RESEARCHES REGARDING OPTIMIZATION OF CONTINUOUS FLOW DOSAGE OF AGRICULTURAL PRODUCTS FOR ASSURING FOOD QUALITY AND SECURITY

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Abstract. The research which results are herein presented, tackle the dosage process optimization in small and medium-sized enterprises. The technical dosage equipment ETD can be interposed in a mill technological flow, in different points of processing the quantitative information, according to the electronic unit program, as well as within combined fodder factories, where several dosage installations may be coupled, and through a central computer, different networks can be achieved, by means of appropriate adjustments. Within the technological flow, the technical dosage equipment performs two main functions: 1) automated setting of product flow rate for a programmed value and maintaining this value within certain preset limits, by respecting the regulations in force concerning the dosage precision imposed for this equipment type; 2) automated control of quantities of products passing through the dosage equipment in a certain period of time. In this paper the experimental tests for this equipment, the determined working qualitative indexes are presented by emphasizing the advantages of using this equipment type in small and medium-sized milling enterprises in rural areas.

Keywords: dosage, milling enterprises, automated control, PLC.

Introduction

The field of systems and equipments for weighing, dosing and packaging agrifood products is one of the fields with a high economical impact in Romania (especially in the recent years) and also in the industrially developed countries.

Weighing, dosing and automated management are processes that eliminate, totally or partially, human intervention in the actual operations. Modern weighing and automated dosing devices represent ingenious technical solutions that comprise fields from both, mechanics and electronics, being characterized by high precision and sensitivity [1; 2].

Usually, operations involving a direct action on the processed material are exclusively done by mechanical mechanisms or components, but also the command and dosage adjustment operations are frequently done by mechanical systems, the electronic systems having a surveillance and fine adjustment role [3].

Technological operations of weighing and dosing are not independent in the manufacturing process of products, but are integrated into various technological processes, so that the result of the operation does not emerge distinctively, but is cumulated in the resulted final product, and as a result, the quality of the dosage/weighing directly influencing the quality of the final product [4].

In the milling process in different points of the mill technological flow, technical equipment used for weighing the grains that enter the processing and the finished products and by-products is provided.

Also, in modern facilities for obtaining concentrated fodder, the dosing and weighing technical equipment is the most reliable in the management process of obtaining feed, consisting of high precision tensometric doses and fully automated control units. Once programmed, it can mix completely independently a variety of recipes from different components.

Aligned with the most modern equipment in the field and encompassing innovative constructive solutions, the Dosing Technical Equipment ETD (Fig. 1), developed at INMA Bucharest has a direct applicability in small and medium capacity milling units, and can be interleaved in their technological flow in several points of processing quantitative information, but also in combined fodder factories, where several dosers can be connected, and, through a central computer, several recipes can be achieved.

Materials and methods

In a technological flow, the Dosing Technical Equipment ETD performs two main functions:

- automatic adjustment of the flow of product to a programmed value and maintaining that value within certain preset limits, in compliance with regulation on dosing precision for this type of equipment;
- automatic management of the quantities of products that pass through the dosing equipment in a certain time.

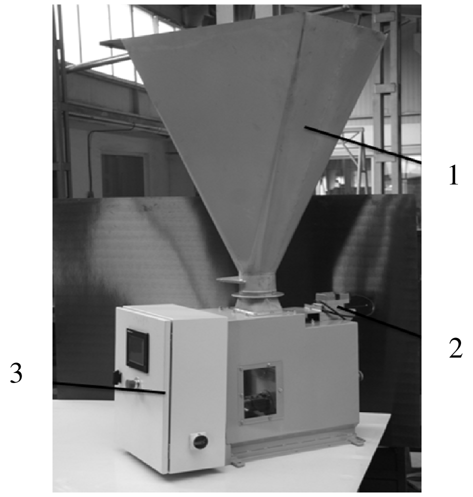

Fig. 1. **Dosing Technical Equipment ETD – overview:** 1 – bunker; 2 – electric actuator; 3 – control panel

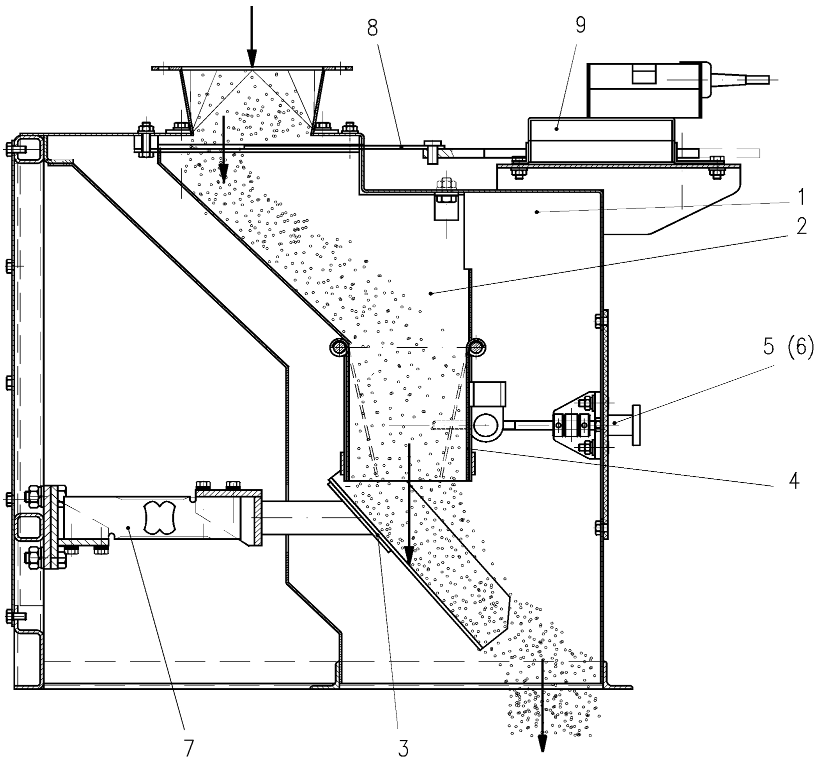

Fig. 2. **Dosing Technical Equipment ETD - technological scheme:** 1 – frame; 2 – guidance funnel; 3 – impact plan; 4 – mobile wall; 5(6) – actuating mechanism; 7 – tensometric dose; 8 – flap; 9 – electric actuator

Mainly, the work process is carried out this way:

- the dosed product flows through a pipe provided at the end with a mobile flap actuated using and electric command by a linear servomotor (electric actuator);
- the product stream dimensioned by the flap falls from a certain height directed through a channel on an inclined plate;

- the inclined plate constitutes the end of a lever that transmits the impact force to a tensometric dose;
- the tensometric dose transforms the impact force into material flow, sending an impulse to the automation system;
- the electric impulse is processed and based on the programming, the automation system makes the comparison, recording and displaying the measured flow and managed values;
- the mobile flap, depending on the command it receives, increases or decreases the product flow in order to stabilize it.

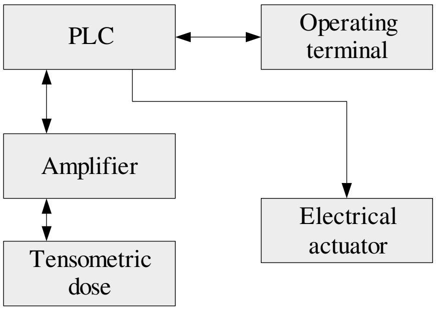

Fig. 3. **Block scheme for automation installation**

The operating terminal acts as graphical user interface. It communicates with the installation PLC on a dedicated RS422 serial communication interface.

Using the settings, the working parameters for ETD are set (reference flow, weight counter) and the product management data are viewed (total amount of material and measured current flow).

The analyzed dosing equipment constitutes an application of dynamics postulates. Thus, knowing that the particle mass impulse *m* and speed *v* is:

$$\vec{H} = m \cdot \vec{v} \tag{1}$$

and that the $\vec{H}$ vector is tied to the $\vec{P}$ vector of the resultant forces applied to the mobile point, through the equation:

$$\frac{d\vec{H}}{dt} = \vec{P}\,. \tag{2}$$

Also, the impulse of a points system is written:

$\vec{H} = \sum_i H_1 = \sum m_i \vec{v}_i$; this vector $\vec{H}$ can be regarded as the impulse of a fictive point with the mass $M = \sum_i m_i$, and the speed equal with the speed of the center of mass (weight). Impulse theorem and center of mass theorem are not independent.

Therefore, $\vec{H} = M \cdot \vec{v}_c$ derived in relation to *t* and considering *M* as constant we have: $\vec{H} = M \cdot \vec{a}_c$.

Thus, we have the impulse variation in the time interval (t_A, t_B):

$$M_B \vec{v}_c(t_B) - M_A \vec{v}_c(t_A) = \vec{S} = \int_{t_A}^{t_B} \sum s_i dt\,, \tag{3}$$

$$\sum m_{i_B} \cdot \vec{v}_c(t_B) - \sum m_{i_A} \cdot \vec{v}_c(t_A) = \vec{S}\,. \tag{4}$$

It results that if the impulse is zero, the exterior forces will have a constant value and vice versa. Therefore, we are constructively and functionally looking to achieve the solution $\vec{s} = 0$.

In order to achieve that, it was constructively imposed that *H* – vertical particle falling height *H* as constant, resulting that *v* as constant because $v = \sqrt{2gH}$ for any particle (v_1 = const.). It results in:

$$\sum m_{i_B} \cdot (V_c)(t_B) - \sum m_{i_A} \cdot (V_C)(t_A) = 0\,, \tag{5}$$

$$V_C(t_A) = V_C(t_B) \tag{6}$$

and

$$\sum m_{i_B} - \sum m_{i_A} = 0 . \tag{7}$$

It results that for this, $M_B = M_A$ therefore, it is ultimately constant with the flow.

Functionally, it was searched that the instant value taken by the tensometric dose and sent to the PLC, compared with the reference value – resulted from calibration and related adjustments – to be constant. If not, by comparing it to the reference value, actions will be taken through the electric actuator on the mobile flap to adjust the flow.

Taking into consideration that the equipment should only take the impulse and the material has to flow as smoothly as possible, an inclined plan was built to serve as an impact receptor.

The inclination value $\angle a$ has to be bigger than the fall limit $\angle$, the $\angle$ when the products start to roll $a_{\min} < a$.

This value $a_{\min}$ is determined from the transport speed formula where the kinetic energy variation is equaled with the mechanical work of the forces acting on the material.

Therefore, we have the formula

$$\frac{G}{g} \cdot \frac{(v - v_0)^2}{2} = GH - G\cos\frac{h}{\sin a} \cdot f , \tag{8}$$

where G – material weight, kgf;
g – gravity acceleration, m·s^{-2};
v – transport speed, m·s^{-1};
h – falling height, m
α – falling angle, degrees;
f = tanρ – friction coefficient, depending on the friction angle of the material on the inclined plan.

When $v_0 = 0$ it results in

$$\frac{v^2}{2g} = h(1 - f\ \mathrm{tg}\, a) , \tag{9}$$

from where

$$v = \sqrt{2gh(1 - \mathrm{ctg}\, a\, \mathrm{tg}\, \rho)} . \tag{10}$$

We have $pt = 90° - \mathrm{ctg}\, 90° = 0 \rightarrow v = \sqrt{2gh}$ at limit $v = 0$, tg$a$ = tgρ.

Results and discussion

Testing of the Dosing Technical Equipment ETD was made at INMA, in laboratory and exploiting conditions, using its own experimental methods, carrying out the following activities: preliminary checks, initial technical expertise, experimenting operating without load, calibrating the weighing system, checking the functioning of the automation installation in simulated mode, experimenting operating under load.

For the experiments in working conditions were used agricultural products such as wheat seeds and bran.

The dosing error (ε_d) was determined with the following relation [5]:

$$\varepsilon_d = \frac{|Q_p - Q_c|}{Q_p} \cdot 100(\%) , \tag{11}$$

where Q_p – programmed flow, t·h^{-1};
Q_c – calculated flow, t·h^{-1}.

The calculation formula for Q_c [6] is:

$$Q_c = \frac{M_p}{T_p} \cdot 3600, \tag{12}$$

where M_p – sample weight, kg;
t_p – sample duration s.

The results of the tests taken in operating conditions are shown in Table 1:

Table 1

Results of test taken in operating conditions [7]

Sample	Programmed flow (Q_p) $t \cdot h^{-1}$	Sample duration (t_p) s	Sample weight (M_p) kg	Calculated flow (Q_c) $t \cdot h^{-1}$	Dosing error (ε_d) %
I	1	60	17 200	1 032	3.20
II		60	17 100	1 026	2.60
III		60	17 250	1 035	3.50
Average		60	17 183	1 031	3.10
I	2	60	34 300	2 058	2.90
II		60	34 400	2 064	3.20
III		60	32 900	1 974	1.30
Average		60	33 866	2 032	1.60
I	3	30	25 500	3 064	2.13
II		30	25 200	3 024	0.80
III		30	25 700	3 082	2.70
Average		30	25 466	3 056	1.86
I	4	30	34 300	4 116	2.90
II		30	34 100	4 092	2.30
III		30	33 900	4 068	1.70
Average		30	34 100	4 092	2.30
I	5	30	42 700	5 124	2.48
II		30	42 400	5 088	1.76
III		30	42 600	5 104	2.08
Average		30	42 566	5 108	2.16

Figure 4 shows the dosing error variation depending on the sample weight on sample duration of 30 seconds.

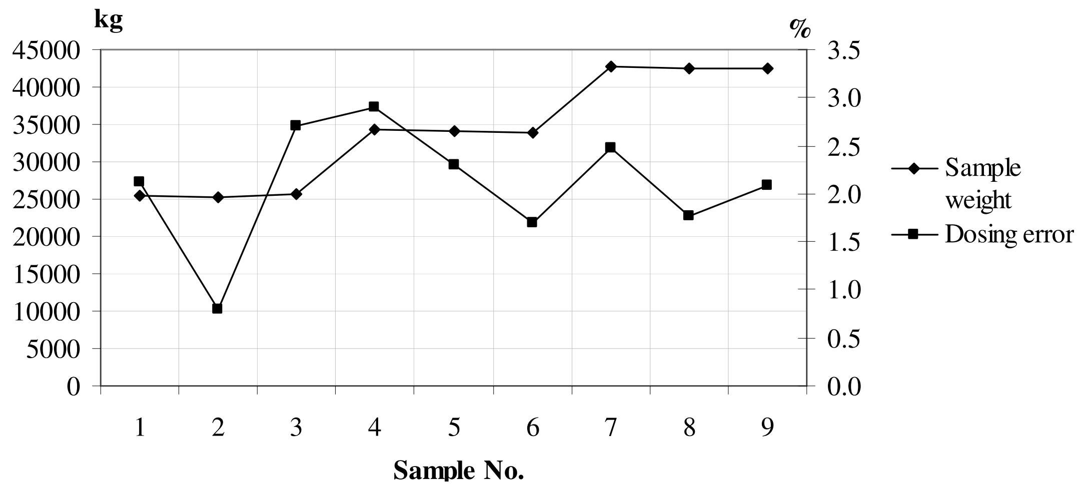

Fig. 4. **Dosing error variation depending on the sample weight**

Conclusions

Continuous flow dosage of finished agricultural products is a complex and important operation for the destination and future processing of those products. This operation is made using the dosing technical equipment integrated in different technological flows in small and medium capacity milling units and also in unit making concentrated fodder, in several points of processing the quantitative information, according to the programming of the electronic unit [8; 9].

Through the constructive and functional solutions adopted following the experimental tests, it was found that the Dosing Technical Equipment ETD offers a series of advantages such as [7]:

- high dosing precision;
- adjusting the product flow to a programmed value;
- automated management of product quantities throughout the whole technological flow;
- easy maintenance and exploiting;
- visualizing the product feed through the transparent tube of the feeding funnel;
- hermetic connection to the piping of the technological installation where it is integrated;
- sound signaling in the event of possible disorders;
- modern design, compact construction saving space and accessibility;
- reduced specific material and energy consumption.

We can therefore conclude that the use of automated weighing and dosing technological operation brings growth in the economical efficiency of the productive unit and has an immediate impact on the management of the processed product.

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