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THEORETICAL CONSIDERATIONS ON DOSING, WEIGHING AND PACKAGING PROCESSES USED IN MILLING UNITS

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ABSTRACT

The paper presents theoretical aspects regarding dosing, weighing and packaging processes used in milling units. The dosing system is a complex assembly of mechanical pneumatic, hydraulic, electrical, electronic components that performs dosing operations. Controlled dosing is not a true measure because the desired value is not the flow of material measured or the volume of material itself but is given by another operation control parameter such as the fill level of the packaging container.

INTRODUCTION

Weighing systems can be referred to as dosing, dosing and measuring systems, consisting of measuring or dosing assemblies and dosing devices, so named according to the dosing material and the degree of compaction thereof, and depending on the different solutions dosing, based on different operating principles, [1,2,3,4]. Thus, dosing devices are important parts of the manufacturing process, the dosing assemblies constituting a combination of different dosing devices, and dosing devices are those multi-component systems provided with metering devices. The basic applications of such dosing devices include the following (Fig. 1): measuring inputs into the system to form the mixture or to transform certain components into new products through chemical or physical transformations; dosing by filling; controlled feed-back dosing, [5,6,20].

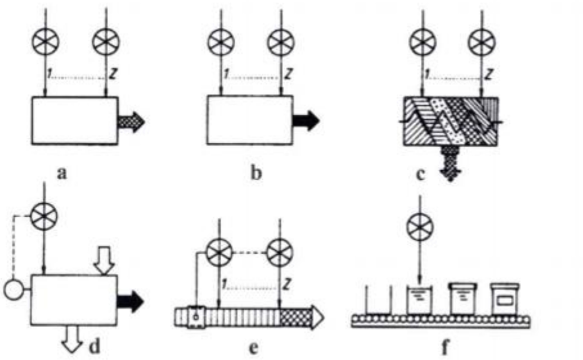

Fig.1. Basic dosing applications **[20]**
a - mixture formation (continuous), b - conversion of materials (continuous), c - batch formation (batch), d - adjustable dosing, e - fractional dosing, f – filling

As a rule, operations requiring direct action on the processed material are conducted exclusively by mechanical mechanisms or components, but the operation and control of dosing are often effected by mechanical systems; the electronic ones having the role of supervision and fine tuning.

Depending on the process requirements, dosing may be continuous or discontinuous. Within dosing installations, it is often found that all of the above mentioned basic applications are used several times within the plant. Dosage always targets bulk material in bulk, so that quantitative material evasion is associated with material mass determination, even if the method itself is based on the volume of skewed material.

In the weighing technique, mass is indirectly measured by mass effects such as inertia, pulse, radiation absorption and heat transport, [7,8,10].

The most accurate methods of measuring masses are gravimetric methods, because the only value measured by these transducers is gravity. Their application extends to bulk materials and fluids, weighing is done by 2 methods: by mass or by mass extraction.

Gravimetric measurement methods may be discontinuous (portions) or continuous, the latter being used for quantities ranging from a few grams / hour to 100 t / hour, mainly for bulk materials, [11,12, 13].

Compared to gravimetric dosing by discontinuous measurement, additional gravitational errors due to conveyor belt velocity and geometry of the weighing conveyor belt load are due to continuous gravimetric measurement. The weighing errors in feeder dispensers (gutters, tubes) are amplified by the conveyor plate and the speed.

The advantage of weighing scales with weight extraction is that many of the errors that influence the weighing process are avoided because in this case the weight is the main measure of measurement.

The dosing of materials in varc by centrifugal or pulse forces depends on the physico-mechanical properties of the dosing materials: the natural tilt angle, the internal friction coefficient, the friction angle and the flow rate. The main application of these methods is for material flows higher than 0.5 t / h. Measuring meters should be calibrated for each type of dosing material.

Radiation dosing of material flow, sometimes called erroneously "nuclear weighing", is based on the radiation absorption phenomenon by the exposed material, thus determining the specific loading of the conveyor belt. Calibration is required for each type of dosing material. This method is suitable for large material flows, as it is found in belt conveyor installations, but is not suitable for weighing due to limited precision.

Weighing systems of gravimetric meters are defined by the following elements: system shape and construction, mechanical construction, weighing sensor type.

The mass of material dosed at a given moment by the gravimetric dosing equipment is determined by measuring very short the weight force exerted by the dosed material on a weighing cell underneath the weighing trough which transforms the weight of the material dipped in an electrical signal, which can then be easily measured and displayed on a screen or listed on a printer.

In principle, electromechanical weighing equipment and devices consist of a load cell, a weighing cell and a display with electronic display. After loading is applied, the weight is indicated immediately [14,15].

The weighing cell is therefore an electromechanical sensor that transforms the weight of the weight exerted by the mass into an electrical signal proportional to the weight of the weighted mass. The weight of the mass is determined by the equation:

$$F_G = m \cdot \left(1 - \frac{\rho_1}{\rho_m}\right) \cdot g$$

Where: ρ_1 – air density,
ρ_m - density of mass,
g – gravitational acceleration.

The characteristics of electromechanical weighing devices are mainly determined by the weighing cells, characterized by the weighing device resolution and the conditions in which it is used.

Weighing devices used in industry or trade, whose calibration can only be verified at two to three years may deviate from the accuracy of between 10-1 and 10-4 in case of less ideal environmental conditions. These require weighing cells with as long a stability as possible.

The most widespread weighing principles are those with force transducers (by deformation), force transducers with electromagnetic re-compensation, and diapers and vibrating wire transducers.

MATERIAL AND METHOD

The main performance parameters of industrial dosing and weighing systems are the dosage / weighing accuracy (%) and the productivity of the dosing / weighing process (dosages / min, kg / hour, etc.).

Dosing precision is a parameter that represents the relation between the actual mass of the dose and the projected value of the dose. In the case of volumetric dosing, the dosage accuracy is evaluated as a mass or mass flow rate because in most cases the doses are expressed in mass units. This is also the reason why the volumetric dispensers are less precise than the gravimetric ones, which is the direct demand from the mass volumetric dose relation M:

$$M = V \cdot \rho \cdot e$$

where:
V – volumetric dose,
ρ – density of the material to be dosed (kg/m^3),
e – fill factor of the dosing chamber.

Dose size variations influence the density ρ of the dosed product, fluctuations due to the product feed mechanism, mechanical vibration of the system, compaction phenomena (in the case of granular and pulverulent products) etc. These phenomena ultimately affect the size of the dose of the product are randomly variable over time, which makes the size of the dose itself a probalistic function of time, [1,18,19].

For the continuous dosing, a series of probalistic sizes are defined which characterize dosing precision (13), the most important ones being the following:

- the mean M_m expressed by the relation:

$$M_m = \sum_{i=1}^{n} M_i / n$$

where:
N - represents the number of samples (n: 20-30 samples).

- the mean square deviation of the experiment dose through the relation:

$$\sigma_M = \sqrt{\frac{\sum_{i=1}^{n}(M_i - M_m)^2}{n-1}}$$

- the probalistic dose error ε_p is expressed in the relation:

$$\varepsilon_p = \pm(2\ldots3)\sigma_M$$

- the systematic dose error ε_s is expressed by the relation:

$$\varepsilon_S = M_m - M = \frac{1}{n}\cdot\left(\sum_{i=1}^{n} M_i\right) - M$$

- total dosing error ε expressed by:

$$\varepsilon = \varepsilon_s + \varepsilon_p$$

or,

$$\sigma_M = \frac{1}{n}\cdot\left(\sum_{i=1}^{n} M_i\right) - M \pm (2\ldots3)\cdot\sqrt{\frac{\sum_{i=1}^{n}(M_i - M_m)^2}{n-1}}$$

Typically, the value of the dose Mm represents the benchmark of the dosing session, and the mean square deviation σM characterizes the probalistic dosing error.

Modern dispensers must ensure an accuracy of 0.2 ÷ 0.5% for proportional dosing and 0.5 to 2% for continuous dosing. In any case, for each type of dispenser, the value of the expression (4.7) must not exceed certain limits set by the application's specificity, [21].

Dosage precision is a parameter of greatest importance to the construction and operation of automated dosing systems, since the precise dosing of dosages is required by norms that must be complied with, whether they refer to manufacturing processes or packaging processes products.

The productivity of the dosing process is defined as the number of doses achieved in the unit of time (for portion dosing) or the quantity of material in the unit of time of productivities: ideal (technological), theoretical and real.

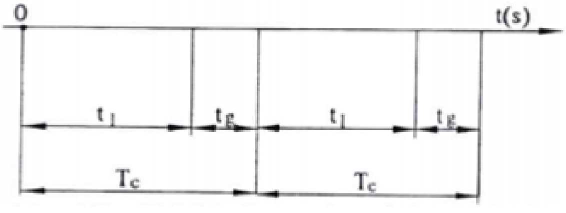

Fig. 2. The working cycle of a dosing system **[21]**

- The real productivity Q is expressed with the relation:

$$Q = \frac{1}{T_C + t_a} = \frac{1}{t_1 + t_g + t_a}$$

where: T_C – cycle time,
t_a – off-cycle times,
t_l – working times,
t_g – empty time.

The theoretical productivity Q_1 is expressed in relation:

$$Q = \frac{1}{t_1}.$$

The following reports are defined in the literature in the field:

$$\eta_1 = \frac{Q}{Q_1} < 1$$ (Machine usage coefficient)

$$\eta_2 = \frac{Q_1}{Q_2} < 1 \leq 1$$ (Productivity coefficient)

Among the three productivities there is the relation:

$$Q = \eta_1 \cdot \eta_2 \cdot Q_2 = \eta_1 \cdot Q_1$$

RESULTS AND DISCUSSIONS

Precision - Productivity - Cost Relation Applied to Dosing Systems

In fig. 3 are presented the evolutions of the dosage accuracy and the real productivity, with the increase of the working time, in the basic regime. It is noted that there is an optimum area at the intersection of curves (precision dosing) and Q (real productivity), the situation is specific for continuous dosing systems and portions, [21].

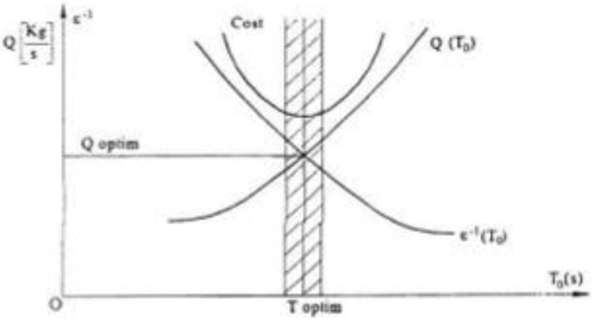

***Fig. 3. Evolution of dosage precision and real productivity with increased working time* [21]**

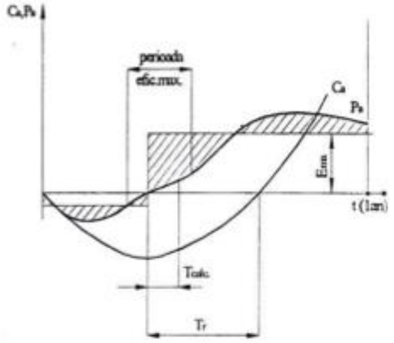

Fig. 4. Evolution of costs related to the implementation of the dosing system **[21]**

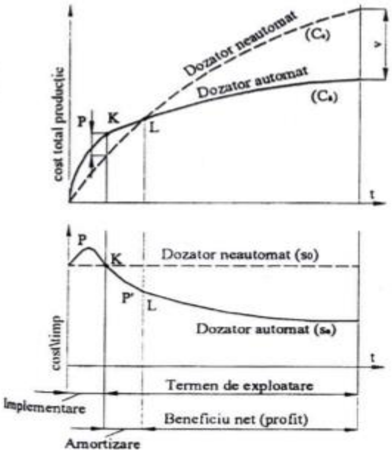

Fig. 5. Evolution of costs related to the operation of dosing systems **[21]**

The evolution of costs related to the implementation and operation of the dosing systems are shown in Fig. 3 and fig. 4 according to fig. 5, a leap of the cost prices (total and specific) for the automatic dispensers, during the implementation period *ρ*, caused by the expenditures for the elaboration of the automation means, their design, the training of the personnel, etc. in point *K*. However, the depreciation period of the investment begins, when the specific costs for the two variants have equaled. During this period, the funds that were spent for applying the automated version will be refunded.

The depreciation period lasts until all deployment costs have been reimbursed - point L ($C_0 = C_a$), which characterizes the effectiveness of automation.

After scratching the damping period, the automatic system brings a greater net benefit than the non-automatic, V:

$$V=C_0-C_a.$$

The operating time of the automatic dispenser is comprised of the depreciation period and the period of net benefit. After the leakage and this period, when the dosing system was used morally and physically, its continued use does not bring any benefit.

The most widespread weighing principles are those with force transducers (by deformation), force transducers with electromagnetic re-compensation, and diapers and vibrating wire transducers.

Static weighing methods with tensiometric marks transducers in which weighing force enters the weighing cells can be determined with tensometric resistance. On the tensiometric marks the electrical resistance of a conductor changes under the influence of an elongation, [18,20].

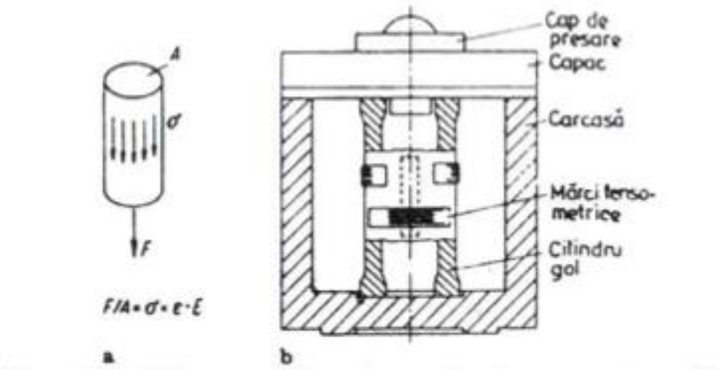

Fig. 6. Measurement of tensile strength **[18]**
a - elastic deformation of a bar, b - dynamometric (weighing cell) strain gauge (Simens)

CONCLUSIONS

The characteristics of granular materials that influence the dosing, weighing and packaging process that must be taken into account when designing and manufacturing the technical equipment for these operations are mainly the following:

- size, shape and distribution of particles;
- the unity of the material subject to dosing, weighing, packaging;
- the angle of settlement α_a, the angle of flow α_c, the angle of natural slope α_n;
- density of bulk material ρ_m and vibration density ρ_{mv};
- fluidization or degassing;
- effective friction angle $\varnothing_e$ and friction angle with a $\varnothing_p$ wall;
- the internal friction angle;
- the flow coefficient ff_c and the flow value ρ_{mv} / ρ_m '
- bulk material f_c resistance;
- adhesion, abrasion, corrosivity, fragility, explosiveness;
- fuel, dustiness, humidity, adhesion, hydrification.

The dosing systems aim at dividing the mass of material, defining two main categories of dosing procedures:

- dosing procedures by measuring the flow of material;
- dosage procedures where the material flow measurement method takes into account other parameters such as fill volume, Coriolis strength, radiation absorption.

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