conferences; 3 theses were published in the proceedings of the International Conference in Kazakhstan

The structure and scope of the thesis. The thesis consists of an introduction, three chapters, conclusion and references.

The main content of the dissertation.

The introduction to the dissertation provides an overview of the current work, analyzes the current state of the research problem; substantiated the relevance of the topic of dissertation research; Purpose, form, objectives of the research, scientific novelty, theoretical and practical significance, basic principles of defense, information about published works on the topic of the thesis and the degree of its development.

The novelty of the first chapter is that in technical theories of bending of rods, the three-dimensional equations of the theory of elasticity are reduced to one-dimensional models. This abbreviation is based on a number of physical assumptions. Technical theories are successfully used in engineering calculations. However, the question of the suitability of one-dimensional models for specific objects has not yet been fully studied. There are many methods for asymptotic analysis of elastic rod theories. The effectiveness of the method often depends on the asymptotic structure of the solution chosen by the researcher. The choice of the asymptotic structure plays the same role as the aforementioned physical hypotheses. If more information is required on how the solution obtained by reducing the diameter of the rod will work, then more in-depth research will be required. In addition, excessive conditions on the right are usually required. What conditions on the right are sufficient (close to necessary) for the reduction to be valid? To find out the similarity on the right, we need Korn's estimate of the difference between the actual solution and the asymptotic anatomy. Korn's estimate allows us to find that this is not confirmed either by the diameter of the rod or by the differential properties of the right-hand sides. The second chapter tries to answer the following question: how to choose the boundary conditions on the graph so that the eigenvalues (frequencies) of longitudinal vibrations have a real value? This is due to the fact that in the theory of elasticity of rods only certain (positive) eigenvalues are used. Since the longitudinal vibrations of the rods are studied in the second chapter, second-order differential equations are given in the arcs of the limit graph.

The third chapter defines the minimum number of specific frequencies for unambiguous restoration of the boundary fixation. An additional example is given. By comparing three different bridge cross-sectional shapes, the maximum critical speed is determined when the bridge cross-section is oval. If a malfunction occurs at both ends of the commissioned pipelines, it is recommended to identify it. The natural frequencies of horizontal oscillations of the pipe are found mathematically. Find the zeros of the identifier using the Maple software package. The accuracy of mathematical detection is higher than that determined by listening by an engineer. The problem of identifying the boundary conditions was also solved at nine natural frequencies.

In conclusion, the main results and conclusions of the dissertation research are presented.