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The methods of functional analysis and the principles of diagnostic of stress-deformed condition of construction structures

The article proposes an approach to the formation of the theoretical foundations of system analysis and the synthesis of the functioning of complex engineering constructions on an example of control of a stressed-deformed state in their operation.

Operation of new and existing technical objects is carried out in accordance with the existing instructions. Operational failures are registered with special commissions and control services. More complex accidents and disasters investigate by special interdepartmental commissions. According to the results of these servises, design and technological solutions aimed at preventing new failures and accidents are adopted [1].

The general complex of work on determining the source and residual life, survivability and safety of elements of complex technical objects such as hydroelectric power stations, rocket and space complexes, aircraft, shipbuilding, nuclear power stations, etc. must include investigations of loads, strains and deformations. Nowadays there are a number of methods for conducting such researches, in particular, the calculation method, the analytical method, the finite element method, the variational and difference method, the method of boundary integral equations on models using photoluminescence, holography, low modulus materials, etc. [2, 3, 4].

Then comprehensive research is carried out [5, 6, 7]. Although the search for systematic approaches to decision-making in the design of complex structures is carried out continuously, the need for them with each passing year becomes more significant.

Solving the problem of reducing the cost of maintenance of complex engineering structures is possible on the basis of the introduction of technical diagnostics as a set of tools and methods of continuous control. Such control is possible due to the introduction of automated diagnostic systems (ADS).

The experience of creating ADS hardware allows you to determine a number of basic principles for the development of such systems [6, 8, 9 and 10]. It should also be noted that the formulation and systematization of the basic provisions of the functionality and technology of complex technical systems can determine the range of tasks that are to be solved as a result of the construction of such ADS. In the case of consideration of complex metal structures in the conditions of operation, the question of diagnosing the stress-strain state of such structures is in the foreground.

The diagnostic methods that determine the complexity of the diagnosis, the duration and volume of the calculation processes, the complexity of the hardware and software, the system performance, the reliability of the diagnostic information, the degree of completeness of the diagnosis and the depth of the search are important for the creation of the ADS [4, 8].

The evaluation of the results for the goal is achieved by introducing the definition of efficiency for complex designs, taking into account the design strategy u ($u \in U$ as a minimum of the resource consumption to achieve the goal); the criterion of the effectiveness of a technical solution that defines the rules of rational behavior of complex design in the form of optimization of the processes of achieving a fixed goal $K(u)$; performance indicator $W(u)$ - integral quality indicator of complex design. For designed complex structures $W(u) \in 0 \div 1$ - a scalar, whose value should be as a maximal.

The morphological analysis of existing requirements allows formulating the following defining parameters:

$m_{ск}$ - the mass of complex design is given;
t - given efficiency;
H - given distance of moving complex system (height);
A - the resource consumption needed to achieve the goal.

On the basis of the dimension theory [9], which was used by us to describe the technological process of a complicated technical design with moving parts, and the morphological analysis of existing requirements concerning the technological efficiency of such a construction, we determined the form of the function in the parametric coagulation of parameters:

$$X(T) = G\frac{m_{ск} T H_{max}^2}{t^3 A}, \tag{1}$$

G – Constanta of predicted efficiency of a complex technical system;
T - time of functioning of a complex technical system at the time of analysis;
H_{max} - the maximum distance of moving a complex technical system.

At the next operating level the problem of choosing a technology of complex design (technological operations of manufacture and putting into operation) is solved. The synthesis of the functions of preparation and putting into operation is based on the solution of the Pontryagin task [5] for linear and nonlinear equations describing the technological processes.

The model of technological processes is described by a system of equations:

$$F_i\left(w_i,\ \dot{w}_i, \dots, w_i^{(k)}, \xi, \dot{\xi}, \dots, \xi^{(k)}, t\right) = 0, \quad i = 1, \dots, l;\ \ w_i \in R^q,\ \ \xi \in R^s \tag{2}$$

ξ - generalized coordinate state of complex construction of R^q (smooth function of time);
w_i - variables of R^s,which characterize the change of external parameters, such as pressure, density, voltage, temperature, etc .;
R^q - q-dimensional vector of external parameters;
R^s - s-dimensional vector of states of complex construction.

With such a statement of the problem of technology synthesis, using the analytical provisions of the theory of systems [6], we can prove the following theoretical positions:

1. For the technological processes described by the linear equations, all aggregates and devices implementing the processes of spatial displacement of objects of complex design for which the notion of absolute solid can be admissible may have a description of these processes in the form of linear differential equations.

   This provision allows us to formulate and prove the theorem that the minimum realization of the spatial movement of the target object during the preparation for operation corresponds at the functional and analytical level to one for each of the target objects of the design.
2. For technological processes described by nonlinear equations, all mechanical systems providing the creation of necessary flows of continuous media between moving parts and the ground structure of a structure are described by physical laws in the form of nonlinear differential equations.

   This provision allows us to formulate and prove the theorem that the minimal realization of mechanical flow processes, which accompany the process of preparation and commissioning of the structure, is achieved, provided that technological processes occurring in the form of processes are selected. These processes do not have a non-stationary dominant or admitting of their linearization.
3. The structure of the structural element, which permits formalization in the form of a combination of a pair of elements, has a minimal parametric realization, which corresponds to its maximum efficiency in achieving the set goal, if the graph in the structure of the structural element contains a perfect substitution.

   This provision allows us to formulate and prove the theorem that a perfect structure of a structure with a minimal input of resources for the realization of the set goals corresponds to a two-row graph with perfect interconnection.

Conclusions

1. At present there is a system of criteria and stocks of strength, which guarantees the performance of the object in accordance with the prescribed operating conditions. However, some standard materials do not contain direct data that quantitatively determine the security of an object. More focused on the quantitative solution of the safety problem of complex structures are the following criteria: reliability in the conditions of operation; survivability (stability) in the formation of damage at different stages of the development of failures, accidents, disasters; safety (taking into account the criteria and characteristics of failures, accidents, disasters). However, the volume of valuation of these safety and reliability characteristics in real engineering practice is extremely small.
2. On the basis of morphological analysis of complex technical constructions it is proved that: the minimum realization of spatial movement of an object during the preparation for operation corresponds at the functional and analytical level to one for each of the target objects of construction; The minimum realization of

mechanical flow processes is achieved by choosing technological functions that do not have a non-stationary dominant or admitting their linearization.

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