Chapter 4

Some Areas of Development of Methods Structural Mathematical Modeling

ABSTRACT

Mathematical modeling of mechanical oscillatory systems using structural analysis methods is considered. The main focus is on the interpretation of the dynamic interactions of the system elements using structural diagrams, which makes it possible to obtain new results in the theory of vibration technologies, transport dynamics and vibration protection. The main approaches to the transformation of mathematical models into structural analogues are presented, including the use of dynamically equivalent automatic control systems. This allows you to apply frequency analysis and dynamic synthesis methods to solve vibration protection problems. Examples of single-degree-of-freedom mechanical systems include models with springs, dampers, and mass-inertial links. Frequency equations and concepts of dynamic stiffness of elements and the system as a whole are analyzed. Particular attention is paid to resonant vibrations and their effect on the dynamic properties of the system.

CHARACTERISTIC FREQUENCY EQUATION: STRUCTURE, DYNAMIC STIFFNESS, FEATURES OF INTERACTION OF ELEMENTS SYSTEMS

Mathematical modeling is widely used in solving various problems related to the assessment of the dynamic state of technical objects (Eliseev, 2018; Lontsikh & Eliseev, 2014). Structural mathematical modeling methods are a fairly developed

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direction defined by interdisciplinary space defined by the methods of system theory, automatic control theory, circuit theory, graph theory in their various forms of applications (Eliseev, Volkov, & Kukharenko, 1990; Eliseev & Khomenko, 2014). The dynamics of mechanical oscillatory systems with concentrated parameters was reflected in many works on the theory of linear and nonlinear oscillations, which, in a certain sense, predetermined the interest in the formation and peculiarities of connections arising in dynamic interactions between the elements of the system under periodic influences. A number of rather developed applications are known related to solving the problems of the theory of vibration technology, vibration technologies, problems of transport dynamics, vibration protection and vibration isolation of technical objects (Belokobylsky, Eliseev, & Sitov, 2013).

The interpretation of the dynamic interactions of elements of mechanical systems, displayed by structural diagrams of dynamically equivalent automatic control systems, became the basis for the formation of unconventional approaches, which initiated the introduction of a number of new questions into the consideration related to ideas of expanding ideas about the set of typical elements, methods of their connection, the possibilities of structural transformations and the identification of dynamic features (Eliseev, Kuznetsov, Bolshakov, et al., 2015; Khomenko, Eliseev, Artyunin, Bolshakov, Kaimov, Kinash, & Nguyen, 2015).

Questions about the relationship between characteristic frequency equations of linear mechanical oscillatory systems with concentrated parameters and ideas about possible structural forms, the implementation of connections between individual elements of the system or their structural analogues are considered.

One of the directions of structural mathematical modeling is the use of dynamically equivalent automatic control systems as mathematical models of structural schemes. The approach is based on dynamic analogies arising from interactions of elements of mechanical oscillatory systems of various nature and corresponding interactions between elements of the automatic control system. The commonality of interactions in systems is determined by one-to-one relationships with the original mathematical model in the form of a system of ordinary differential equations with constant coefficients. The approach is generalized and can be extended to systems with distributed parameters (Eliseev, 1978; Halperin, 1968; Shatalov, 1962) .

Figures 1, *a-e* show different interpretations in representations of the original physical model as a mechanical oscillatory system with one degree of freedom. Such models are widely used in the tasks of machine dynamics and protection of equipment and equipment from vibrations, shocks, etc. The mechanical system in Figure 1, *a* consists of the so-called typical mechanical elements in the form of a spring *k*, a damper *bp* and a mass-inertial link *m*. The mass inertial element can be considered as a control object (in the tasks of vibration protection - an object