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STRUCTURAL AND PARAMETRIC SYNTHESIS OF FUNCTIONAL MECHATRONIC MODULES OF MACHINES FOR FORMATION OF TRANSPORTATION PACKAGES OF FOOD PRODUCTS

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Abstract: *The paper deals with the research direction of mechatronic systems operations control, which is understudied and not realised in terms of correction system's energy resource. The authors suggest a technique for implementing energy efficiency management for a mechatronic packaging module system, based on the classical principle of least action, according to which working bodies movement is ensured. The control system was expected to be able to estimate the possible trajectories of working bodies movement by analyzing the energy cost of the mechatronic packaging system. To perform this task an additional energy control vector was added to the mathematical model, which value significantly influences the calculation of the control output characteristic. It is also suggested to estimate the energy cost of a mechatronic packaging system by analyzing integral energy characteristics obtained during the technological cycle packaging cycle, taking into account the energy consumed.*

Keywords: *Efficiency, Effectiveness, GPS, Seismic Protection Methods, Model*

INTRODUCTION

Traditionally, the quality of mechatronic systems control is determined by a set of indicators. Among the main ones, the indicator of electrical energy efficiency, which is characterized by the following factors: design solutions quality (choice of the structure, scheme and technical means of control); taking into account dynamic operation modes and adjusting the regulators accordingly; choice of laws of change of control and disturbing influences.

However, it is quite difficult to use single conceptual approach to determine the energy efficiency criteria of mechatronic packaging systems because of their specificity, which requires taking into account the impact of functional and structural features of their structures on a case-by-case basis.

Along with that, there is another possible direction of correction of mechatronic systems, which is poorly researched and almost not realized – the correction of the energy resource of the system.

Microprocessor control system operation mechatronic packing module should contain additional means of evaluation and analysis of criteria for efficient use of energy resource and have an impact on the executive system, which will ensure the movement of the working body in accordance with the optimal trajectory. This means that to increase the efficiency of energy resource use it is necessary to expand the information resource of the control system of the mechatronic module of packing.

EXPOSITION

Problem statement. The formulated problem defines the main purpose of research of mechatronic packaging systems – to develop a mathematical model for estimating the energy

resource of mechatronic packaging systems, taking into account the structural features of the interconnection of energy and information resources.

Main part. The methodology of estimation and management of mechatronic module energy resource involves the development of a mathematical model.

The typical control structure of the mechatronic packaging module can be seen in the form

$$x^{\cdot}(t) = f[t, x(t), H(t,\tau), u_{\downarrow}1, (t-\tau_{\downarrow}1), u_{\downarrow}2(t-\tau_{\downarrow}2] \quad (1)$$

Where $x = \{x_i\}$ - are the variables; $f(\cdot)$ - are the correction function vectors; $H(t,\tau)$ - are the coupling functions between variables; u_1 – characteristic of the control system, $u_1 = \{u_{1i}\}; u_2$; - characteristic of external influences, $u_2 = \{u_{2i}\}; \tau_1, \tau_2$ - characteristic of delays in processing and signaling. The disadvantage of such a control system is the lack of control and influence on the energy balance of the mechatronic module.

Further modernization of the control system implies the creation of the objective function of energy resource management in the structure (1) and is to support or increase the efficiency of the system, namely:

$$E[x(t),\ f(\cdot), u_1(t), T] \geq E_0 \quad (2)$$

$$x[(t,T), u] \approx x_0(t,T), \quad (3)$$

where, T - is the time interval during which the control signal operates; $x_0(t,T)$ - is the function of the optimal law of motion.

If equation (2) is added to the control algorithm of the mechatronic packing module, then along with the kinematic and dynamic characteristics of the operation it is possible to obtain instantaneous changes of the energy resource of system E at the interval T. However, the energy resource values will have an error of information delay, the value of which depends on time of information gathering and signaling.

We use the algorithm for determining the magnitude of error used in complex control systems and introduce the notion of conditional error tolerance, which in our case will have the predicted value of estimating the efficiency Δ.

In this case, the task of the energy resource management subsystem will be to form a control signal $u_1(t)$, which, given the given energy resource management functions, takes into account the deviation of the obtained values from the real variables at the interval such that the efficiency of energy use of the mechatronic system *E(x)* is substantially is not reduced and is always within the specified error:

$$\left|E[x(0,t)] - E[x_0(0,t)]\right| \leq \Delta \quad (4)$$

To realize condition (4), the control process $u_1(t)$ is supposed to be carried out by known methods, which have different nature of its formation: adaptive, synergistic, programmatic, restrictive. Regardless of how the control signal is generated, the end result of a change in energy resource in the mechatronic pack module is to establish a relationship between the control signa $u_1(t)$ for the actuator and its component subsystem $u_2(t)$, which forms the optimal balance characteristic. Thus, the operation of the new mechatronic packing module control system is described by inequality

$$E[x(t), u_1(t), u_2(t), T] \geq E_0 \quad (5)$$

Another dominant factor in the operation of the control system of mechatronic packaging modules is the constant analysis of energy processes during their operation.

To analyze the quantitative assessment of the efficiency of energy use of the mechatronic module energy resource, it is proposed to determine the coefficient of integral energy characteristics obtained during the technological cycle of packing taking into account the consumed energy.

The main components of this coefficient are:

- energy efficiency of mechatronic packaging system

$$k_{p.a} = \frac{E_M}{E_M + \Delta E_n + |\Delta E_{0M}|} \quad (6)$$

where E_M – is the energy spent by the mechatronic system to carry out the work of packing in time T; ΔE_n - is the total energy of losses in all elements of the electromechanical system during time T; $\Delta E_0 = \Delta E_M - E_{0M}$ - the difference between the real and theoretical (under ideal working conditions) energy of the mechatronic system spent on the work of packing.

- full energy efficiency

$$k_{p.n} = \frac{P_M}{S}, \quad (7)$$

where, S is the total power of the mechatronic packaging system that characterizes the mode of its power consumption;

- efficiency of electric energy conversion

$$k_{p.e} = \frac{P_e}{S}, \quad (8)$$

where, P_e - is the active power consumed by the mechatronic packing system.

To verify the adequacy of the analytical results obtained, an experimental installation of a functional mechatronic module of linear movement of structural units of group packing was made (Fig.1). The operation of the mechatronic module control system was based on the implementation of the specified law of motion of the working body under the condition of energy resource management according to the suggested mathematical model.

Fig. 1. General view of the experimental installation of a mechatronic module with a linear motor, for the performed technological linear movement of structural units of group packaging: 1 - a linear motor; 2 - controller; 3 - feedback system.

The results of analytical studies of energy consumption are presented in the form of graphs of energy consumption (total and reactive) during the implementation of the optimal law of movement of a number of consumer packages. A variable external factor for determining the quality of consumption by the mechatronic module of the energy resource was the angle of inclination of the generating plane (Fig. 2).

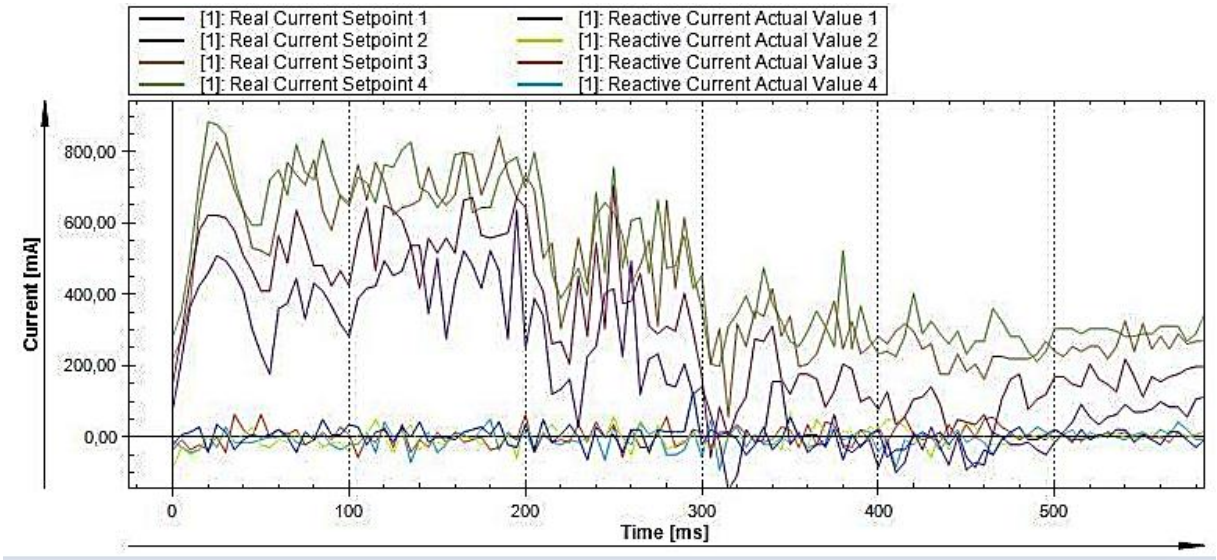

Fig. 2 Energy consumption in the mechatronic module of linear displacement during the operation of pushing a row according to the optimal law of motion (mass of 4 packages 2 kg, distance 270 mm) with the angle of inclination of the plane:: 1- 0^0; 2- 30^0; 3- 60^0; 4- 90^0.

CONCLUSIONS

The mathematical model of mechatronic packaging system allows to determine the main ways to increase the efficiency of its energy resource taking into account the structural features of the structure by:

- development of optimal structure of mechatronic modules and its elements based on their energy consumption characteristics;
- determination of quality of control system of mechatronic packaging systems by the criterion of efficient electic energy use;
- development of methods for diagnosing and recovering energy resources of mechatronic packaging systems.

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