GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA
FACULTY OF ELECTRICAL ENGINEERING

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27-29 SEPTEMBER, 2023

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

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GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA

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PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the Second International Conference ***Electrical Engineering, Informatics, Machinery and Automation - Technical Sciences applied in Economy, Education and Industry-ETIMA*.**

ETIMA has a goal to gather the scientists, professors, experts, and professionals from the field of technical sciences in one place as a forum for exchanging the ideas, strengthening the multidisciplinary research and cooperation, and promoting the achievements of technology and its impact on every aspect of living. We hope that this conference will continue to be a venue for presenting the latest research results and developments on the field of technology.

Conference ETIMA was held as online conference. More than sixty colleagues contributed to this event, from five different countries with more than thirty papers.

We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA'23 by presenting the results of their current research and by launching the new ideas through many fruitful discussions.

We invite you and your colleague to attend ETIMA Conference in the future as well. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information as well as to involve as much as possible the young researchers into this scientific event.

The Organizing Committee of the Conference

ПРЕДГОВОР

Меѓународната конференција ***Електротехника, Технологија, Информатика, Машинство и Автоматика-технички науки во служба на економија, образование и индустрија-ЕТИМА*** е организирана од страна на Електротехничкиот факултет при Универзитетот „Гоце Делчев“.

ЕТИМА има за цел да ги собере на едно место научниците, професорите, експертите и професионалците од полето на техничките науки и да претставува форум за размена на идеи, да го зајканува мултидисциплинарното истражување и соработка и да ги промовира технолошките достигнувања и нивното влијание врз секој аспект од живеењето. Се надеваме дека оваа конференција ќе продолжи да биде настан на кој ќе се презентираат најновите резултати од истражувањата и развојот на полето на технологијата.

Конференцијата ЕТИМА се одржа online и на неа дадоа свој придонес повеќе од шеесет автори од пет различни земји со повеќе од триесет труда.

Сакаме да ја искажеме нашата благодарност до сите колеги кои придонесоа за успехот на ЕТИМА'23 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Организационен одбор на конференцијата

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ALGORITHMIC METHOD IN DYNAMIC DOSING SYSTEMS BASED ON WEIGHT MEASURING PRINCIPLES

Vladimir Gebov [1]
[1]South West University in Blagoevgrad,
email: askon@swu.com

Abstract

Algorithmic method and a technical solution are suggested in order to increase performance of worm-and-wheel dosing systems (bagging machines) operating on weight measuring principles. The results from the weight measuring processed by using Fourier transformation and extrapolation of the weight transformation curve. The method applied in an algorithm for controlling weight in two situation of the working cycle of the flour-bagging machine: selective weight measurement of net and tare. The algorithm allows increasing the productivity without changing the mechanical design of the machine. This improvement helps make the machine competitive with the best Western packaging machine manufacturers.

Key words

Bulk dosing systems, dynamic weigh, extrapolation, algorithmic method

Introduction

Dosing of bulk materials for production purposes is a very common process. Most dosing appliances and machines based on indirect methods for mass measuring by accepting specific weight and bulk materials' flow as measured quantities. However, these parameters influence the weight precision rather somewhat negatively.

In order to improve enterprise' competitiveness in a market economy the quality of products should be constantly increasing, and by extension productivity. In accordance to ISO 9001 for products' quality certification, one of the requirements is that precision in packaging should be constantly improved and controlled. The paper aims to improve precision in dynamic dosing of packaged (in bags) flour as well as to increase productivity requirements.

Some basic factors, which influence batching, are "deposing on walls", "the sinusoidal features of bulk flow during worm-and-wheel dosing", unequal humidity and different aerated indices of bulk materials, etc. A controlling algorithm compensates factors that alter slowly in the course of time (humidity). Other factors lead to serious errors in weight measuring (deposits of measured quantities), thus they have to identify and made evident by alarm indicators [1].

Decisive factors, which increase precision of dynamic measuring, are "determined deviations", which result from the sinusoidal law in worm-and-wheel feeding. Another is random distribution of flour specific gravity during dosing. Both characteristics must taken into consideration.

Typical Requirements of Bulk Material Dosing Devices

The base for a classification of different dosing and proportioning devices for bulk materials is a prior definition of the associated requirements and the expected performance measures. For this, it is common sense to concentrate on the following four basic characteristics:

I. *Accuracy*. The accuracy of a dosing or weighing system is the degree of closeness of measurements of a quantity (e.g. massflow) to that quantity's true value).

II. *Stability*. The stability of a bulk material dosing unit typically defined as a time interval in which the accuracy definitions associated to the system can guaranteed without any manual intervention.

III. *Availability*. The availability of a dosing unit can defined as the typical ratio between the times where the system is operatable and the total working time in a defined period.

IV. *Productivity*. Productivity depends on the proper functioning of the above process characteristics and then on the requirements for high economic indicators of the process. Higher productivity means less energy costs, labor costs, and higher competitiveness in a dynamically changing market. This article proposes a general solution for increase productivity based on controlling algorithm.

1. General Classification of Bulk-Material Dosing Devices

The base for a classification of different dosing and proportioning devices for bulk materials is the former definition of the functional entities of those machines. For this, it is reasonable to distinguish three main functional elements of typical dosing devices:

(i). Measuring, (ii). Conveying and (iii). Controlling. The combination of either any two or all three of these basic elements defines the specific character of the equipment, as shown in Fig.1

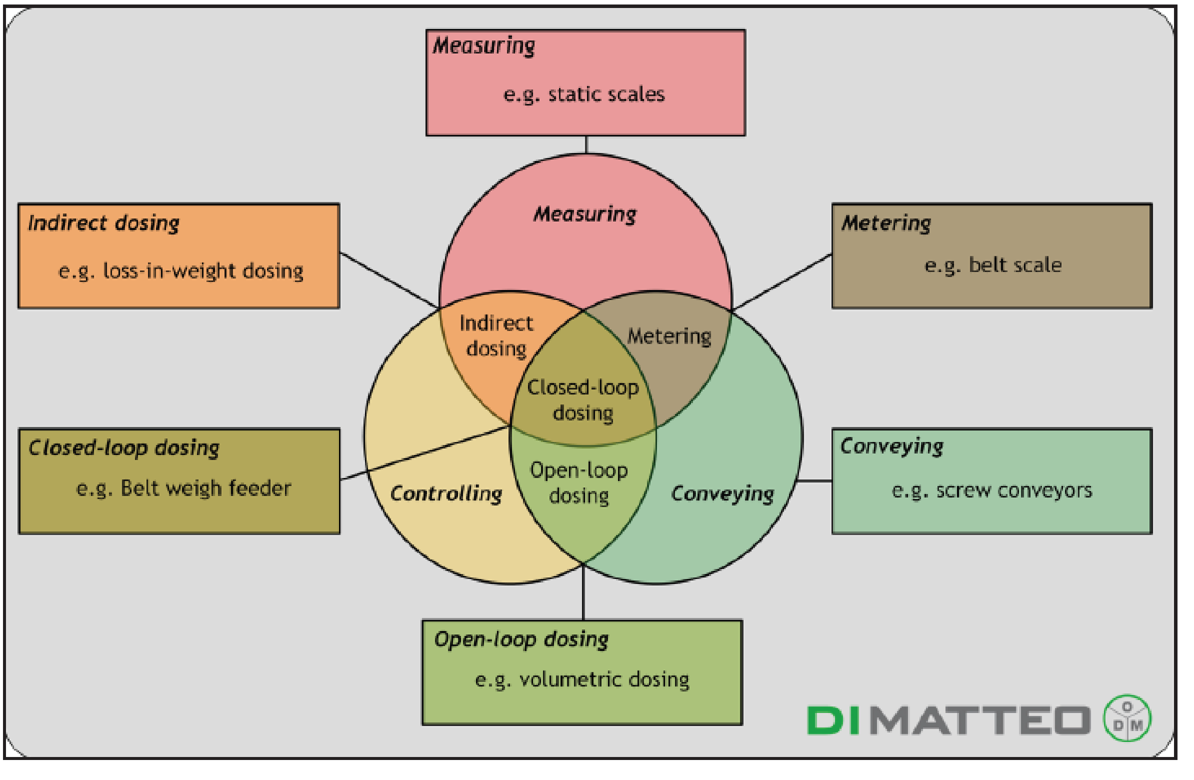

Fig. 4 Classification of different dosing/metering/weighing devices based on three basic functional elements

Here, it is possible to name six different classes of machines as a general taxonomy for the proportioning of bulk materials. The exact definition and corresponding aspects are summarised within Table 1.

Table 1 Overview of different dosing/metering/weighing devices

Class of Machine	Measuring	Metering	Indirect dosing	Open-loop dosing	Closed-loop dosing
Description	The actual volume V or weight m of the material is measured and used to define the actual amount at .a given time	The material is conveyed with a certain conveying speed **v** and at the same time the actual massflow is determined based on a measured weight **m**[kg]. **M**[kg/h] is define by v [m/s], l**m**[kg] and L[m] length of the scale.	The actual volume V or weight m of the material is measured and used to define the actual amount at a given time and at the same time a separate conveying system is controlled in order to achieve a certain volume flow **V** or mass flow **M** .	The actual conveying speed v is controlled based on a pre-defined calibrated relation in order achieve a certain volume flow . V or mass flow M	The actual weight **M** or volume **V** and the actual conveying speed v is measured to calculate the **M** actual mass flow or volume flow **V**. The actual conveying speed continuously controlled in order to achieve a desired mass or volume flow.
Measured values	**m** [kg], V [m^3]	v [m/s], **m**[kg]	v [m/s], m[kg]	-	v [m/s], m[kg], **V** [[m^3/h], **M** [kg/h
Control variables	-	v [m/s] **M** [kg/h]	**V** [m^3/h], **M** [kg/h]	v [m/s]	v [m/s] -> **V** [m^3/h], **M** [kg/h]
Type of operation	-	Continuous	Discontinuous	Continuous	
Type of dosing			Gravimetric	Gravimetric	
Example	Silo scale	Belt scale	Differential dosing setups (e.g. loss-in-(weight systems	Screw conveyor wit pre-defined calibrated relation between volume and screw speed	Weigh Scale

Source: author based on [5]

In this article we sugest new combination of dosing sytem based on combination between Open-loop dosing and Closed-loop dosing used in bag filling machine of the flour in mill factory. This is the first step to increase productivity of the bag-filling machine.

2. Discontinuous batching dosing system for bulk material

The chart for batching and dosing bulk materials as shown in Fig. 1 includes a worm-and-wheel mechanism driven by an electric motor, weigh-measuring transformer, and a regulating unit for feeding and dosing. The regulator is a position regulator. Theoretically, it is well known that best results for precision and quick action are achieved when a 5-sector speed diagram is used [2]. Conducted experiments show that different parts of the speed diagram can optimized in order to increase precision [3].

In Fig. 2, shown discontinuous batching dosing system completed with two-bag filing machine work in DEM Kulpin – Serbia. Two control system work synchronously with one belt for filled bags. These bag filling machine work semi-auto mode. The operator attaches an empty bag to the machine's outlet valve screw and then everything is automatic including dumping the finished bag onto the belt. In new systems bag filling machine assembled with bag placer and all the process is automatically. The two bag filling machines synchronized with each other through a connected algorithm.

The block diagram of the discontinuous batching dosing system shown in Fig3. This dosing principle chosen because it provides maximum accuracy with high productivity. This is necessary because of the market.

Fig. 5 Bag Filling machines in mil factory Kulpin, Serbia

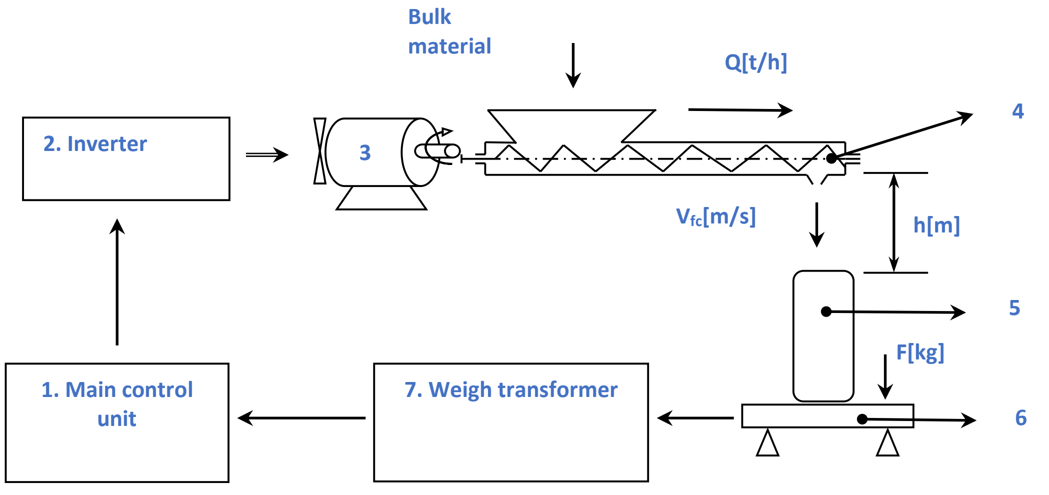

Fig. 6 Electronic system for dynamic dosing in worm-and-wheel mechanisms 1 - Main control unit; 2 - Frequency control of the asynchrony electro motor; 3 – 3-phase electro motor; 4 - dosing worm-and-wheel mechanism; 5 - Bag; 6 – Tens metric system; 7 - Weigh transformer;

Basic advantages of the system:

1. Main control unit is controller based on microprocessor MC9S12DG256 with 24 DI, 24 DO and ADC7730 with two analog input for tense system, one analog input for measure temperature with DS18B20 – one wire temperature sensor. The kernel of the software work in *real time* and Interrupt handling done through a priority matrix. In this way measuring and control system work properly. The author developed this controller and system software. The controller and system software used in many applications and systems more than 15 years.
2. Inverter selected *senseless technology*, which achieves better speed control both at a constant level and during braking, which, compared to ordinary inverters, is decisive for achieving higher weigh accuracy.
3. 3-phase asynchronously electro motor selected for *reliability* and price
4. Dosing worm-and-wheel mechanism made with additional *spreader wheel* and additional hopper for *pre-volume dosing.*
5. Tense system work with two cell connected to ADC7730 in continuous conversion mode. The 16-bit analog to digital conversion work continuously with time of conversion about 10 mSec. ADC7730 has key features Offset Drift: 5 nV/ºC, Gain Drift: 2 ppm/ºC, Line Frequency Rejection>150 dB, Buffered Differential Inputs, Programmable Filter Cutoffs Specified for Drift Over Time

3. Model of the technological cycle of the bag filling process

When dosing bulk materials the periodic constituent changes in accordance to the sinusoidal law [1]:

$$\overset{*}{m}(t) = m_{stat}(t) + \hat{m}_{din}\sin(\omega t + \varphi_0), \qquad (1)$$

Where

- $m^*(t)$ - the mass of the total material for a certain time interval t
- $m_{stat}(t)$ - defines the linear mass gradient
- $m_{din}(t)$ - defines the periodic change of mass. This compound is a result of the spiral of the dosing auger.

We can determine the force exercised by the falling bulk flow onto the tens metric system:

$$F_{\Sigma}(t) = \overset{*}{F}(t) + \tilde{F}(t) = \underbrace{m_{stat}(t)g + \hat{m}_{din}\sin(\omega t + \varphi_0 + \tau)}_{product\_in\_bag} + \underbrace{\sqrt{2gh}\,\frac{dm_{stat}(t)}{dt} + \hat{m}_{din}\cos(\omega t + \varphi_0 + \tau)}_{falling\_column} \quad (2)$$

Where

- $\overset{*}{F}(t)$ - force of the weight of the flour in the sack
- $\tilde{F}(t)$ - force of the weight of the flour above the sack

The weight of the falling material is determined by

$$M_{\Sigma\, fc} = \overset{*}{M}(t) + \tilde{M}(t) = \sqrt{2gh}\,\frac{dm(t)}{dt} + \int_0^{\tau} \hat{m}_{din}\sin(\omega t + \varphi_0)dt \quad (3)$$

Where

- $\overset{*}{M}(t)$ - The mass of the flour, proportional to the *h* height from the bag to the dosing auger, as well as to the auger performance dm(t)/dt
- $\tilde{M}(t)$ - The mass of the flour defined from sinusoidal influence of the auger

From (2) and (3) the difference between the falling material and the dynamic constituent of the force on the tens metric system can estimated as:

$$\Delta\tilde{F}(t) = \tilde{F}(t) - \tilde{M}(t) = \hat{m}_{din}\cos(\omega t + \varphi_0 + \tau) + \hat{m}_{din}\frac{\cos(\omega\tau + \varphi_0) - \cos(\varphi_0)}{\omega}$$

$$\Delta\tilde{F}(t) = \hat{m}_{din}\left(\cos(\omega t + \varphi_0 + \tau) + \frac{\cos(\omega\tau + \varphi_0) - \cos(\varphi_0)}{\omega}\right) \quad (4)$$

4. Technological process controlled by Algorithm

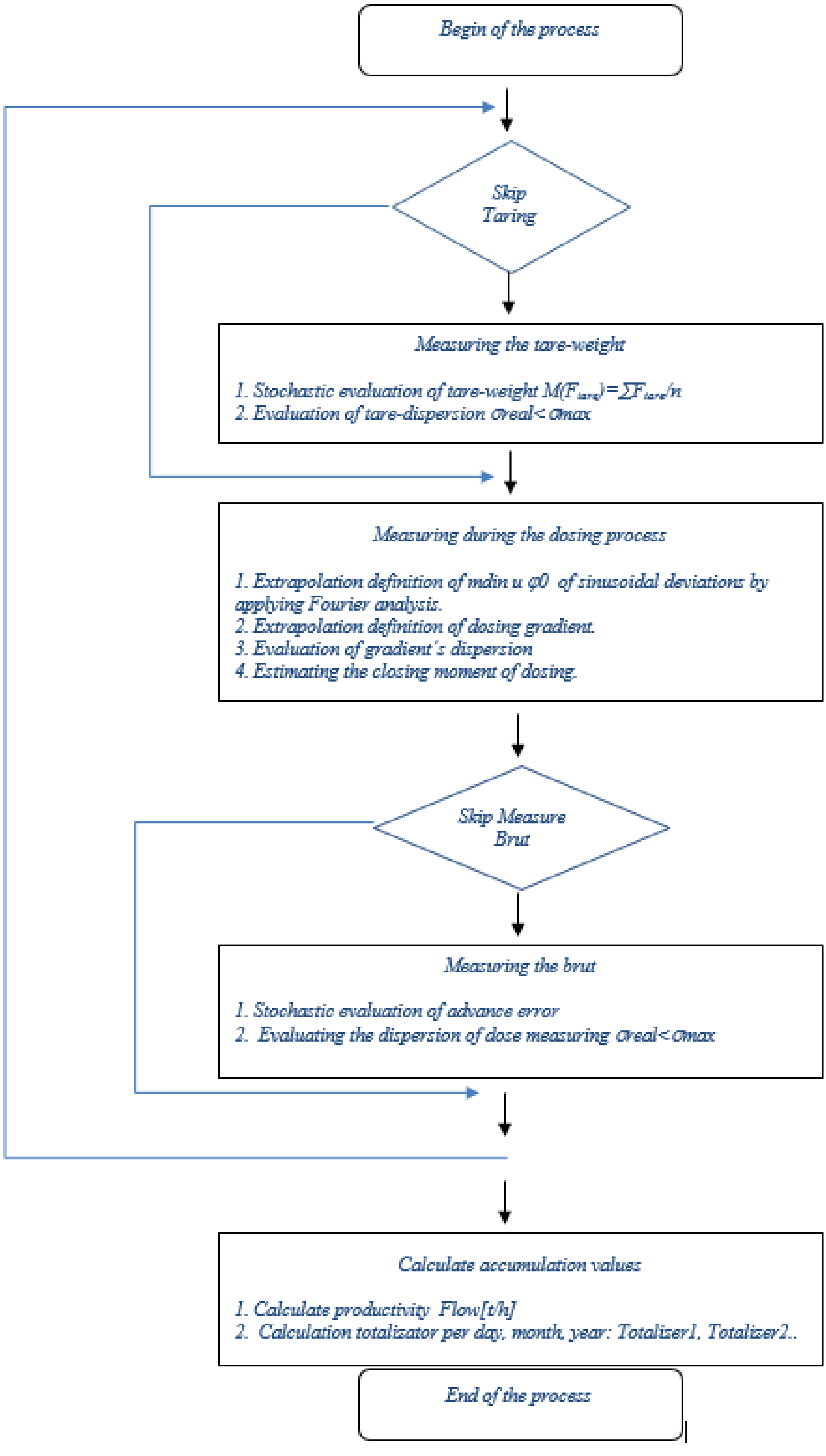

Fig. 3. Algorithm showing the discrimination of error in dynamic dosing by applying the extrapolation method

Results

Estimating the error from the tare measurement and the error from the measurement of the weight value - gross, allows the transition to an accelerated mode of operation. When these two values approach the minimum allowable, it goes into *turbo* operation mode.

For machines that use closed bags with valve filling of the packages, the performance limited by the speed of the valve, which is limited to 8 seconds + 2 seconds for releasing and filling the new bag. This limits the productivity to 9.0t/h.

Compared to western companies such as PAGLIERANI and FAVEMA on a similar technique, whose productivity is 7.5t/h, one can see the significant advantage obtained when using the algorithm in terms of the productivity indicator.The measurements and experiments were made on machines of the company Askon EOOD, which operate in Bulgaria, Serbia, BiH, Romania.

Table 2 Productivity of the bag-filling machine with different type cycles calculate in case of 25kg charge.

Type of machine	Measuring Tare [Sec]	Closing low clap	Dosing Fast and Fine	Closing high clap[Sec]	Measuring Tare [Sec]	Cycle Time [Sec]	Product. [t/h]
Common	4.0	1.0	5.0	1.0	4.0	15	6.0
With algorithm	0	1.0	5.0	1.0	0	7	12.9
Algorithm+ advanced fill	0	1.0	4.0	1.0	0	6	15.0

Conclusions

In today's conditions of strong competition and lack of workers, the productivity of machine equipment is of great importance. The competition in the market for technological equipment intended for flourmills in the European market, as well as in the world, imposes high criteria regarding the performance quality indicators of the machines and systems used in the production of flour and milled products. The price and reliability of the equipment are not sufficient criteria when choosing a certain type of equipment. The publication offers an algorithmic method that allows increasing the productivity of flour packaging machines by 25-30%. This method is applicable to all machines operating in the milling industry, regardless of supplier. The application of the algorithmic method allows to significantly increasing the performance without the need to change the mechanics or electronics. Only the pre-dosing module also implies mechanical changes to the packaging machines. A specialized software has developed which, through an online statistical analysis of the deviations of the measurement of the weight of the dose and the tare, provides an assessment of the possibility of applying the algorithm to a randomly selected machine.The algorithm works completely autonomously and does not require any settings or manipulations by the operator.

Reference

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