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Increasing the efficiency of the functional mechatronic module for packaging liquid food products

Oleksandr Savchuk, Oleksandr Gavva, Liudmyla Kryvoplias-Volodina
National University of Food Technologies (NUFT), Kyiv, Ukraine

Introduction. Improving the efficiency of functional mechatronic modules for dosing liquid food products is an urgent problem in the modern food industry. Existing solutions, although providing tightness and ease of operation, have limitations in regulating flow characteristics, which leads to the formation of product residues and reduced production efficiency.

This research is aimed at developing and implementing new approaches to controlling the flow of liquid food products in mechatronic modules to ensure continuous and accurate dosing. The proposed solutions will optimise production processes, reduce product losses and increase the overall efficiency of food processing companies [1].

Relevance. The need for accurate and efficient liquid food dosing systems is constantly growing. Existing mechatronic modules do not always meet modern production requirements. This research is aimed at developing innovative solutions to improve the accuracy and flexibility of dosing systems, which will increase the competitiveness of food companies.

The aim of the study is to optimize the process of dosing liquid food products by analyzing and improving the design of mechatronic modules. In particular, the research is aimed at studying the impact of different types of shut-off elements (ball valves, seat valves, etc.) and control systems on the dosing accuracy and stability of the equipment. The results will allow us to develop recommendations for selecting the optimal components and system parameters to ensure high efficiency and quality of food dosing.

Discussion of the research results. The scientific novelty of the study lies in the development and experimental substantiation of the optimal operating parameters of the mechatronic module for dosing liquid food products using different types of locking elements. For the first time, a detailed comparison of the efficiency of ball valves and seat valves under dynamic operating conditions was carried out, which made it possible to determine the optimal type of locking element for different technological processes [4,5]. The results obtained can be used to create more efficient and flexible production lines in the food industry (fig.1).

To control mechatronic dosing systems, two types of distributors are currently used: proportional and discrete. When developing the mathematical model of the distributor, the main difference is the type of the applied signal. Thus, for proportional distributor the signal changes smoothly from zero to the final value. For discrete spreader the input influence is stepwise. Note, in the case of proportional distributor the input signal can also be set as a step input. The distributor coil is an electromagnet (hereinafter referred to as EM). EM (Fig.1, a, c) consists of a cylindrical body-magnet conduit 1, in which coaxial winding 3 is located. Inside the housing there is a cylindrical armature 2. The magnetic flux passes through two gaps: working flat 4 and parasitic radial 5. Where F_e is the electromagnetic force, y is the spool linear displacement.

Fig.1, b) shows the dependence of the force developed by the electromagnet force F_e on the spool displacement in case of using discrete distributor with electromagnet with 'flat stop'. distributor with electromagnet with 'flat stop'.

Mathematical modelling of the distributor system is performed in the form of in the form of equations and block diagrams of its individual elements. Modelling of the system is especially important, as it is faster and cheaper than carrying out a physical experiment.. The results obtained from the mathematical simulation can be used to optimise the system, The results obtained from mathematical modelling can be used for system optimisation, determination of operating modes, causes of possible failures, etc.

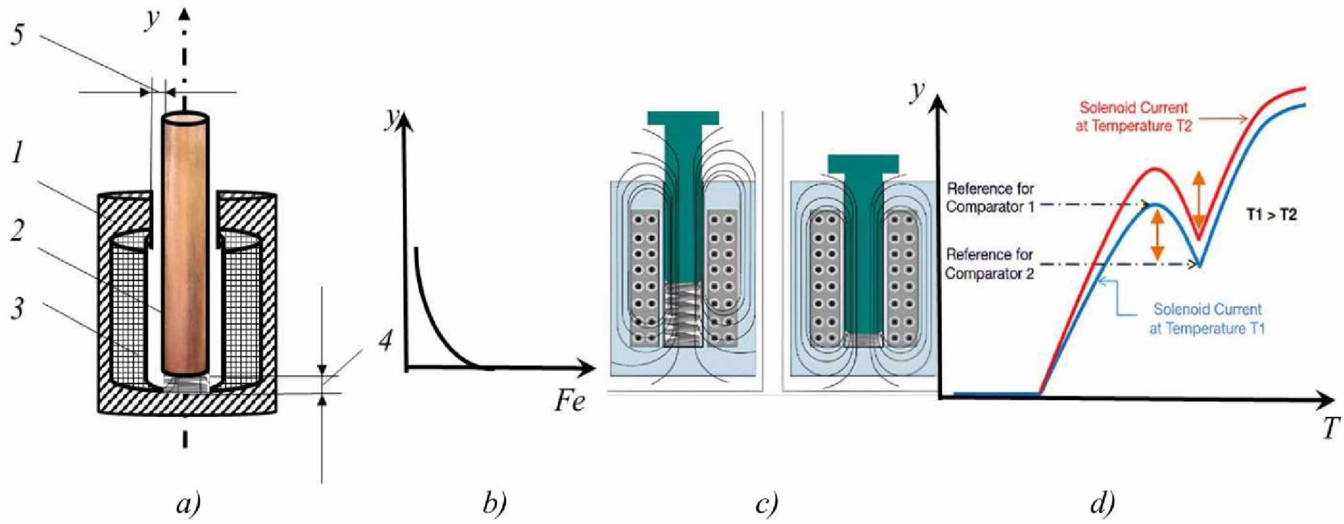

Figure 1. Experimental model of a controlled solenoid as part of a precessionary distributor

During operation, the dosovalno-fasuvalna system is subjected to control and disturbing influences, as a result of which changes in the state of the system occur in time. In real conditions, impacts on the system are most often random, causing random or stochastic (uncertain) processes in the system. In practice, the information on characteristics of random influences on the system with pneumatic drive is usually very limited, so the so-called deterministic influences are widely used in the research of dynamic properties of the system. Typical deterministic influences are three types of influences: step, pulse and harmonic. In the case of harmonic influences, the behaviour of the system is considered in the frequency domain of signals, in which it is possible to solve the problems of system stability quite effectively, as well as to study the influence of various factors on the dynamic characteristics of individual elements and the system as a whole [1,2].

An IIOT gateway can be a dedicated hardware appliance and/or a software program that collects, (preprocesses and) aggregates data, before forwarding them to cloud (Fig.2).

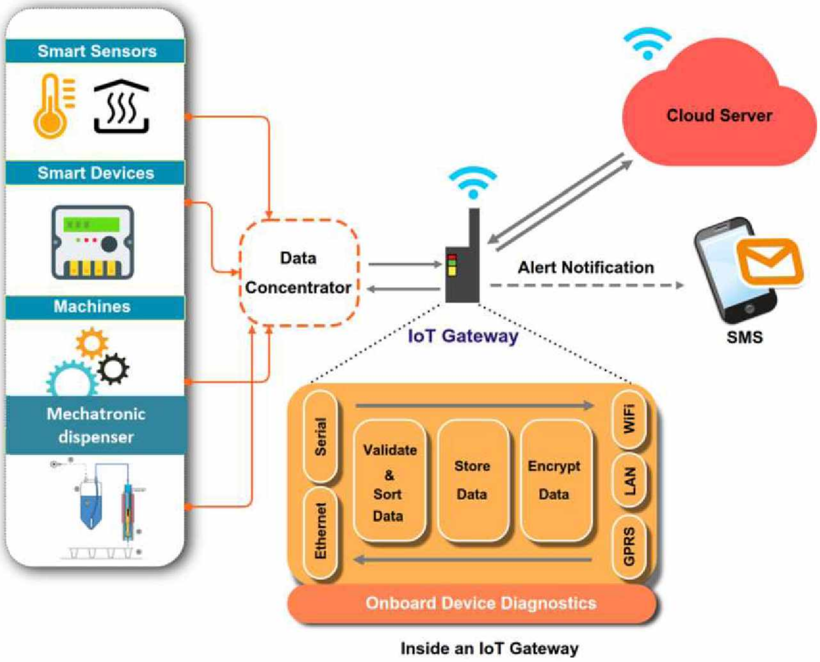

Figure 2. IIoT – Gateway

In full-scale tests of a system containing complex objects, frequency methods of analysing dynamic characteristics are not applicable. In practice, methods of research and calculations of the system in the time domain. In this case, transients caused in systems by step, pulse or harmonic influences are determined.The first types of signals are used in real conditions, to check the adequacy of the calculated and obtained as a result of physical experiments transients. In addition, the processes of stepwise processes at staggered impact on the system give a visual representation of such dynamic properties of mechatronic dosing system as speed, oscillation and duration of the process itself [7]. When developing, researching and operating control systems with mechatronic-type metering device when using pneumoautomatics elements, it is necessary to evaluate with the help of dynamic characteristics of the created packaging equipment. Pneumatic distributors, which are part of the system and designed to regulate the parameters of the working medium flows in the metering units, according to the law of the input signal, are characterised by their own properties.

Conclusions

The method of calculation of working processes in the mechatronic module of the metering unit controlled by proportional valves has been developed. For the first time, a pressure-controlled proportional tracking system was used to determine the current effective area in proportional valves based on the control signal and pressure drop.

A bench was designed and constructed to investigate the dependence of the current effective area of the proportional valve on the control signal and pressure drop. The experimental data obtained were used in the calculation method and programme developed to determine the structure of the proportioner. As a result, a multifunctional direct pass system for calculation of the effective area of the selected proportional valve in the range from 0 to 100% and at pressure drop in the range from 0 to 0.4 MPa was obtained.

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