TASHKENT UNIVERSITY OF
INFORMATION TECHNOLOGIES
NAMED AFTER MUHAMMAD AL-KHWARIZMI

MUHAMMAD AL-XORAZMIY NOMIDAGI
TOSHKENT AXBOROT TEXNOLOGIYALARI
UNIVERSITETI

# BULLETIN OF TUIT:

## MANAGEMENT AND COMMUNICATION TECHNOLOGIES


***ISSN:2181-1083 DOI:0***

***Yakubov Sobir, Daminova Barno № 3s(58)2024***

# General formulation of the optimization problem for the elements of elastic structures

Yakubov Sobir,
General technical sciences,
Institute of Military Aviation
of the Republic of Uzbekistan,
Karshi, Uzbekistan
Sobiryakubov@mail.ru

Daminova Barno,
Algorithms and programming technologies,
Algoritms and programming technologies
Karshi State University
Karshi, Uzbekistan
barnod@mail.ru

*Abstract*— **This paper considers the classical formulation of the problem of optimal design of engineering structures. The results of solving optimal design problems determine the shapes, internal properties and operating conditions of structures that deliver the extremum of the selected characteristics of structures, taking into account additional restrictions.**

*Keywords*— *optimization, mechanical models, functionals, stress-strain state, strength, stability.*

## 1. INTRODUCTION

When designing various engineering structures, namely: construction projects, aircraft manufacturing, rocket manufacturing, shipbuilding, etc., problems arise in calculating and optimizing plate structural elements of complex configuration (plates of non-rectangular outline, with cutouts, multi-connected, etc.). The mathematical complexity of calculating such plate elements of arbitrary outline, especially their optimization, has led to a significant lag in scientific research and publications on the listed issues from the calculation and optimization of "traditional" types of structural elements.

## 2. RELATED WORKS

Russian scientists L.V. Kantorovich, N.N. Moiseyev, V.S. Mikhalevich, B.N. Pshenichny, Yu.M. Danilin, L.A. Rastrigin, L.I. Polovinkin, R.G. Strongin and others made a great contribution to the development of optimization methods.Optimal design of structures is one of the most complex and urgent problems in mechanics.When optimizing structures, the weight of the structure, cost, oscillation frequency, etc. are taken as the target function. The most widely posed problem is the design of structures of minimum weight, which are widely used in such branches of the national economy as construction, rocket engineering, aircraft construction, shipbuilding, etc.

The theory of optimal structures has been developed largely due to the works of famous scientists I.M. Rabinovich, A.I. Vinogradov, H.M. Mushtari, V.V. Vasiliev, Yu.N. Nemirovsky, A.A. Chiras, V.K. Kabulov, T.R. Rashidov, T. Buriev, K. Abdirashidov [7-8].

## 3.1. METHODS (OPTIONAL)

The paper proposes a new approach to automating the solution of optimization problems of engineering structures and buildings, based on the developed mathematical models. Theoretical prerequisites and principles for constructing automated design systems for solving classes of optimization problems of structural elements and buildings have been developed. Based on the systems approach, the issues of the internal organization of such systems, the functions of individual blocks and modules, and the end-to-end automation of the process of solving optimization problems from formulation to obtaining numerical results have been studied. A class of efficient algorithms for random search of both local and global extremums has been developed. The principles and methodology for constructing problem-oriented PPPs for optimal design of classes of structures have been developed. A number of important problems of calculating and optimizing engineering structures have been solved. Scientific and practical significance of the research results. The developed algorithms for solving optimization problems.

## 3.2. FORMULATION OF THE PROBLEM.

The formulation of the problem of optimization of elements of elastic structures is as follows: formulation of the main governing equations (mathematical models); selection of optimized functionality; restrictions on state functions and required control variables. An essential element of the problem statement is the choice of a mechanical model. First, select the state variables and its equations

$$L\,(x,\ u, h,\ q)=0, \qquad (1)$$

relating these variables to the physical and geometric parameters of the structure and external influences. Here is a vector function that determines the state of the structure. The independent variable takes values from the region Ω. Let L in (2.19) denote the differential operator with respect to the spatial coordinates xi. Equation (1) defines a system of differential equations that are generally nonlinear.

In this work, the main attention is paid to those theories in which the conditions of geometric and physical linearity are assumed to be fulfilled, and therefore the behavior of structures is described by operators linear with respect to state variables. Operator L depends on the projection vector function h={(h1 (x), ..., hn (x)} and the vector function of external influences q. The numbers m, n, l are specified and it is assumed that the boundary conditions that determine the methods of fastening and loading structures are included in the operator L.

The system of equations (1) with given initial data must be closed and determine the state variables characterizing the stress-strain state (SSS) of structures. Functions hi (x) determine the shape and physical and mechanical properties of the material of the structure. hi (x) can be, for example, distributions of thicknesses and cross-sectional areas of the body, functions that determine the position of the middle surfaces of curved rods and shells, and angles that specify the orientation of the anisotropy axes at each point of the elastic body.

In addition to the listed functions, structural optimization problems include functional characteristics - functionals that depend on u, h, q:

$$J_1 = J_1(u,h,q),..., J_2 = J_2(u,h,q). \quad (2)$$

In problems of optimization of elastic structures there are two types of functionals: Integral functionals

$$J_i = \int_{S_x} S_x(x,u,h,q)\, d\,\Omega,\ i = 1,\ ...,\ \tau_1. \quad (3)$$

And local functionality

$$J_j = \max_x f_j(x_1\, u(x),\, h(x),\, q(x)),\ j = \tau_1 + 1,\ ...,\ \ \tau_1 + \tau_2. \quad (4)$$

Fi denotes given differential expressions, and denotes given integers, and . By means of (3), such characteristics of the structure as weight, energy of elastic deformations, frequencies of natural vibrations, and critical load are represented. Local characteristics are maximum deflection, stress intensity.

Due to design requirements, there are restrictions placed on control variables and state functions. They form a system of inequalities and are written in vector form as:

$$\Psi(x,u,h,q,J_1,\ ...,\ J_2) \le 0 \quad (5)$$

The vector components are specified functions of the arguments. In specific problems, inequalities (5) can be restrictions of various types on stresses, deformations, displacements, integral stiffness or compliance, as well as on natural frequencies of oscillations and values of critical parameters of buckling.

One of the functionals under consideration or their function is accepted as the functional to be optimized. The optimization problem is to find a function h(x) that delivers a minimum (maximum) to the functional

$$J = F(J_1,\ ...,\ J_\tau) \quad (6)$$

and satisfying the relationship (1 – 6).

## 4. RESULTS

It should be noted that the number of considered functionals and imposed restrictions, which are assumed to be consistent, can in principle be arbitrarily large. There is only one optimized functionality or design quality criterion in each specific problem of type (1 – 6). So, for example, according to the moment theory of shells, the tasks of minimizing the weight of the shell with restrictions on deflections or minimizing the maximum deflection for a given weight can be set. But the problem of simultaneous minimization of the two indicated functionals does not make sense when using the classical definition of optimality.

## 5. CONCLUSION

Correct formulation of optimization problems with a vector quality criterion becomes possible when using the concept of optimality in the Pareto sense or other concepts of multicriteria optimization. The choice of functionals considered in optimal design is part of the formulation of optimization problems. This choice is influenced by many factors: the main purposes of the design; terms of Use; technological capabilities and implementations; cost restrictions; properties of the model adopted to describe the mechanical behavior of the structure; a priori properties of the optimal problem. The following describes the functionalities most often considered when optimizing a design. [7]

Weight – one of the main characteristics of the design, and therefore in most cases of optimal design, this functionality is either considered as an optimized quality criterion, or appears among other accepted restrictions. The weight of a structure characterizes both the consumption of materials necessary for its creation and some of its operational properties.

Weight is an integral characteristic of the design. For solid homogeneous bodies, the weight is proportional to the volume they occupy:

$$J = j\int_\Omega d\Omega \quad (7)$$

where j is the specific gravity of the material. For thin-walled structures made of homogeneous materials, the weight is represented by the integral of the thickness distribution function h:

$$J = j\int_\Omega f(h).d\Omega \quad (8)$$

For example, for a solid plate fixed along the contour Γ in the x, y plane (x, y are Cartesian coordinates), f=h(x, y), Ω is the area limited by the contour Γ. In this case, reducing the weight of the structure can be achieved as by changing the function h(x, y) for a fixed region Ω, and by simultaneously varying the thickness and shape of the regions. In the case of optimization of inhomogeneous bodies, the weight functional depends on the structures of the material, for example, on the concentration of binders and reinforcing additives of composite materials. If we denote by ha, ja, hc, jc the concentrations and specific gravities of reinforcing and binding components, then

$$J = \int_\Omega (j_a h_a + j_c h_c) d\Omega, \quad (9)$$

where Ω is the area occupied by the structure.

Rigidity. Often, in optimal design, the amount of work produced by external forces due to static loading of an elastic body is used as a measure of the stiffness properties of a structure. This functionality is called structural compliance. If an elastic body is fixed to part of the boundary Gi, and loads q are applied to another part of Γσ, then compliance is determined by the integral over Γσ of the scalar product of the vectors of elastic displacements u and external forces:

$$J = \frac{1}{2}\int_{\Gamma_\sigma} q \cdot u\, d\Gamma_\sigma \quad (10)$$

With a more general definition of the compliance functional, q and u can be understood, respectively, as generalized forces and generalized displacements.

***Stability.*** When optimizing thin-walled structures compressed by conservative forces, functional types of Rayleigh relations are considered, determining the critical values of loading parameters for which a loss of stability occurs. Let us denote by P the loading parameter, pT the work performed when bringing a unit volume of the structure to a critical state, and by Π the density of the potential energy of elastic deformations after loss of stability. Using classical concepts of the theory of elastic stability, we arrive at the following expression for the critical value P:

$$p = \int_{\Omega} \Pi(u,h)\, d\,\Omega \Bigg| \int_{\Omega} T(u,\, h)\, d\Omega \qquad (11)$$

Typical problems in the theory of optimal design of compressed structures are the problems of maximizing the critical value P0 (P0 is the minimum of the eigenvalues) for a given weight of the structure and the problems of minimizing the weight under the constraint , where μ is a given number. The results of solving these problems are given in [1-7].

***Local functionals.*** Above, we considered integral-type functionals, which are taken into account in optimization problems using classical methods of variational calculus. However, many important problems lead to functionals that depend on the values of state functions at previously unknown points. The main strength and deformation characteristics have a local character. Local functionals include such a characteristic of the rigidity of a structure as the maximum displacement of points of an elastic medium. As applied to shells and thin-walled structures, rigidity is estimated by the value of the maximum deflection

$$J = \max_{x \in \Omega} |u(x)|, \qquad (12)$$

and the problem of optimizing rigidity when varying the design variable h is naturally formulated as the problem of minimizing the maximum deflection.

Local functionals also include many strength characteristics of the structure. A typical functional of this type is written as follows:

$$J = (f)_{\Omega_{\varphi}} = \max_{x} f \qquad (13)$$

Here is the stress intensity or another measure of the stress state of an arbitrary point of the structure, and Ω0 is the set of points where the maximum of f is realized. Note that with proportional loading of bodies, the requirement to expand the range of permissible loads leads to the problem of minimizing the value of J

## REFERENCES

[1] Kabulov V.K., Nazirov Sh.A., Yakubov S.Kh. Algorithmization of solving optimization problems. – Tashkent: Fan, 2008. – 204 p

[2] Nazirov Sh.A., Yakubov S.Kh. Algorithmic system automating optimization processes for designing engineering structures and buildings // State Patent Office of the Republic of Uzbekistan. Certificate, DGU 01422. 11/13/2007.

[3] Nazirov Sh. Yakubov S.Kh. Development of an algorithmic system for solving classes of optimization problems // Strategy and development of science and technology in the XXI century: Proceedings of the Republican scientific-practical conference. Bukhara, 2009. v.2. – P. 91-94.

[4] Yakubov S.Kh. Methods and algorithms for the synthesis and analysis of design and technological solutions in the automated design system of engineering structures and buildings M.: INFRA-M, 2019.-164 p.

[5] Yakubov S.Kh., Khamraev A.A., Khushbokov I.U., Nurmatov Z. Algorithmization of CAD optimization of thin-walled elements of engineering structures//Universum: technical sciences: electron, scientific. journal. 2022. 11(104). - P. 54-59.

[6] Yakubov S.Kh., Khamraev A.A., Khushbokov I.U. Algorithmization of optimization models and algorithms for automated design of engineering structures (Russian Edition) // LAP LAMBERT Academic Publishing (October [10] 2022) Language : Russian 128 pages. ISBN-10: 6205507722. ISBN-13:978-6205507728.

[7] Raximov N. et al. As a mechanism that achieves the goal of decision management //2021 International Conference on Information Science and Communications Technologies (ICISCT). – IEEE, 2021. – С. 1-4.

[8] Raximov N., Primqulov O., Daminova B. Basic concepts and stages of research development on artificial intelligence //2021 International Conference on Information Science and Communications Technologies (ICISCT). – IEEE, 2021. – С. 1-4.