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BASIC THEORETICAL PRINCIPLES OF THE ELECTRIC ANALOGY METHOD

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A task is set to develop electrical analogy method for analyzing and designing electromechanical systems of technological equipment with consideration for properties of fibrous products and dynamics of its movement during formation and transportation process.

Specific of the developed procedure is its physical orientation on the basis of the electrical analogy method, i.e. representation of electrochemical systems in form of equivalent electric circuits. Analog modeling of electrical networks is the most convenient means for analysis and designing of technological and dynamic modes of operation of complicated textile equipment and for implementation models on a PC.

Direct analogy mathematical model for electromechanical systems is an electrical network. It is easy to convince oneself in identity of mathematical descriptions by comparing equations of electrical networks with equations of the prototype mechanical system.

The model under consideration is based on the electric analogy principle, where elements of mechanical systems are represented and regulated.

Comparison of the model of direct analogy of electromechanical system in form of electric network and structural model demonstrate that the first one distinguishes itself by a significantly greater visualization, since each mechanical element has its electrical image.

It is shown below that electrical network–analogue appears to be convenient also for pure circuit analysis of complex electromechanical systems, their transformation and simplification.

At present, structural models are implemented with the aid of modern computers and with the appropriate software.

Advantage of direct implementation of simulative model electric circuits becomes apparent when prototype systems have a great number of linear passive elements (inductances, L; capacitances, C; resistive elements, R), i.e. they have a branched electrical network and complex mechanics.

Electrical network remains a visual and generalized image of a prototype system also with indirect method of its implementation thanks to advantages of electrical analogy. With indirect methods, electrical network model is implemented completely as a circuit design, directly according to the diagram of this circuit, enabling each element to change its parameters independently. In this case, a special "four-terminal network method" was used.

In this article, based on the above said, along with well-proved principles of structural modeling of electromechanical systems of technological equipment, possibilities of direct and indirect use of electrical analogies of mechanical systems, as well as issues of generalization of experimental data and development of engineering and designing methods for solving problems of controlling process of formation, winding-up and transportation of materials are considered.

It should be stressed that method of generative electrical modeling provides a better visualization of physical process, which enables to go into the heart of the matter, and sometimes to discover some logic and regularities in the system, which are difficult to identify when solving problems with regard to separate individual cases.

Characteristic feature of correct statement of modeling problems consists in physical approach to investigations carried out on models [1]. A model is analyzed and revised part by part by means of conducting additional experiments in individual systems, which can be analyzed separately, for instance, by introducing disturbances, carrying out linearization, etc.

It should be stressed that issues of employment of electrical modeling of dynamic systems did not receive sufficient attention in technical literature.

For a wide class of nonlinear problems of dynamics of electomechanical systems with forwarding and twisting mechanisms, namely, for cases when electromagnetic inertia of drivers should be taken into consideration, family of nonlinear mechanical characteristics, deformation properties of products of spinning and other factors, to investigate dynamics of systems considering flexible and elastic couplings in power transmissions, employment of structural modeling method, especially direct analogy method, requires development of special procedures, which are beyond of the scope of standard methods of modeling with differential equations.

Formation of equivalent electrical circuits of models for mechanical systems is carried out in accordance with the electromechanical analogy theory [2].

Let us consider electromechanical analogy theory with regard to modeling of elastic systems consisting of finite number of lumped mass, which is connected with elastic couplings. Elastic system, position of which is determined with the aid of n independent coordinates, is a system with n degrees of freedom.

A distinction is made between mechanical systems with linear and angular movements, which are expressed with similar equations. For the purpose of analysis of deformation properties of fibrous product during its transportation, let us define fundamental quantities of longitudinal displacement of the mechanical system: linear displacement y, m; force F, N; mass m, kg; rigidity $c_п$, N/mm; compliance $e_c=1/c_п$, mm/N; frictional resistance $S_{f.r}$, N·s/mm.

Electric models in form of circuits and passive elements can be built according to two electromechanical analogy systems [3].

A real mechanical structure during modeling, as well as during analytical study is represented in form of a dynamic system consisting of idealized elements.

One-dimensional linear mechanical systems contain elements (components) of three types: elastic, inertial and friction ones.

Elastic elements are marked by the fact that in them there is a restoring force (proportional to the extent of element's deformation), which counteracts the relative displacement of ends (deformation). Elastic element is represented in form of an idealized spring, which is deprived of friction and mass.

Inertial elements are represented in form of "material points" - absolutely rigid bodies and are described with the aid of absolute displacements.

Elements of (linear) viscous friction are those in which a force counteracts relative displacement of ends, being proportional to the speed of relative flow. Similar to the fact that idealized elastic elements are deprived of friction, friction elements are deprived of elasticity and mass. It is common practice to designate elements of (linear) viscous friction as $S_т$, N·s/mm.

Mechanic elements m, e, $S_т$ are simulated accordingly by passive elements of electrical network L, C, R. External elements effect the elastic system, which, in general case, can be time variant according to any law. External force is simulated by voltage source U(t), internal resistance of which is low. Values of external forces, assigned in the simulator (model), will not depend on the load, i.e. from the network which simulates the elastic system.

It is assumed that with application of loading of the prototype system values of external sources also do not change.

According to analogy system, circuit of electric model copies the representation of the mechanical system.

Mechanical elements and their electrical analogues are presented in Fig.1.

It is advisable to employ method of four-terminal network to construct electrical models of complex dynamic systems consisting of elastic, inertial and friction elements connected in form of chains of these elements or containing several branches from such chains [4]. Method of four-terminal network enables to use a unified approach to solve problems with lengthwise and twisting movements.

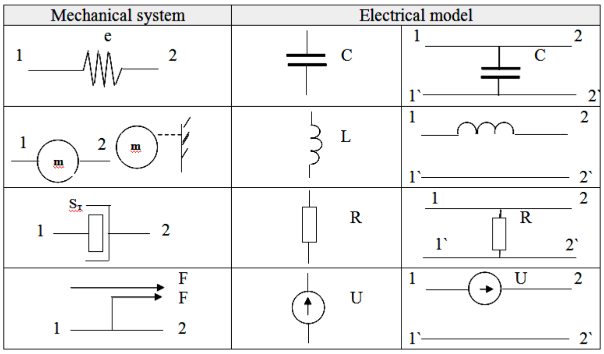

Fig. 1. Mechanical elements and their electrical analogs

A model is constructed from separate elements of four-terminal networks the same way, like prototype system is composed from elements-components. Each element of the prototype mechanical system is replaced by an element of electrical model – by a four-terminal network representing relations between forces and dynamic displacements at the ends.

Fig. 1 displays equivalent networks (four-terminal networks) for elements of elastic system under tension and twisting. Lumped mass has a equivalent network in form of inductance. Models of friction element are four-terminal networks, which have ohmic resistance.

In coupling points of passive four-terminal networks (replacing elements of the mechanical system) voltage sources are included, which correspond to application of external forces.

Open-circuit terminations of four-terminal networks correspond to a rigid fixation of end of the mechanical element. Short-circuited outputs of the four-terminal network correspond to free points.

The direct analogy method being used provides physically a clearer idea of systems under consideration, possesses certain advantages in simulating systems with reversible transducers of energy. On the basis of direct analogy method, controlled four-terminal networks can be created, which represent elements of electromechanical systems and areas of movement of fibrous products, with the aid of which different operational modes can be investigated (including high-speed mode).

Important advantage of this method is the fact that models offer the possibility to increase reliability and accuracy of simulation results. This can be explained by the fact that this method enables to construct models not on the basis of formal display of initial equations of the system under investigation, and according to the equivalence principle of equations of object and model with regard to results to be obtained, i.e. to make correction on the basis of simulation of real characteristics of electromechanical systems.

On the basis of the above said, employment of direct analogy methods for some problems of elecromechanics is quite justified, especially when utilization of methods of the automatic control theory and computers raises the capabilities of passive electrical networks with R, L, C.

On the basis of electromechanical analogy method the authors have studied dynamics of fibrous material in the controlled area of the card; in addition, they have studied process of formation of the lay at the outfeed of the card's measuring hopper. Drafting and forming zones are represented as systems of automatic control [4].

CONCLUSION

Along with well-proved principles of structural modeling of electromechanical systems of technological equipment, possibilities of direct and indirect use of electrical analogies of mechanical systems, as well as issues of generalization of experimental data and development of engineering and designing methods for solving problems of controlling process of formation, winding-up and transportation of fibrous materials are considered.

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