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MECHATRONIC MODULE FOR WEIGHT DOSING OF VISCOPLASTIC FOODS

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Abstract: *In the paper, the processes of extrurion and dosing of viscoplastic food products using a tensometric weighing system has been considered. The study has been carried out to determine the dynamic forces that affect the tensometric system in filling packagings proccess. The loads that products were stressed by when passing a screw feeder have been evaluated. The filling process has been investigated by simulation using the FlowVision software. To ensure uniform loads on the weighing system, the changes in the indications of the filling system when using a telescopic tube have been studied. The design of a mechatronic module for dispensing viscoplastic food products by weighting method has been proposed.*

Keywords: Weight dosing, strain gauge system, simulation modeling, mechatronic module.

INTRODUCTION

The development of the packaging industry and changing requirements for modern consumer packaging create the background for weighing principle of dosing. Thus, due to quick readjustment, high accuracy, and control of the dose formation parameters, strain gauge systems are widely used in machines for bulk and liquid food products dosing (Gavva O., Bespalko A., Volchko A., Kohan O., 2010). In the case of viscoplastic food products, the development of such systems is constrained by a significant dynamic tolerance in dose formation due to its rheological characteristics (Krykh H., 2007).

EXPOSITION

During the consideration of dose formation methods, it was noted that one of the most popular solutions is using of dispensers with a feed-screw.

The dosing is managed by controlling the pressure in the discharge chamber (P2). The pressure should be sufficient for deformation and moving of products, and at the same time should not result to a loss of product properties. To estimate the required screw speed, it is necessary to determine the pressure drop between the discharge chamber and the tube exit. The starting point of the calculation is ensuring of a certain consumption of products (Q).

The pressure in the discharge chamber (P_2), to ensure a certain productivity, must be:

$$P_2 = \tau + \Delta p_1 + \Delta p_2 \quad (1)$$

The product transfer into the container should be deformed uniformly, filling it. At the outlet of the tube the pressure should be greater than τ, which corresponds to the rheological properties of the product.

Using the well-known calculation method (Levit I., Sukmanov V., Afenchenko D., 2015, Bravo V. L., Hrymak A. N., Wright J. D. 2000, Mikulionok I. O. 2013), it is possible to determine the pressure in the discharge chamber. The pressure difference in the tube (Δp1) is determined by the formula:

$$\Delta p_2 = \frac{8 \cdot Q \cdot \eta_{e\phi} \cdot l_2}{\pi \cdot (d/2)^4} \quad (2)$$

η_e – effective viscosity; l_2 – tube lenght; d – tube diameter.

The pressure difference, when passing the duct reducer unit (Δp2), is determined by the formula:

$$\Delta p_1 = \frac{128 \cdot Q \cdot \eta_{e\phi} \cdot l_1 (D^3 - d^3)}{3 \cdot \pi \cdot D^3 \cdot d^3 (D-d)} \quad (3)$$

l_1 – lenght of duct reducer unit; D,d – initial and final diameter of duct reducer unit.

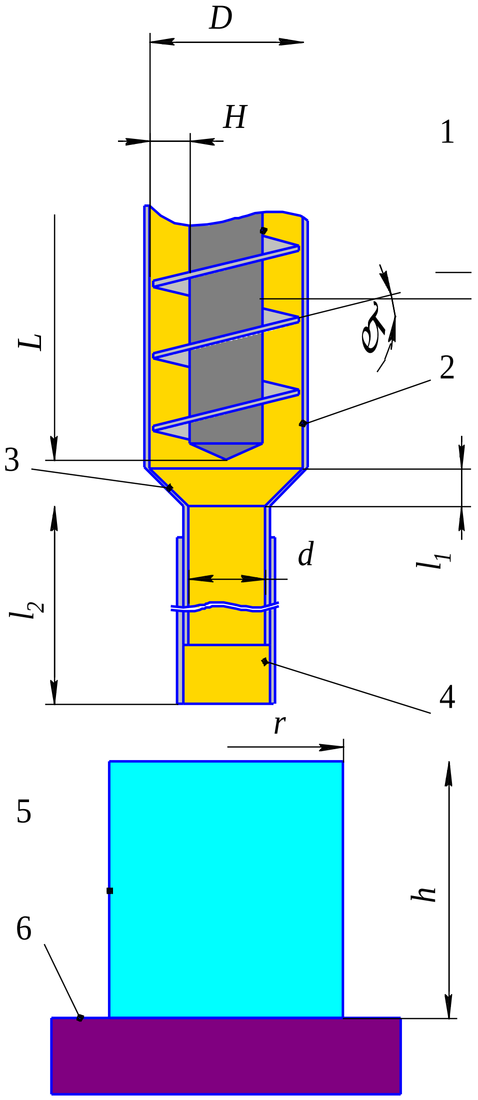

Fig. 1. Analitic model: 1 - screw; 2 - hopper; 3 - duct reducer unit; 4 - telescopic pipe; 5 - packaging; 6 - weighing element

Which in turn is used to determine the speed of screw rotation:

$$n = \left(\frac{\pi \cdot D \cdot H^3 \cdot \sin^2 \varphi}{12 \cdot \eta_{e\phi}} \cdot \left(\frac{P_2 - P_1}{L} \right) \cdot F_p + Q \right) \cdot \frac{2}{F_d \cdot \psi \cdot \pi^2 \cdot D^2 \cdot H \cdot \sin \varphi \cdot \cos \varphi} \qquad (4)$$

H - the depth of the helical surface; φ - the angle of the thread; F_p - coefficient of pressure flow formation; F_d - the coefficient of the formation of the screw surface of the screw for forced flow stopping; P1 - pressure in the loading zone.

It should be noted that in this case, the use of a telescopic tube is not taken into account. In the case of using cylindrical containers, the length of the telescopic tube is a function of the time of dose formation (3). Also at the initial time there is a gap (Δh) between the tube and the container bottom, as a result of which the movement of the tube does not start simultaneously with products filling, and therefore the final formula will be as follows:

$$l_2 = l_b - \frac{Q \cdot t_i}{\pi \cdot r^2} + \Delta h \qquad (5)$$

L_b – initial tube lenght; t_i – curent time of formation time; r – radius of container.

The force that the strain gauge system perceives includes the weight of the product in the container, the pressure that occurs when the product falls into the container and the resistance to stress, which is specified by the rheological properties of the product (4).

$$P = m \cdot g + S \cdot \rho \cdot v + \tau \qquad (6)$$

m - the mass of products in container; ρ - the bulk mass of the product; v - velocity of product falling at the point of contact with the product surface located in the conteiner; S - volumetric feeder productivity.

In the conducted simulation (Fig 2.), two variats of filling of the containers with products, using a fixed tube or a telescopic tube, were considered in order to determine the behavior of the product during the dosing and change of the strain gauge system values. The following assumptions were made in the simulation model: the dynamic parameters of the screw do not affect the output rate; the process is considered as isothermal; there are no product stagnation zones in the middle of the tube.

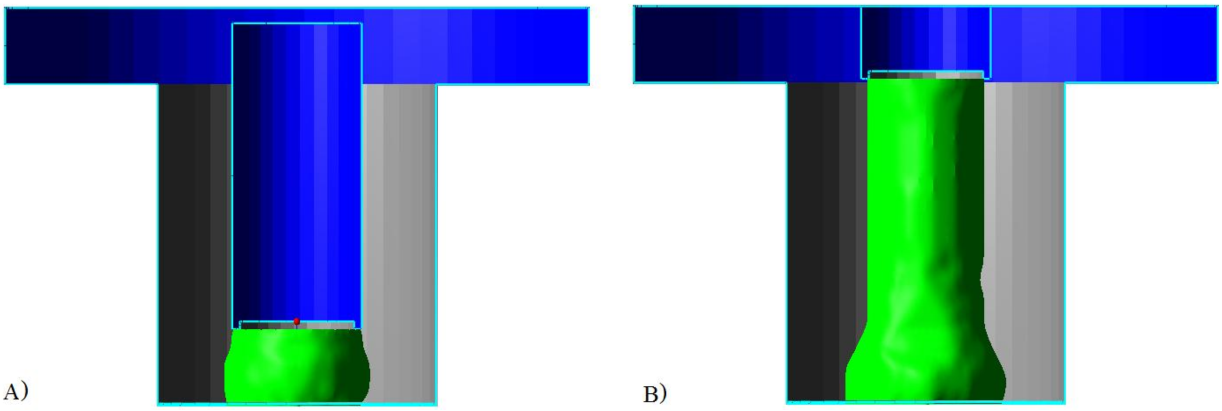

Fig. 2. Simulation model of the dosing process: A - with a fixed tube; B - with telescopic tube

It was found that when a telescopic tube was used, the forces which impact on the strain gauge system were almost linear, while a system with an fixed tube could not be approximated by line with sufficient accuracy.

Based on the simulation results (fig. 3), a mechatronic module for dosing semi-solid food products with a telescopic tube and an electronic control system is proposed (Bogdan Palchevsky, Anton Shvits, Volodymyr Pavlin 2014).

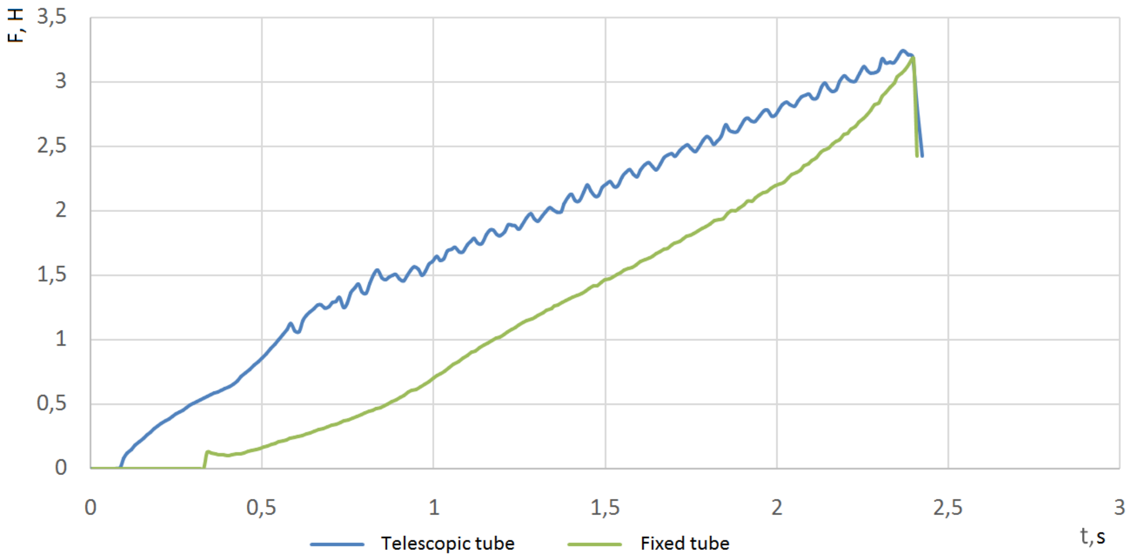

Fig. 3. Indicators of the strain gauge system in the process of dose formation

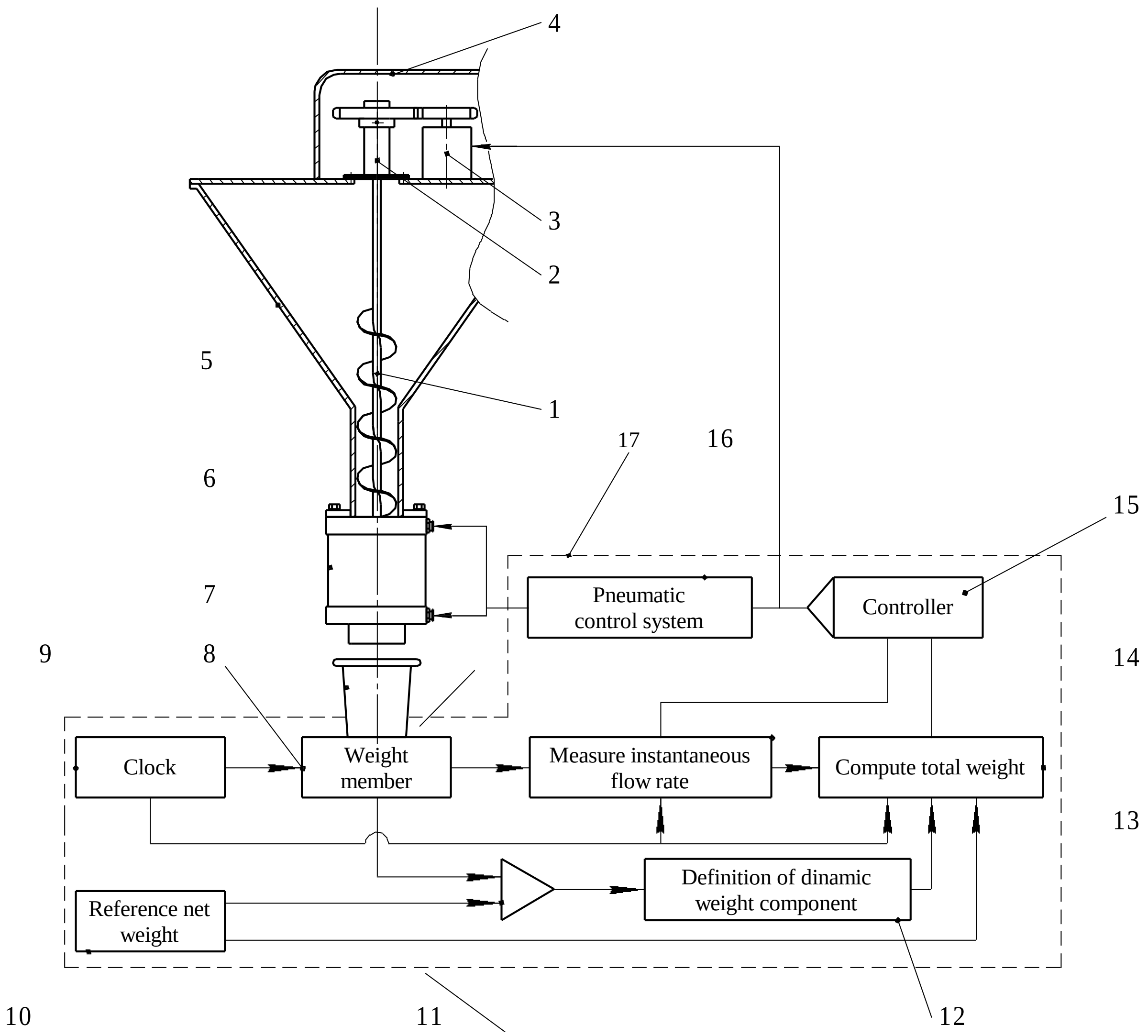

Fig. 4. Diagram of the mechatronic module of the carriage of semi-solid products: 1 - screw; 2 - drive unit; 3 - motor; 4 - cover; 5 - hopper; 6 - telescopic tube; 7 - packaging; 8 - weighing element; 9 - timer; 10 - reference net weight; 11 - comparator; 12 - definition of dynamic weight component; 13 - unit for calculating the total weight; 14 - block for determining instantaneous flow rate; 15 - controller; 16 - pneumatic control system; 17 - control system

The fig. 4 shows a diagram of the mechatronic module for weighing dosing of semi-solid products. After calibration of empty containers, the screw starts the dosing. The control system processes the data of the weighing system, determining the tolerance of the dynamic and rheological components, calculates the actual product amount in the container. The controller, using the data obtained, controls the dosing by managing the screw and telescopic tube. The screw, after the formation of 70-80% of the dose, slows down, to reduce the dynamic tolerance. The tube is rising during the dosing at the same time of container is filling. It should be noted that the "tail-back-weight" was not be taken into account.

CONCLUSION

The analysis of the modes of viscoplastic products movement in a screw feeder has been done. A simulation model has been created to study the effect of the product flow on the strain gauge system. The data obtained can be used to establish the law of change in the speed of screw rotation and the speed of tube movement to ensure accuracy of dose forming by the weight method.

REFERENCES

Bogdan Palchevsky, Anton Shvits, Volodymyr Pavlin (2014). *Information support of integrated flexible information systems.* Lutsk: "Vezha-druk"

Bravo V. L., Hrymak A. N., Wright J. D. (2000), *Numerical simulation of pressure and velocity profiles in kneading elements of a co-rotating twin screw extruder*. Polymer Engineering & Science. 40, (2), 525–541.

Gavva O., Bespalko A., Volchko A., Kohan O. (2010). *Packaging equipment*. Kyiv: Upakovka.

Krykh H. (2007*). Features of application the rheological models of non-newtonian liquids.* Vydavnytstvo L′vivs′koyi Politekhniky.

Levit I., Sukmanov V., Afenchenko D., (2015). *Rheology of food produckts*. Poltava: PUET.

Mikulionok I. O. (2013). *Screw extruder mixing and dispersing units.* Chemical and Petroleum Engineering, 49 (1-2), 103–109.