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COMPUTATIONAL ALGORITHM FOR THE HUMIDITY OF A LOW GRANULATION MIXTURE OF MATERIAL

BY

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Abstract. An important parameter that needs to be measured and corrected in the installations which work with a low granulation material (*e.g.* sand), is the one that concerns the amount of water and, respectively, the humidity contained in the prescribed mass (of that material). This mass is made up of materials of the same type that have different degrees of humidity. The aim of this paper is to establish the mathematical algorithm on the basis of which one can determine the values of the above mentioned parameters using an automatic computational system.

Key words: low granulation material; amount of water; humidity.

1. Introduction

In certain fields of activity, such as that of metal foundries, it is necessary to make mixtures of materials of the same type (*e.g.* sand), which have, however, different physical characteristics (*e.g.* different degrees of humidity). The resulting mixture material should have, in its turn, certain imposed physical parameters. This means, first of all, that such parameters should be evaluated and then, if need be, they might be modified, so that the desired values may be obtained.

This depends, from one situation to another, on several factors, from

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among which we can mention: the scheme regarding the handling of the material, the manner in which the mixture is obtained, the presence of the apparatus for measuring and adjusting the required physical parameters, and, last but not least, the existence of an algorithm for calculating the parameters specific to the mixture of material that has been obtained.

The rest of the paper presents the way in which the amount of water and, respectively, the humidity of a low granulation mixture of material can be determined by calcululus and can be adjusted.

2. The Installation for Handling and Collecting the Material

Let us consider, specifically, the case of an installation that comprises three conveyor belts, CB_i , (i = 1, 2, 3), each of which can take material out of an individual bunker, IB_i , (i = 1, 2, 3), in order to discharge it on the conveyor collector belt CCB, which, in its turn, deposits it on a collector bunker, CB (Fig. 1). The amount of material that is gravitationally discharged from each individual bunker to the corresponding conveyor belt depends on the size of the (bunker's) flow cross section, whose value may be established with the help of a slide valve SV_i , (i = 1, 2, 3); by modifying its position, the length of one of the sides of the flow cross section (rectangular in shape) is modified, while the other side keeps a similar, constant length for all the individual bunkers present in the installation (http://www.automatica.ro/.../cantar-totalizator-de-banda; http://www.automatica.ro/.../dozatoare-gravimetrice...; http://www.componente-industriale.ro/...).

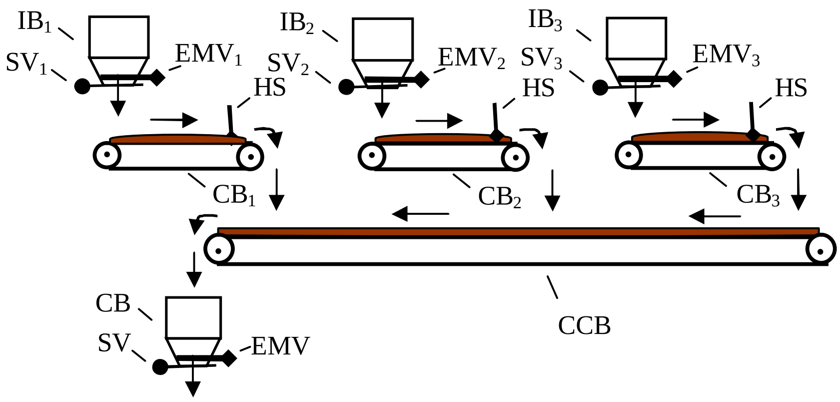

Fig. 1 – Block diagram of an installation for transporting and collecting material, endowed with three conveyor belts and a collector belt: CB_1, CB_2, CB_3 – conveyor belts; IB_i , (i = 1, 2, 3) – individual bunkers; CCB – collector conveyor belt; CB – collector bunker; HS – humidity sensors; SV, SV_i , (i = 1, 2, 3) – slide valves; EMV, EMV_i , (i = 1, 2, 3) – electromagnetic valves.

Considering the fact that in a starting phase each conveyor belt absorbs from the electricity grid relatively high voltage currents, the starting up of the conveyor belts is achieved sequentially, with a certain time lag in between them; in the case under study, the first to start operating is the collector conveyor belt. As regards the conveyor belts, belt number 2 and, respectively, belt number 3 will start operating at a time interval Δt_1 and respectively Δt_2, as compared to time 0, which is the moment when belt number 1 starts functioning (Fig. 2).

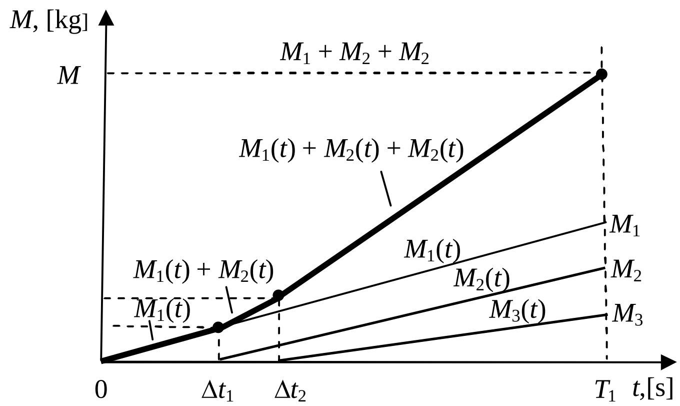

Fig. 2 – The evolution in time of the masses of material, M_1, M_2 and M_3, transported on three conveyor belts, and respectively M, on the collector belt: Δt_1, Δt_2 – the time interval after which the second and, respectively, the third conveyor belt can start; T_1, the operating time of conveyor belt 1, respectively, the period in which the mass of material M is deposited on the collector belt (respectively in the collector bunker).

At the same time with the starting up of the individual conveyor belts, several electromagnetic valves, EMV_i, (i = 1, 2, 3), corresponding to the individual bunkers are opened on command; all this time valve EMV, corresponding to the collector bunker is kept shut.

The whole process is driven with the help of an operative command and control system that administrates the start-ups/stops, the measurement and control operations for the whole installation.

At the same time, during the operating period of the installation, the operative command and control system receives information from the electronic scales (situated on the collector belt) and evaluates in real time the flow and amount of material introduced in the collector bunker.

In what concerns the shut down of the whole installation, it should be mentioned that this is also done sequentially: after a command received from the command and control system, the electromagnetic valves EMV_i, (i = 1, 2, 3), that lock the flow sections of the individual bunkers are shut simultaneously (see Fig. 2), thus stopping the flow of material on the conveyor belts; there follows a short period of time in which the rest of material from the conveyor belts and from the collector belt is discharged, then these belts are also stopped.

The whole shut down sequence is managed in such a way that, in the end, the whole amount of prescribed material of mass M is deposited.

The problem posed is to establish the computational algorithm for the calculus of the amount of water and of humidity contained in the mass of material (*M*) deposited in the collector bunker, so that it may subsequently be corrected and brought to the prescribed value.

The measurement of this amount of water can be performed by means of direct measurement, with the help of several humidity sensors (HS in Fig. 1) placed in intimate contact with the material which is transported on each conveyor belt, followed by the analytical computational estimation of the total amount of water present in the mass of material, deposited in the collector bunker.

Thus, in this approach, a humidity sensor HS is in permanent and profound contact with the material transported on each individual conveyor belt, as shown in Fig. 1. During the functioning period, each sensor performs and transmits in a sequence, at very short time intervals, a great number of measurements corresponding to the samples of material that come into contact with each and every humidity measurement sensor.

The information offered by each humidity sensor is transmitted to the operational computational system, which uses a mathematical algorithm in order to determine the value of the total amount of water and, respectively, of humidity present in the mixture of material which is deposited in the collector bunker.

3. Humidity Computational Algorithm

In order to determine the computational algorithm for the humidity of the mass of material *M* deposited in the collector bunker by a given number of conveyor belts, it is important to know certain things: how the running conveyor belts are started and stopped, the humidity values corresponding to the mass of material samples (which are being measured), the rhythm in which this information is conveyed from the humidity measurement sensors to the operational computation system, the value of the flow cross sections of individual bunkers, from which the material is discharged on the conveyor belts, etc.

The way in which the total mass of prescribed material (*M*) is formed is shown in Fig. 2, for the case in which the installation works with three conveyor belts.

The determination of the humidityof a mass of material *M* deposited in the collector bunker presupposes the prior determination of the amount of water, *W*, which is contained in this mass of material.

In order to do this, it is first necessary to know how is formed the mass of material M_i, deposited by each conveyor belt in the collector bunker, in a certain period of time; secondly, it is necessary to know the way in which is calculated the sum total of humidities, measured for each sample of mass of material that circulates on the belt *i*, ($i = 1, 2,...,n$) (where n represents the total number of conveyor belts that can be operated Fig. 3).

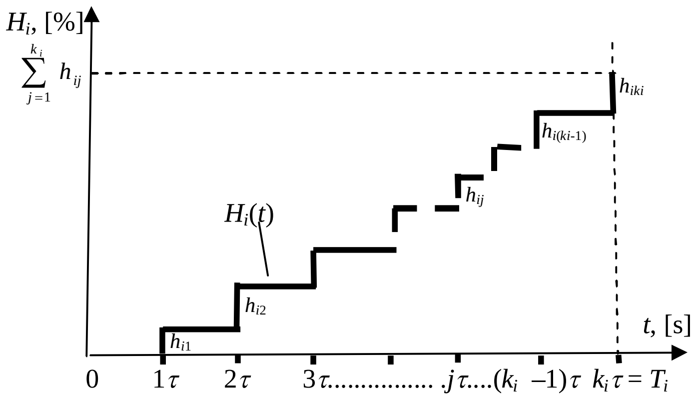

Fig. 3 – The sequential evolution of the sum total of humidities $H_i(t)$, contained in the material transported on the conveyor belt i: τ, the sampling (measurement),period of the total operating interval,T_i; k_i, the number of measurements performed in the operating period T_i, for the conveyor belt i, (i = 1,...,n, where n – the maximum number of conveyor belts that can operate) h_{ij}, humidity, measured in (%), corresponding to the material sample j, (j = 1, 2,...,k_i) transported on the conveyor belt i.

Taking into account what is shown in Figs. 2 and 3, for the particular situation of an installation with three working conveyor belts, the relations between the total working time spans (for each and every conveyor belt) and the corresponding number of measurements (sampling) k_i , (i = 1, 2, 3) are the following: $T_1 = k_1\tau$ (for conveyor belt 1), $T_2 = k_2\tau = T_1 - \Delta t_1$ (for conveyor belt 2) and, respectively, $T_3 = k_3\tau = T_1 - \Delta t_2$ (for conveyor belt 3), where the smaller the sampling period, the better the calculus accuracy of the humidity (H_i) sum total.

Taking into account what was presented above, the determination of the general calculus relation of the total amount of water, and, respectively of the humidity corresponding to the mass of material M deposited in the collector bunker by a number n of conveyor belts, will be carried out in two stages.

a. The determination of the analytical calculus expression of the total mass of humid material M deposited in the collector bunker.

The total mass of material M deposited in the collector bunker is formed as a sum of masses of material, in conformity with the relation:

$$M = M_1 + M_2 +.....+ M_n, \text{ [kg]}, \tag{1}$$

where: M_1, M_2,...,M_n represent the masses of material transferred from each individual bunker into the collector bunker by means of the n conveyor belts.

The calculus relation of the masses of material transferred in a certain period of time can be rendered more explicit as follows:

$$M_1 = \rho v_1 s_1 T_1;\ M_2 = \rho v_2 s_2 T_2;............M_n = \rho v_n s_n T_n, \tag{2}$$

where: T_1, T_2,....,T_v represent the running time periods of the *n* conveyor belts (in operation), for a complete operational cycle, [s]; v_1, v_2,....,v_n represent the rate of flow of the material through the (flow) section corresponding to each individual bunker, [m/s]; ρ represents the density of the material (considered approximately similar for the material transported on each of the *n* belts, [kg/cm].

When a low granulation material is transported (*e.g.* sand), we can approximate that $v_1 \approx v_2 \approx ... \approx v_n = v$, *i.e.*, the flow rate of the material is the same, irrespective of the flow section of the individual bunker (irrespective of the slide valve opening).

As a result, the calculus relations of the masses of material deposited in the collector bunker become:

$$M_1 = \rho v s_1 T_1;\ M_2 = \rho v s_2 T_2;...\ M_n = \rho v s_n T_n\,. \qquad (3)$$

If we take into consideration that:

a) the flow sections of the individual bunkers are rectangular, their surface can be calculated with the relations:

$$s_1 = lh_1,\ s_2 = lh_2;...\ s_n = lh_n,$$

where: *l* represents the length of one side of the section, which has the same value for all the individual bunkers; h_1, h_2,....,h_n represent the lengths of the sides (openings) of the flow sections, which can be adjusted (if necessary) by modifying the position of the corresponding slide valve;

b) the general calculus expression (Fig. 3) for the total material transfer time T_i from an individual bunker (belonging to *i* conveyor belt) and the collector belt is given by the relation

$$T_i = k_i \tau,$$

then, by making more explicit the individual time intervals for providing the material (on the collector band) for each of the *n* working conveyor belts, T_i, (i = 1, 2,....,n), they can be calculated with the relations:

$$T_1 = k_1 \tau,\ \ T_2 = k_2 \tau,...,\ T_n = k_n \tau.$$

Under these conditions, the calculus expressions of the masses of material transported on each conveyor belt become:

$$M_1 = \rho v l \tau h_1 k_1;\ M_2 = \rho v l \tau h_2 k_2;...\ M_n = \rho v l \tau h_n k_n \qquad (4)$$

and respectively,

$$M = \rho v l \tau (h_1 k_1 + h_2 k_2 + ... + h_n k_n). \qquad (5)$$

b. The determination of the calculus relation of the total amount of water and, respectively of humidity

The total amount of water, *W*, present in the mass of humid material *M* deposited in the collector bunker is calculated as the sum of the quantities of water W_i, (i =1, 2,...,n), present in the masses of material, transported by each of the n conveyor belts in the duty period, *i.e.*,

$$W = W_1 + W_2 + ... + W_n, \text{ [kg]}. \tag{6}$$

In this relation, the quantities of water W are calculated while taking into consideration the sum total of the humidities (in percentages) H_i , (i = 1, 2,...,n), which correspond to the k_i , (i = 1, 2,...,n) samples of mass m_i ($m_i = M_i/k_i$), evaluated in the duty period of number i conveyor belt (Fig. 3), *i.e.*, hence it results:

$$W_i = \frac{M_i}{k_i} \cdot \frac{H_i}{100} = \frac{1}{100} \cdot \frac{M_i}{k_i} \sum_{j=1}^{k_i} h_{ij}, \text{ [kg]}, \tag{7}$$

hence it results,

$$W = \sum_{j=1}^{k_i} \frac{M_i}{k_i} \cdot \frac{H_i}{100}, \text{ [kg]}. \tag{8}$$

Considering the calculus expressions of the masses of material $M_1, M_2, ..., M_n$ and, respectively, M, determined by relations (4) and, respectively, (5), and, at the same time, multiplying and dividing relation (8) by the total mass M of material, is obtained the final relation for the determination of the amount of water contained in the mass of humid material deposited in the collector bunker:

$$W = \frac{M}{100} \cdot \frac{\sum_{1}^{n} (H_i h_i k_i)}{\sum_{1}^{n} (h_i k_i)}, \text{ [kg]}. \tag{9}$$

Knowing the quantity of water W, we can determine the humidity corresponding to the mass of humid material M, deposited in the collector bunker with the relation:

$$H = \frac{100}{M} W, \ [\%]. \tag{10}$$

4. Conclusions

From the analysis of relations (8),..., (10) it results that, in order to determine the amount of water and, respectively, the amount of humidity, contained in a quantity of material deposited in a collector bunker by a certain number of conveyor belts, it is necessary to find the following information regarding the installation:

a) the total mass of material M deposited in the collector bunker during the functioning period of the first conveyor belt that is first set in operation (conveyor belt number 1). This value is measured by means of special electronic scales;

b) the openings of the flow sections h_i, (i = 1, 2,....,n), where n is the maximum number of conveyor belts that can be set in operation) corresponding to each individual bunker that deposits material on the corresponding conveyor belt;

c) the sum total of humidities, H_i, (i = 1, 2,....,n) in percentages, calculated as the sum of humidities corresponding to the k_i, (i = 1, 2,....,n) samples of mass m_i where $m_i = M_i/k_i$, (i = 1, 2,....,n) are samples that are evaluated in the duty period of the conveyor belt number i;

d) the number of samples (measurements) k_i, (i = 1, 2,....,n) that are performed for each and every conveyor belt in the corresponding duty period; the values for the parameter k_i are determined in an analytical manner, by dividing the total functioning interval T_i, corresponding to the conveyor belt number 1 by the sampling period τ (the same for all the functioning conveyor belts), *i.e.* $k_i = T_i/\tau$.

It should be mentioned that these operations are done automatically, with an automatic data gathering and processing system; the start-up command for the whole system is given manually (by the operative personnel); the whole operation is stopped automatically, the command being given by the command and control system when the whole prescribed quantity of material M (evaluated by electronic scales) has been deposited in the collector bunker.

The command and control system evaluates automatically, on the basis of the calculus relation (9) the whole amount of water W, present in the mass of material M deposited in the collector bunker, and, depending on the result obtained which is displayed on a monitor, the operative personnel will be able to take the proper decisions, in order to bring this parameter to the specified value.

We should also specify that, in order to carry out these operations automatically, a specialized computational program, and, respectively an interface were devised that can take over the input parameters and, respectively, the transfer of the output parameters to the installation execution elements.

Finally, it should be mentioned that this computational algorithm is implemented and used in foundry sand processing installations, after it has been checked and certified from a qualitative point of view.

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ALGORITM DE CALCUL A UMIDITĂȚII UNUI AMESTEC DE MATERIAL CU GRANULAȚIE SCĂZUTĂ

(Rezumat)

O mărime importantă, care trebuie determinată şi corectată, în instalațiile în care se lucrează cu material cu granulație redusă (de exemplu, nisip), este aceea care se referă la cantitatea de apă, respectiv, la umiditatea pe care o conține o masă prescrisă (din acel material), masa care se constituie prin amestec de materiale de acelaşi tip, dar cu umidități diferite. Scopul prezentei lucrări, este acela de a stabili algoritmul matematic, pe baza căruia să se poată determina, utilizând un sistem automat de calcul, valorile mărimilor menționate.