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Features of Solving Optimization Problems Taking Into Account the Specificity of the Process of Designing Engineering Structures

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Abstract:- The paper presents the main features of the approach used to solve optimization problems taking into account the specifics of the design process of engineering structures based on system analysis. System analysis provides the conditions for joint optimization of both the structural parts of the system (its subsystem) and the system as a whole, as well as the software of the tasks being solved. The ultimate goal of using system analysis in the design is the actual design of the system, its subsystems and components to achieve optimal efficiency and cost-effectiveness.

Keywords*:- Design, Object, Engineering Structures, Design Process, Control Process, Formalization, Algorithmization, System Analysis, Mathematical Model, Mathematical Modeling, Optimization Problems, Goal Function, Optimization.*

I. INTRODUCTION

The creation of any object is preceded by design, i.e. description of the object to be created. At the same time, the design object is understood as any "object" that does not yet exist in reality, for example, a machine, building and structure, process, system, computer complex, etc. In the future, we will be interested in design objects, mainly in the form of engineering structures and structures.

When setting optimization problems in the design of engineering structures and structures, one can find a double interpretation (understanding) of the system analysis (approach): on the one hand, it is the analysis of any really existing system; on the other hand, the formation of system parameters to achieve the set goals. In real conditions, these two sides are inseparable, since it is impossible to create a system that ensures the set goals without analyzing the content and defining real processes that will lead to the desired result. System analysis provides conditions for joint optimization of both the structural parts of the system (its subsystem) and the system as a whole, as well as the computer software. The ultimate goal of using systems analysis in design is to actually design the system, its subsystems and components to achieve optimal efficiency and economy. Despite the fact that there are no strictly defined rules in the system analysis, the main features are quite fully disclosed in [1,3].

The purpose of the design process is, first of all, to develop the technical documentation required for the manufacture of the design object on the basis of a priori (initial) information and a posteriori (additional) information obtained in the design process. Design is essentially a feedback control process (Fig. 1).

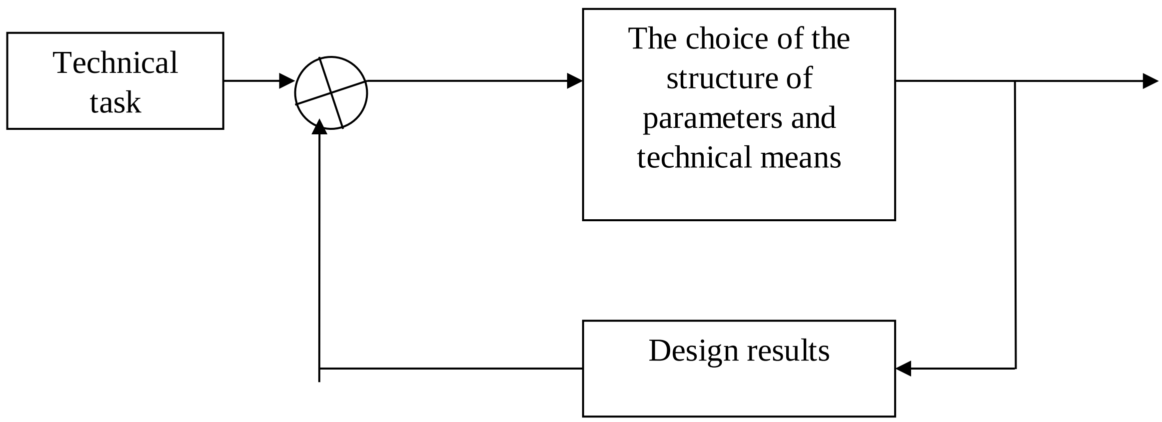

Fig.1. Design as a feedback control process

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The terms of reference, (TOR) generates inputs or inserts that are compared with the design results, and if they do not match, the design cycle is repeated again until the error (deviation from the specified technical requirements) is within acceptable limits.

The design process is carried out by the design system, i.e. a set of designers interacting with each other and the technical means necessary for the design. In essence, design systems can be viewed as complex human-machine multi-loop, multidimensional feedback control systems that require the collection, transmission, processing and use of information to achieve the design goal. They must be subject to one or another optimization criterion, for example, the criterion of the shortest duration or maximum performance with limited costs, or the criterion of the fastest payback of the designed system, etc. To reduce the design time, it is necessary to increase the speed of useful signals and to prevent the influence of interference, i.e. signals that do not carry useful information. Such hindrances can be incorrect or inaccurate intermediate results, or an unsuccessful choice of the structure of the design system, when the signals necessary for making decisions at some lower level reach the upper levels, where they can be not only useless, but also harmful. Thus, the systems approach, principles and methods of control theory are of significant interest for the rational organization of design processes [4,5].

II. METHODS

The process of designing engineering structures and structures can also be represented in the form of a hierarchy of decisions, which is conveniently represented using a graph. Taking point O (Fig. 2) as the formulation of the problem, the options for its solution can be represented by the sections a_1, a_2, a_3, etc. Several subproblems correspond to each variant: v_{11}, v_{12}, v_{21}, v_{22}, v_{23}, v_{31}, v_{32}, v_{33}, etc. Sometimes it may be possible to obtain acceptable solutions for all subproblems, in which case the designer must choose the option that best suits the design purpose.

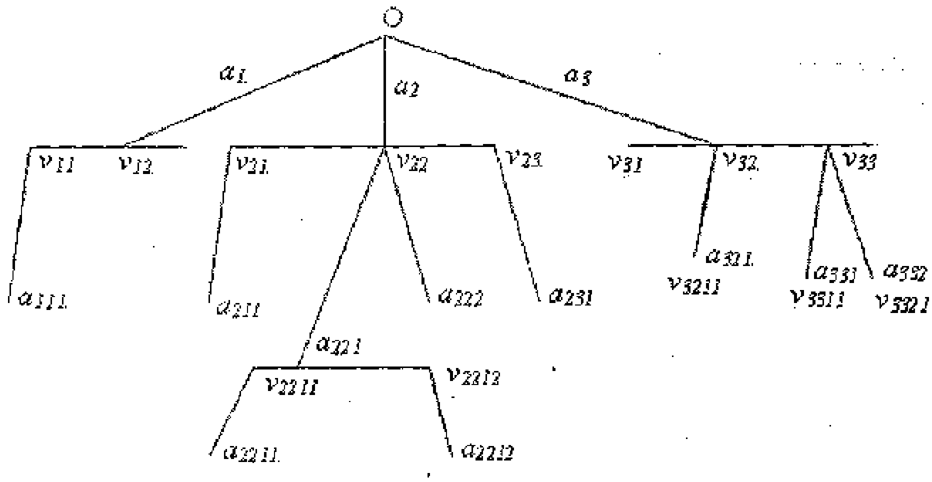

Fig. 2. The design process as a hierarchy of decision making

Suppose, for example, that after choosing option a_3 and solving all related sub problems v_{31}, v_{32}, v_{33}, it is found that there is no next level solution for sub problems v_{32}. Then it is necessary to discard option a_{321} and try to find a solution to other problems associated with options a_{331} and a_{332}. If, however, it turns out that none of the sub problems v_{3311} and v_{vvv} can be solved, then it is necessary to return back to the branching point of the previous, higher level (in this case, to the point O). The choice of ai options is a creative and difficult to formalize process. But as you move down the tree, the complexity of the formalization decreases, and the implementation of its solution becomes easier.

III. RESULTS AND DISCUSSION

Taking into account the specifics of the design process of engineering structures and structures and the tasks to be solved, the main features of the approach used can be reflected in the following provisions:

1. As an optimized projected engineering structure or structure, a certain complex of elements corresponding to the performance of functions is taken, endowed with specified properties and having abstract connections with external conditions and systems. In this complex, in the process of research, each element can be given the desired properties without taking into account the real characteristics in order to identify the possible contribution of these properties to the processes under study and, therefore, to justify the requirements for a promising solution of this element. In practical optimization problems, it is assumed that the properties of elements and their functional and technical characteristics are known, and therefore, the functioning processes are considered in the field of admissible (taking into account the accepted restrictions) solutions of systems. Both in the first and in the second, as well as in the case of software (development of algorithmic complexes), the evaluation of the complex under consideration is made taking into account the totality of known processes and phenomena and the relationship between them. All this brings to the fore such features of the model of the designed engineering structures and structures,

which help to clarify the mechanism of functioning of this complex in order to choose the least weight or costs. The most important thing is that in all cases the system includes the concept of a whole, consisting of interrelated, interacting and interdependent parts. Moreover, the properties of these parts depend on the system as a whole, and the properties of the system depend on the properties of its parts.

2. For a specific designed engineering structure and structure, a place in the general structure of other systems must be determined. The systematic approach requires a reasonable allocation of the system under study in the general composition of systems designed to maintain normalizing parameters, dividing it into subsystems. Structures or structures are considered as an independent object of study and optimization, but taking into account the necessary exchange of information with adjacent and external systems and within it - between subsystems. The selected general structure of systems should clearly outline the boundaries of the system under study and facilitate the selection (structuring) of such subsystems that are available for research in size and are homogeneous in description. All this ensures the organization of connections at each successive level of descent from the system to individual elements from top to bottom with the subsequent transfer of the received information upward (bottom-up). Integrity properties should be inherent in both the general structure of compensation systems and the subsystems of structures and structures: changes that have arisen in any of their parts affect both other parts and their entire set.

3. An engineering structure or structure is represented as a model. When designing complex systems, such as engineering structures and structures, knowledge is required about the quantitative and qualitative patterns of behavior of the system and its individual elements, depending on the nature of changes in numerous factors (parameters). The model should be similar to the original, but also different from it.

Its distinctive features are manifested in the fact that it undergoes such transformations in the desired direction, which are impossible with a direct study of the original. Mathematical modeling allows you to study only those parameters of the original that have a mathematical description that adequately reflects the behavior of the original. When developing a model, it is very important to get rid of connections and relationships that make it difficult to understand the object of research in accordance with the set goals.

At the same time, it is important that fundamentally clear ideas do not become overgrown with heavy and cumbersome details. The choice of a model is a central part of the work on the formation of the research methodology and depends on the main idea that determines the search for the extremum of the goal function. To solve a number of optimization problems, the well-known mathematical methods of finding the extremum of functions of several variables can be applied, for example, in classical mathematics, this is the solution of a system of linear equations obtained by equating to zero the partial derivatives of the function under study with respect to the optimized parameters, and the method of indefinite Lagrange multipliers.

These methods are valid in the absence of constraints on the optimized parameters or under equality constraints. With inequality constraints, nonlinear mathematical programming methods are used, subdivided according to the organization of the search process by the method of blind and directed search. The first of them includes the method of continuous enumeration of options with their ordering according to efficiency criteria and the method of statistical tests (Monte Carlo method).

Directional search methods include gradient, steepest descent, coordinate descent, etc. There are other nonlinear programming methods as well. Ultimately, the choice of a method is determined taking into account many considerations, of which not the least role belongs to the convenience of accessing the algorithm, the duration of the calculation, etc. It is also obvious that solving problems requires informal actions, the ability to intervene in the counting process and get intermediate results for the implementation of the dialogue mode.

It is known [3] that the choice of a model largely depends on intuition, experience, skills of informal thinking, on ideas about the essence of the interconnection of inputs and outputs for the system itself. At the same time, first, it is necessary to clarify the tasks, the solution of which should be facilitated by the model.

When setting this task, the model should provide:

a) the ability to generalize any initial conditions (factors) into a form of design information that greatly facilitates the targeted selection of competing options for structures and structures, the composition of subsystems and modes of their operation;

b) Investigation of the nature of the relationship between the defining parameters of systems and subsystems, depending on the conditions of the object's functioning;

c) presentation of the defining parameters in the form of coordinates of the state of the system, the use of which makes it possible to calculate any technical and economic indicators, both of a separate subsystem and of the system as a whole.

The structure and structure model can be deterministic according to the conditional interconnection of inputs and outputs for the system itself. It is practically impossible to manage with one model; a system of models is needed - a set of interconnected models of individual subsystems. The system of models should create the ability to independently solve individual problems without violating their subsequent coordination, taking into account all the connections between subsystems.

4. To assess the quality of solutions of the designed structures and structures, a set of indicators is selected. As a rule, the purpose of the system analysis is to achieve the best (optimal) solution of the designed structures and structures in terms of their structural, economic and other indicators,

with all possible characteristics of external relations. However, optimum and optimality are not absolute concepts; they require precise definition of optimality criteria, i.e. the main features on the basis of which the comparison of the effectiveness of various solutions is made.

The solution that is the best in some conditions and according to one criterion may turn out to be far from the best in other conditions and according to another criterion. Optimization according to one criterion (sub optimization) is most often performed for technical systems in terms of reduced and costs (in this study, the weight of the structure is taken as the objective function).

5. The results of the analysis on the model of structures and structures should be transferred to real systems. Transferring solutions to a real object requires confidence in the adequacy of the solution. Adequacy is assessed by analogy of the properties of a real object and a model in terms of basic features. Adequacy is achieved if the model fully reflects the stress-strain state (SSS) of the actually existing designed structures and structures. The main provisions of the system approach listed and accepted for execution characterize only the initial basis of the method, however, the effectiveness of its use completely depends on the chosen method of their implementation [2].

IV. CONCLUSIONS

To systematize and generalize information about the main features of system analysis, which contribute to the presentation of disparate data in an ordered form with a smaller number of existing variables, it is necessary: to systematize the relationship between systems designed to maintain normalized parameters; analyze numerous initial conditions, find a form of their generalization; suitable for the classification of the defining conditions of the VAT system; to identify an appropriate classification of a structure or structure, contributing to the targeted selection of their competing options; determine the principles of decomposition of systems, based on the analysis of their totality as a whole; formulate the initial basis for building a mathematical model of a structure or structure; to classify optimization problems arising in the practice of research and design [4,5].

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