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OPTIMIZATION OF ELASTIC CONTINUAL SYSTEMS BASED ON ROD SYSTEMS

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Annotation: One of the determining indicators of the quality of optimal structures such as mesh slabs, shells, domes of space frames, etc. As large rod systems there is a minimum mass. It allows not only to establish the minimum amount of material required for the production of traditional structures used in construction practice that are far from optimal in terms of weight of rod systems.

Key words: Rods, analogues, avoiding, minimization goal, masses, algorithms for solving the problem, loadings, solution model, shells of complex, underfilled matrices, difficulties caused.

Problems of optimization of spatial rod systems with respect to mass under many load cases, due to their multi-extremal nature, belong to nonlinear programming problems. The search for a global extremum is hampered by the nonlinearity and non-redundancy of the function. In addition, as the dimension of problems increases, difficulties arise due to the filling, conditionality, and inversion of weakly filled matrices, which have to be dealt with in optimization problems. All this negatively affects the possibilities of implementation, the results of calculations, and the calculation time of rod systems. In connection with the above difficulties that arise when solving problems of mass optimization of discrete and discretized systems, it is proposed to search for the optimum of the original problem based on a combination of decomposition techniques of unconditional minimization methods and the finite element method.

Minimization of the mass of solid plates, shells of complex shapes, etc. based on discretization using mathematical programming methods is one of the main approaches to the study of optimization problems of elastic continuum systems. However, with this search approach it is possible to optimize almost any continuum systems; however, the number of parameters is usually limited due to the difficulty of implementing problems of higher dimensions. If we take into account that the problem of optimizing a rod analogue in its general form is a multi-extremal problem, then the possibilities of searching for mass-optimal continuum systems with this approach are even more limited.

In order to solve the problem of mass optimization of continuum systems based on rod analogues, avoiding the computational difficulties that arise during

implementation, it can be considered not in a general form, but as a series of problems, according to formulations, but with a single goal - mass minimization. Let us consider the type of problems that are most common in the practice of designing structural systems.

Problem 1. Optimal distribution of thicknesses of continuum systems based on minimization by mass of rod analogues using a decomposition technique that combines minimization by mass of the rod system as a whole with subsequent local minimization of its individual subsystems.

Problem 2. Synthesis of optimal structures of plate elements of continuum systems at constant thicknesses.

Problem 3. Optimal distribution of continuum thicknesses for fixed values of nodal displacements of plate elements.

Since optimization for the mass of continuum systems is carried out on the basis of rod analogs, all three problems use a general mathematical model with appropriate transformations.

Algorithms for solving problem. The model for solving the problem has the following form:

1. The original continuum system is approximated by a rod system (rod analogue). Moreover, the frequency of dividing the lattice of the rod analog is assigned in such a way as, on the one hand, to obtain acceptable results, and on the other, to reduce computational processes.
2. The conditional extremal problem of optimization of a rod system of the form using penalty functions is reduced to an unconditional extremal problem
3. The above problem of optimization of the rod system is solved by unconditional minimization methods, analysis is carried out and stressed subsystems are identified.After optimizing the core system as a whole, local minimization is carried out using the mass minimization of its individual subsystems using unconditional minimization methods in sequence. (Fig. 1).

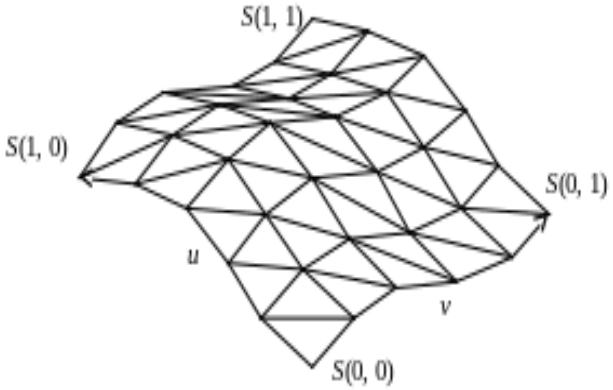

Fig. 1: Approximation of a continuum system by a rod analogue

An analysis of rod subsystems with an optimal lattice configuration as a whole is carried out.

A reverse transition is made from the rod analogue with the optimal lattice configuration and the synthesis of the rod system as a whole is carried out. The approach proposed in the work for finding the minimum mass of plate-rod systems of a closed volume is a special case of the developed algorithm.

Algorithm for solving problem 2. The model for solving the problem has the following

form.

1. The original continuum system is divided into finite elements and, based on the finite element method, a static calculation is carried out for a given number of load cases.
2. After analyzing the stress-strain state of the continuum system as a whole, more stressed plate elements are approximated by rod analogues while maintaining the conditions of equality.
3. The optimal structure of rod analogs is being synthesized with a constant height for the case of many load cases using unconditional minimization methods.
4. The optimal structures of rod analogues are analyzed, the elastic moduli and Poisson's ratios of the corresponding plate elements are adjusted.
5. A continuous system with refined rigidity characteristics of plate elements in elements in order to check the stress-strain state is again calculated by the finite element method.

Algorithm for solving problem 3. The model for solving the problem has the following form.

1. The original continuum system is represented by rod analogues with a lattice splitting frequency, which makes it possible to evaluate the actual nature of the operation of such a system.
2. A static calculation of the rod analogue is made for a given number of loads. The obtained values of nodal displacements are substituted into the mathematical model of the problem.
3. The problem is transformed into linear or convex programming problems based on the substitution of the value of nodal displacements obtained in the static calculation.
4. The problem of optimizing the rod system by mass is solved and the transition from the rod analogue to a continuous system with an optimal thickness distribution is carried out.

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