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MATHEMATICAL ALGORITHM FOR CALCULATING THE COEFFICIENTS OF EXTRACTION OF A PLANSIFTER COMPARTMENT IN WHEAT MILLING PLANT

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The sifting process is influenced by a number of factors that can decrease the separation efficiency, and interactions between these factors are so complex that there is no precise method for evaluating and predicting the degree of separation of the sifted material from the initial mass. This led to the low efficiency of industrial equipments for sifting. Therefore, it is important to better understand this process and to define the optimal conditions of sifting. Expression of sifting process through mathematical relationships is, generally, empirical, worldwide the researchers proposing different models approaching more or less to reality. These models were verified experimentally and the coefficients of mathematical relationships and the degree of correlation with experimental data were determined. In industrial milling units, grinding of seed or crushed seed fraction, are always followed by a sifting stage in a plansifter compartment for dividing grist on fractions. In this paper is presented an algorithm for calculating the coefficients of extraction on frames, on frames packages and on the entire plansifter compartment using experimental data obtained from the first plansifter compartment of a wheat milling plant with a capacity of 100 t/24 h. Coefficients of extraction shows the degree of separation of the sifted particles from the initial material feeding the sieve or sieve package at a time. Through this the sifting efficiency for a frame or a packet is actually estimated. Their knowledge is essential for assessing the technological passages yields of grain milling unit. Based on this algorithm the coefficients of extraction of frames and packages of frames are then calculated.

Keywords: plansifter compartment, sifting efficiency, coefficient of extraction, grist, mathematical algorithm

1. Introduction

Sifting, or mechanical classification, is probably one of the oldest and the most widespread processes for separating heterogeneous mixtures of solid-solid type. Size distribution of grist processed at each technological passage in industrial mills is very varied due to adopted working regime at each pair of

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grinding rollers, and due to the physical characteristics of wheat seeds and intermediate products of grist. Therefore, the conditions of grinding, grinding machine type, speed of working bodies, may affect this distribution by size of grists [1, 2]. In [3], one of the first papers which addresses the issue of sifting, a dynamic analysis of the sifting process is described and the factors that affects the sifting performance are studied.

Liu, [4], and Allen, [5], consider that, from many factors that influence the effectiveness of sifting process, the most important are the size and shape of the grist particles, sifting surface characteristics, quantity of grist which reaches on the surface of the sieve, sieve kinematics and the relative motion of material on its surface, opinion supported by other authors [6-9]. The same conclusion is drawn by Standish and Sultanbawa, [10, 11], which consider that, although sifting process is very familiar, it has a number of variables that can lead to erroneous data in analysis of the sifting process.

Choice of fabric (textile or metallic) and the aperture size of fabric for the sieves that are inside plansifter compartment are done depending on the dimensional characteristics of the grist particles that reach the compartment. In [12], Alkhaldi makes a comparative analysis between two types of sifting surfaces in simulation of sifting process.

Also, the movement of particles on sifting surface depends on the material feeding zone, and on the size of the apertures, [13, 14]. Moreover, actuating and equilibration of plansifter influence directly the effectiveness of sifting process, an improper equilibration results in decreasing the lifetime of machine and to decrease of sifting efficiency, [15, 16, 17, 18].

Of all the variables of sifting process, obturation of sifting surface apertures is considered to be the most important. Apertures obturation occurs when the revolution of plansifter actuating mechanism is chosen wrong and because of this the refusal particles get stuck in the fabric apertures. Thereby, the effective transfer area is reduced, resulting a decrease in the efficiency of sifting (sifting performance or capacity) and the degree of separation of the particles (sifting efficiency) [6, 7, 9, 10, 19].

Separation efficiency on a sifting surface can be appreciated through the coefficient of extraction of that surface. Within a plansifter compartment, frames are disposed on packages (each having the same characteristics of fabric). Within the package frames, generally work in series (consecutive), while the frame packages can work both in parallel and in series. The coefficient of extraction of a sifting frame represents the ratio between the quantity of sifted material and the quantity of material which feeds the respective sifting frame. By extension, coefficients of extraction can be calculated for each frame package or at each plansifter compartment, which is composed of several overlapping frame packages.

Knowing the debits of material that enters at each plansifter compartment, as well as debits of each fraction of material separated at respective compartment (evaluated by its outputs), can be determined the coefficients of extraction of packages and compartments.

2. Material and method

In our paper, is presented a calculation algorithm for the coefficients of extraction of packages and frames at first plansifter compartment from the breakage phase of milling plant. For this purpose samples were taken from the technological flow of the milling plant and debits were determined at entry into compartment and the five outputs of it. In figure 1 is shown the interior scheme of the compartment and calculation scheme for the coefficients of extraction.

From fig. 1,a is noted that the first plansifter compartment of the analyzed milling plant consists of five packages. First package has seven sieve frames no. 20 (with the aperture side of 1050 μm) and second package – four frames no. 40 (aperture side of 470 μm). Packages III and IV have three sifting frames for the separation of flour, package III contains frames no. IX (with size of an aperture of 170 μm), and package IV contains frames no. X (with size of an aperture of 150 μm). Last package, package V, has two frames with metal fabric no. 56 (aperture being of 310 μm). Within packages the frames work consecutive, and within compartment the first three packages work in parallel, and the third package, the fourth and the fifth package work consecutively.

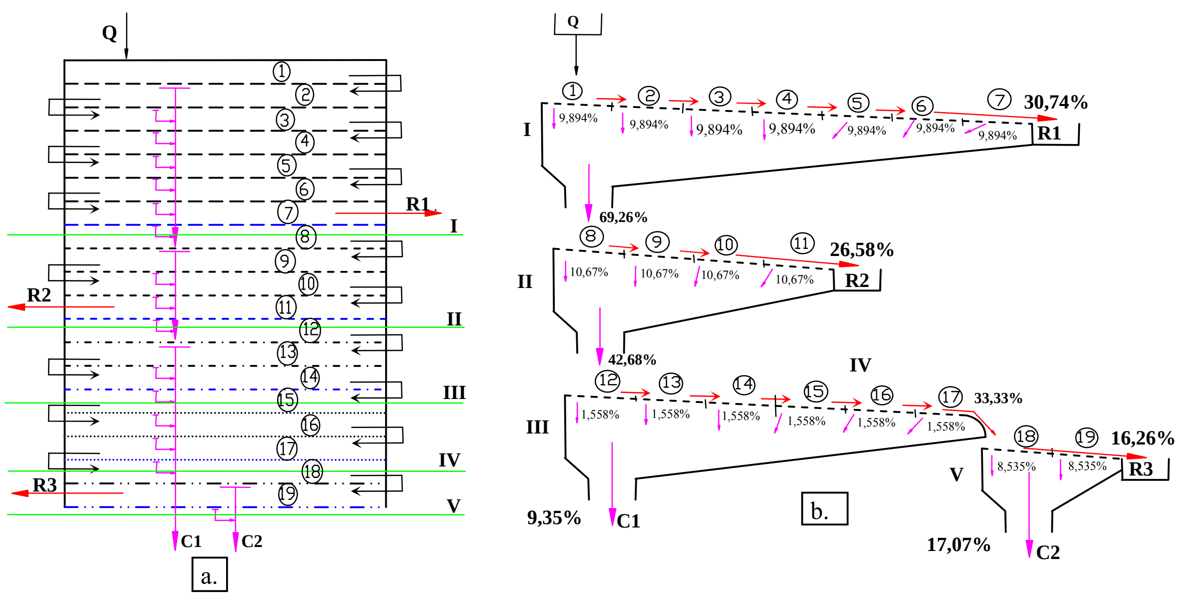

Fig. 1. The interior scheme of the analyzed plansifter compartment (a) and calculation scheme the coefficients of extraction of the frames and packages at the same plansifter compartment (b)

Experimental data, shown in table 1, corresponding to quantities of material gathered at the entrance and the five outputs of compartment for a test period of 10 seconds.

According to the data in table 1, at first package, on those seven frames, is sifted 69.26% from material, and 30.74% of it constitutes in refusal R1. At package II from 69.26% material is sifted 42.68%, and 26.58% of it constitutes in refusal R2. At packages III and IV, from 42.68% reaching, 9.35% constitutes sifting C1, and the refusal of these two packages, 33.33%, reach on package V, where 16.26% is withdrawn as a refuse R3, while 17,07% constitutes sifting C2.

Notations from fig. 1.a have the following meaning:

- Q – feed debit of plansifter compartment, equal to the amount of grist that comes from the rollers mill;
- R1 – first refusal of the compartment and it is the grist fraction with particle diameter greater than 1050 µm that will reach at second break passage for a new grinding;
- R2 – second refusal of the compartment, fraction that will reach to a sorting compartment;
- R3 – the third refusal of the compartment, fraction that will reach to a sorting compartment;
- C1 – first sifting of the compartment, which represents a second quality flour;
- C2 – second sifting of the compartment, constituting a dunst which is directed to a grinding technological passage.

Table 1.

Debits at entrance (Q) and at the five outputs (R1, R2, R3, C1, C2) of the plansifter compartment:

Grist fraction	Q	R1	R2	R3	C1	C2
Grist quantity, [g]	7294.6 g (100%)	2242.6 g (30.74%)	1939 g (26.58%)	1186.4 g (16.26%)	681.7 g (9.35%)	1244.9 g (17.07%)

In our analysis we considered that the frames of package are not sifting the grist equally, and the percentage of sifted material within each package follows an exponential distribution, percentage of sifted material decreasing from the first to the last frame of the package.

Thus, the relation which expresses the material debit refused by a package is the following:

$$R_i = Q_i \cdot e^{-b \cdot L} \qquad (1)$$

where: R_i is the refusal of package i; Qi – material debit which feeds the package i; L – total length of the frames from the package (which is the sum of frame length of the analyzed package – L=n×l; l – length of one frame); b – exponent (coefficient of unevenness at feed).

Knowing the length of one frame and the quantities of material Q_i and R_i we can determine the coefficient b for each package, using the relationship:

$$b = -\frac{1}{L} \cdot \ln\left(\frac{R}{Q_i}\right) \tag{2}$$

At package III and IV (package with flour sieve that work consecutively), on the assumption that the frames do not sift equally, it can be considered that the percentages of sifted material is proportional to the size of the aperture side of frames that compile the two packages.

Thus, at package III, the three flour frames (no. IX) have the size of aperture of 170 μm, and at package IV flour sieve no. X have the size of aperture of 150 μm. Thus, one can write, the ratio of dimensions:

$$C_{III} = C \cdot \frac{170}{150+170} = 0.531 \cdot C \quad ; \quad C_{IV} = C - C_{III} = 0.469 \cdot C \tag{3}$$

where: C is the total material sifted at the two flour frame (III and IV); $C_{III}+C_{IV}=C1$.

In conclusion on package III we consider that is sifted 53.1% from sifting C (of the two package), and on the package IV is sifted 46.9% from the entire sifted material.

Knowing the calculus relationship for refusal of each frame, percentages for refusals R1, R2, R3, percentages for sifted material C1 and C2, and the percentage for sifting C1 of package III and IV, one can be determine the coefficients of extraction on package and on frame for the plansifter compartment using the assumption that grist is sifted equally by each frame.

3. Results and discussion

The algorithm presented below is new and has not been used in the scientific literature.

1. For package I

a. Considering those presented previously, based on the experimental data one can calculate the unevenness coefficient for feeding of frames, b, from relation of R1:

$$R1 = Q \cdot e^{-b_I \cdot 7l} \Rightarrow \frac{R1}{Q} = e^{-b_I \cdot 7l} \Rightarrow \ln\left(\frac{R1}{Q}\right) = -b_I \cdot 7l \Rightarrow b_I = -\frac{1}{7l} \cdot \ln\left(\frac{R1}{Q}\right) \tag{4}$$

b. Knowing exponent b_I the calculus relationship for the refusal of each frame is determined.

$$R_{I,i} = Q_{I,i} \cdot e^{-b_I \cdot i \cdot l} = Q_{I,i} \cdot e^{-\left[-\frac{1}{7l} \cdot \ln\left(\frac{R1}{Q}\right)\right] \cdot i \cdot l} = Q_{I,i} \cdot e^{\frac{i}{7} \cdot \ln\left(\frac{R1}{Q}\right)} \tag{5}$$

where $i = 1 \div 7$.

c. Further, feed debits of package frames and their sifted material, is determined by the relation:

$$Q_{I,i} = R_{I,i-1} \Rightarrow P_{I,i} = Q_{I,i} - R_{I,i} \tag{6}$$

where $Q_{I,1} = Q$ and i = 1÷7.

d. Knowing the feed debits and the material sifted on frames relations for the coefficients of extraction of each frame may be written:

$$\eta_{I,m} = \begin{cases} \dfrac{P1}{Q_{I,1}}, & if\ m = 1 \\ \dfrac{P_{I,m}}{Q_{I,1} - \sum\limits_{i=1}^{m-1} P_{I,i}} = \dfrac{P_{I,m}}{R_{I,m-1}}, & if\ m \geq 2 \end{cases} \tag{7}$$

where m = 1÷7 and i > 1.

e. Knowing the coefficients of extraction of frames the coefficients of extraction of the package can be calculated:

$$\begin{aligned} \eta_I = & \sum_{1 \le i_1 \le 7} \eta_{i_1} - \sum_{1 \le i_1 < i_2 \le 7} \eta_{i_1} \cdot \eta_{i_2} + \sum_{1 \le i_1 < i_2 < i_3 \le 7} \eta_{i_1} \cdot \eta_{i_2} \cdot \eta_{i_3} - \\ & - \sum_{1 \le i_1 < i_2 < i_3 < i_4 \le 7} \eta_{i_1} \cdot \eta_{i_2} \cdot \eta_{i_3} \cdot \eta_{i_4} + \sum_{1 \le i_1 < i_2 < i_3 < i_4 < i_5 \le 7} \eta_{i_1} \cdot \eta_{i_2} \cdot \eta_{i_3} \cdot \eta_{i_4} \cdot \eta_{i_5} - \\ & - \sum_{1 \le i_1 < i_2 < i_3 < i_4 < i_5 < i_6 \le 7} \eta_{i_1} \cdot \eta_{i_2} \cdot \eta_{i_3} \cdot \eta_{i_4} \cdot \eta_{i_5} \cdot \eta_{i_6} + \\ & + \sum_{1 \le i_1 < i_2 < i_3 < i_4 < i_5 < i_6 < i_7 \le 7} \eta_{i_1} \cdot \eta_{i_2} \cdot \eta_{i_3} \cdot \eta_{i_4} \cdot \eta_{i_5} \cdot \eta_{i_6} \cdot \eta_{i_7} = \\ & = \sum_{k=1}^{7} (-1)^{k-1} \sum_{1 \le i_1 < i_2 < i_3 < i_4 < i_5 < i_6 < i_7 \le 7} \eta_{i_1} \cdot \eta_{i_2} \cdot \eta_{i_3} \cdot \eta_{i_4} \cdot \eta_{i_5} \cdot \eta_{i_6} \cdot \eta_{i_7} \end{aligned} \tag{8}$$

where $\eta_{i_1} = \eta_{I,1}$, $\eta_{i_2} = \eta_{I,2}$, $\eta_{i_3} = \eta_{I,3}$, $\eta_{i_4} = \eta_{I,4}$, $\eta_{i_5} = \eta_{I,5}$, $\eta_{i_6} = \eta_{I,6}$ and $\eta_{i_7} = \eta_{I,7}$

For the other four packages one proceeds in a similar manner. The relations presented are new in the scientific literature and has not been used in other papers.

2. For package II

a.

$$\begin{aligned} & R2 = (Q - R1) \cdot e^{-b_{II} \cdot 4l} \Rightarrow \frac{R1}{Q} = e^{-b_{II} \cdot 4l} \\ & \Rightarrow \ln\left(\frac{R2}{Q - R1}\right) = -b_{II} \cdot 4l \Rightarrow b_{II} = -\frac{1}{4l} \cdot \ln\left(\frac{R2}{Q - R1}\right) \end{aligned} \tag{9}$$

b. $$R_{II,j} = (Q - R1)\cdot e^{-b_{II}\cdot j\cdot l} = (Q - R1)\cdot e^{-\left[-\frac{1}{4l}\cdot\ln\left(\frac{R1}{Q}\right)\right]\cdot j\cdot l} = (Q - R1)\cdot e^{\frac{j}{4}\cdot\ln\left(\frac{R1}{Q}\right)} \tag{10}$$

where j = 1÷4.

c. $$Q_{II,j} = R_{II,j-1} \Rightarrow P_{II,j} = Q_{II,j} - R_{II,j} \tag{11}$$

where $Q_{II,1} = Q - R1$ and j = 1÷4.

d. $$\eta_{II,n} = \begin{cases} \frac{P_{II,1}}{Q_{II,1}}, & if\ n = 1 \\ \frac{P_{II,n}}{Q_{II,1} - \sum_{j=1}^{n-1} P_{II,j}} = \frac{P_{II,n}}{R_{II,n-1}}, & if\ n \geq 2 \end{cases} \tag{12}$$

where n = 1÷4 and j > 1.

e. $$\eta_{II} = \sum_{k=8}^{11} (-1)^{k-1} \sum_{8\leq i_8 < i_9 < i_{10} < i_{11} \leq 11} \eta_{i_8}\cdot\eta_{i_9}\cdot\eta_{i_{10}}\cdot\eta_{i_{11}} \tag{13}$$

where, $\eta_{i_8} = \eta_{II,1}$, $\eta_{i_9} = \eta_{II,2}$, $\eta_{i_{10}} = \eta_{II,3}$ and $\eta_{i_{11}} = \eta_{II,4}$

3. For package III

a. $$\begin{aligned} & Q - R1 - R2 - 0{,}531\cdot C1 = (Q - R1 - R2)\cdot e^{-b_{III}\cdot 3l} \\ & \Rightarrow \frac{Q - R1 - R2 - 0{,}531\cdot C1}{Q - R1 - R2} = e^{-b_{III}\cdot 3l} \\ & \Rightarrow \ln\left(\frac{Q - R1 - R2 - 0{,}531\cdot C1}{Q - R1 - R2}\right) = -b_{III}\cdot 3l \\ & \Rightarrow b_{III} = -\frac{1}{3l}\cdot\ln\left(\frac{Q - R1 - R2 - 0{,}531\cdot C1}{Q - R1 - R2}\right) \end{aligned} \tag{14}$$

b. $$\begin{aligned} R_{III,k} &= (Q - R1 - R2)\cdot e^{-b_{III}\cdot k\cdot l} = \\ &= (Q - R1 - R2)\cdot e^{-\left[-\frac{1}{3l}\cdot\ln\left(\frac{Q-R1-R2-0{,}531\cdot C1}{Q-R1-R2}\right)\right]\cdot k\cdot l} = \\ &= (Q - R1 - R2)\cdot e^{\frac{k}{3}\cdot\ln\left(\frac{Q-R1-R2-0{,}531\cdot C1}{Q-R1-R2}\right)} \end{aligned} \tag{15}$$

where k = 1÷3.

c. $$Q_{III,k} = R_{III,k-1} \Rightarrow P_{III,k} = Q_{III,k} - R_{III,k} \quad (16)$$

where $Q_{III1} = Q - R1 - R2$ and k = 1÷3.

d. $$\eta_{III,u} = \begin{cases} \dfrac{P_{III,1}}{Q_{III,1}}, & if\ u = 1 \\ \dfrac{P_{III,u}}{Q_{III,1} - \sum\limits_{k=1}^{u-1} P_{III,k}} = \dfrac{P_{III,u}}{R_{III,u-1}}, & if\ u \geq 2 \end{cases} \quad (17)$$

where u = 1÷3 and k > 1.

e. $$\eta_{III} = \sum_{k=12}^{14} (-1)^{k-1} \sum_{12 \leq i_{12} < i_{13} < i_{14} \leq 14} \eta_{i_{12}} \cdot \eta_{i_{13}} \cdot \eta_{i_{14}} \quad (18)$$

where $\eta_{i_{12}} = \eta_{III,1}$, $\eta_{i_{13}} = \eta_{III,2}$ and $\eta_{i_{14}} = \eta_{III,3}$

4. For package IV

a. $$Q - R1 - R2 - C1 = (Q - R1 - R2 - 0{,}531 \cdot C1) \cdot e^{-b_{IV} \cdot 3l}$$
$$\Rightarrow \frac{Q - R1 - R2 - C1}{Q - R1 - R2 - 0{,}531 \cdot C1} = e^{-b_{IV} 3l}$$
$$\Rightarrow \ln\left(\frac{Q - R1 - R2 - C1}{Q - R1 - R2 - 0{,}531 \cdot C1}\right) = -b_{IV} \cdot 3l \quad (19)$$
$$\Rightarrow b_{IV} = -\frac{1}{3l} \cdot \ln\left(\frac{Q - R1 - R2 - C1}{Q - R1 - R2 - 0{,}531 \cdot C1}\right)$$

b. $$R_{IV,s} = (Q - R1 - R2 - 0{,}531 \cdot C1) \cdot e^{-b_{IV} \cdot 1l} =$$
$$= (Q - R1 - R2 - 0{,}531 \cdot C1) \cdot e^{-\left[-\frac{1}{3l} \cdot \ln\left(\frac{Q - R1 - R2 - C1}{Q - R1 - R2 - 0{,}531 \cdot C1}\right)\right] \cdot sl} = \quad (20)$$
$$= (Q - R1 - R2 - 0{,}531 \cdot C1) \cdot e^{\frac{s}{3} \cdot \ln\left(\frac{Q - R1 - R2 - C1}{Q - R1 - R2 - 0{,}531 \cdot C1}\right)}$$

where s = 1÷3.

c. $$Q_{IV,s} = R_{IV,s-1} \Rightarrow P_{IV,s} = Q_{IV,s} - R_{IV,s} \quad (21)$$

where $Q_{IV1} = R_{III,3}$ and s = 1÷3.

d.
$$\eta_{IV,v}=\begin{cases}\dfrac{P_{IV,1}}{Q_{IV,1}}, & if\ v=1\\ \dfrac{P_{IV,v}}{Q_{IV,1}-\sum_{s=1}^{v-1}P_{IV,s}}=\dfrac{P_{IV,v}}{R_{IV,v-1}}, & if\ v\geq 2\end{cases} \tag{22}$$

where v = 1÷3 and s > 1.

e.
$$\eta_{IV}=\sum_{k=15}^{17}(-1)^{k-1}\sum_{15\leq i_{15}<i_{16}<i_{17}\leq 17}\eta_{i_{15}}\cdot\eta_{i_{16}}\cdot\eta_{i_{17}} \tag{23}$$

where $\eta_{i_{15}}=\eta_{IV,1}$, $\eta_{i_{16}}=\eta_{IV,2}$ and $\eta_{i_{17}}=\eta_{IV,3}$

5. For package V

a.
$$R3=(Q-R1-R2-C1)\cdot e^{-b_V\cdot 2l}\Rightarrow\frac{R3}{Q-R1-R2-C1}=e^{-b_V\cdot 2l}$$
$$\Rightarrow\ln\left(\frac{R3}{Q-R1-R2-C1}\right)=-b_V\cdot 2l\Rightarrow b_V=-\frac{1}{2l}\cdot\ln\left(\frac{R3}{Q-R1-R2-C1}\right) \tag{24}$$

b.
$$\begin{aligned}R_{V,t}&=(Q-R1-R2-C1)\cdot e^{-b_V\cdot 1l}=\\&=(Q-R1-R2-C1)\cdot e^{-\left[-\frac{1}{2l}\cdot\ln\left(\frac{R3}{Q-R1-R2-C1}\right)\right]t1l}=\\&=(Q-R1-R2-C1)\cdot e^{\frac{t}{2}\cdot\ln\left(\frac{R3}{Q-R1-R2-C1}\right)}\end{aligned} \tag{25}$$

where t = 1÷2.

c.
$$Q_{V,t}=R_{V,t-1}\Rightarrow P_{V,t}=Q_{V,t}-R_{V,t} \tag{26}$$

where $Q_{V1}=R_{IV,3}$ and t = 1÷2.

d.
$$\eta_{V,w}=\begin{cases}\dfrac{P_{V,1}}{Q_{V,1}}, & if\ w=1\\ \dfrac{P_{V,w}}{Q_{V,1}-\sum_{t=1}^{w-1}P_{V,t}}=\dfrac{P_{V,w}}{R_{V,w-1}}, & if\ w\geq 2\end{cases} \tag{27}$$

where *w* = 1÷w and t > 1.

e.
$$\eta_{IV}=\sum_{k=18}^{19}(-1)^{k-1}\sum_{18\leq i_{18}<i_{19}\leq 19}\eta_{i_{18}}\cdot\eta_{i_{19}} \tag{28}$$

where $\eta_{i_{18}}=\eta_{V,1}$ and $\eta_{i_{19}}=\eta_{V,2}$

Knowing the coefficients of extraction of the five frame packages of the compartment, the coefficients of extraction of the entire plansifter compartment can be calculated.

As it has been previously discussed, within compartment the first three packages work in parallel and the third, the fourth and the fifth package work consecutively. Thus, it is possible to calculate the average coefficients of extraction, for packages III, IV and V, with the following relationship:

$$\eta_{III-V} = \eta_{III} + \eta_{IV} + \eta_{V} - \eta_{III} \cdot \eta_{IV} - \eta_{III} \cdot \eta_{V} - \eta_{IV} \cdot \eta_{V} + \eta_{III} \cdot \eta_{IV} \cdot \eta_{V} \quad (29)$$

In this situation, the coefficient of extraction of the entire compartment is given by the following relationship:

$$\eta_{compartiment} = \eta_{I} \cdot \eta_{II} \cdot \eta_{III-V} \quad (30)$$

Numerical application (case study)

Based on experimental data and using the mathematical algorithm presented above the following values were obtained for the feed debits, masses of the refusal and of the sifted material and the coefficients of extraction for each frame and for each package of compartment (tables 2÷11).

1. For package 1

Table 2.

Values of refusals and sifted material for frames of package I, determined with relationships (4), (5) and (6)

Refusal $R_{I,i}$ (i = 1÷7) , [g]	$R_{I,1}$	$R_{I,2}$	$R_{I,3}$	$R_{I,4}$	$R_{I,5}$	$R_{I,6}$	$R_{I,7}$=R1
	6163.4	5207.6	4400.1	3717.8	3141.3	2654.2	**2242.6**
Sifting $P_{I,i}$ (i = 1÷7), [g]	$P_{I,1}$	$P_{I,2}$	$P_{I,3}$	$P_{I,4}$	$P_{I,5}$	$P_{I,6}$	$P_{I,7}$
	1130.2	955.8	807.5	682.3	576.5	487.1	411.6

One can observe that refusal $R_{I,7}$ is equal to refusal R1 of the compartment, refusal experimentally determined (see table 1). It is also noted that the first frame of the package I is fed directly by all quantity of grist that comes from the roller mill of break 1 (see fig. 1), and that the refusal $R_{I,1}$ of these frame represents the amount of material that feeds the frame I,2, refusal of this frame ($R_{I,2}$) feeds the frame I,3 and so on.

Coefficients of extraction were determined for each frame of the package I (table 3).

Table 3.

Coefficients of extraction for frames of package I (relation 7)

$\eta_{I,m}$	$\eta_{I,1}$	$\eta_{I,2}$	$\eta_{I,3}$	$\eta_{I,4}$	$\eta_{I,5}$	$\eta_{I,6}$	$\eta_{I,7}$
	0.155	0.155	0.155	0.155	0.155	0.155	0.155

Coefficients of extraction of package I was determined by the relation (8) and has the value $\eta_I = 0.692$.

2. For package II

Table 4.

Values of refusals and sifted material for frames of package II (determined with relationships 9, 10, 11)

Refusal $R_{II,j}$ (j = 1÷4), [g]	$R_{II,1}$	$R_{II,2}$	$R_{II,3}$	$R_{II,4}$=R2
	397.,4	3129.8	2463.5	**1939.0**
Sifting $P_{II,j}$ (j = 1÷4), [g]	$P_{II,1}$	$P_{II,2}$	$P_{II,3}$	$P_{II,4}$
	1075.6	846.6	666.3	524.5

It is noted that the refusal $R_{II,4}$ is equal with refusal R2 of compartment, experimentally determined.

It is observed (fig. 1) that the first frame of the package II (frame II.1), is fed by the quantity of material sifted at the first package. One can also observe that the refusal $R_{II,1}$ of first frame of the package II represents the quantity of material that fed the frame II,2, refusal $R_{II,2}$ of this frame fed the frame II,3, and so on.

Table 5.

Coefficients of extraction for the frame of package II (calculated with relation 12)

$\eta_{II,n}$	$\eta_{II,1}$	$\eta_{II,2}$	$\eta_{II,3}$	$\eta_{II,4}$
	0.213	0.213	0.213	0.213

The coefficients of extraction of package II was determined with the relation (13) and has the value $\eta_{II} = 0.616$.

3. For package III

Table 6.

Values of refusals and sifted material for frames of package III (determined with relationships 14, 15, 16)

Refusal $R_{III,k}$ (k = 1÷3), [g]	$R_{III,1}$	$R_{III,2}$	$R_{III,3}$
	2987.3	2866.7	2751.0
Sifting $P_{III,k}$ (k = 1÷3) , [g]	$P_{III,1}$	$P_{III,2}$	$P_{III,3}$
	125.7	120.6	115.7

It is observed that the first frame of the package III (frame III,1) is fed by the quantity of material sifted at the first and second package, and refusal $R_{III,1}$ of frame III,1 fed the frame III,2, then refusal of frame III,2 ($R_{III,2}$) fed the frame III,3.

Table 7.

Coefficients of extraction for the frame of package III (calculated with rel. 17)

$\eta_{III,u}$	$\eta_{III,1}$	$\eta_{III,2}$	$\eta_{III,3}$
	0.040	0.040	0.040

Coefficients of extraction of package III was determined with the relation (18) and has the value $\eta_{III} = 0.116$.

4. For package IV

Table 8.

Values of refusals and sifted material for frames of package IV (calculated with relationships 19, 20, 21)

Refusal $R_{IV,s}$ (k = 1÷3), [g]	$R_{IV,1}$	$R_{IV,2}$	$R_{IV,3}$
	2640.0	2533.5	2431.3
Sifting $P_{IV,s}$ (k = 1÷3) , [g]	$P_{IV,1}$	$P_{IV,2}$	$P_{IV,3}$
	111.0	106.5	102.2

Packages III and IV works in series so that the refusal of the last frame of frame III, $R_{III,3}$, fed the first frame of package IV, and refusal $R_{IV,1}$ of first frame of package IV fed the frame IV,2 and refusal of this frame ($R_{IV,2}$) fed the frame IV,3.

Coefficients of extraction of frames of the package IV were calculated with relation (22).

Table 9.

Coefficients of extraction of frames from package IV:

$\eta_{IV,v}$	$\eta_{IV,1}$	$\eta_{IV,2}$	$\eta_{IV,3}$
	0.040	0.040	0.040

Coefficients of extraction of package IV was determined with the relation (23) and has the value $\eta_{IV} = 0.116$.

5. For package V

Table 10.

Values of refusals and sifted material for frames of package IV (calculated with relationships 24, 25, 26)

Refusal $R_{V,t}$ (k = 1÷3), [g]	$R_{V,1}$	$R_{V,2}$
	1698.4	**1186.4**
Sifting $P_{V,t}$ (k = 1÷3), [g]	$P_{V,1}$	$P_{V,2}$
	732.9	512.0

Is observed that refusal $R_{V,2}$ is equal with refusal R3 of compartment, experimentally determined.

Packages III and IV works in series with the package V thus refusal of the last frame of package IV, $R_{IV,3}$, fed the first frame of package V (V,1). One can also observe that the refusal $R_{V,1}$ of first frame of the package V fed the frame V,2, the last frame within plansifter compartment.

The coefficients of extraction for the two frames within package V were determined.

Table 11.

Coefficients of extraction for the frames of package V:

$\eta_{V,w}$	$\eta_{V,1}$	$\eta_{V,2}$
	0.301	0.301

Coefficients of extraction of package V was determined with relation (28) and has the value $\eta_V = 0.512$.

Knowing the coefficients of extraction values for each frame package of the compartment and using the relations (29) and (30) the coefficients of extraction of the entire plansifter compartment was calculated:

$$\eta_{compartment} = \eta_I \cdot \eta_{II} \cdot \eta_{III-V} = \eta_I \cdot \eta_{II} \cdot (\eta_{III} + \eta_{IV} + \eta_V - \eta_{III} \cdot \eta_{IV} - \\ - \eta_{III} \cdot \eta_V - \eta_{IV} \cdot \eta_V + \eta_{III} \cdot \eta_{IV} \cdot \eta_V) \\ \Rightarrow \eta_{compartment} = 0.264$$

6. Conclusions

Coefficients of extraction of plansifter compartments show the sifting efficiency given by each of the frames included in a package, as well as yield for each package within a compartment.

It is necessary to determine the relationship (bond) between the refusal and sifting values of each frame from a package of a plansifter compartment to establish the distribution of material percentage sifted from the first to the last frame of the package.

Based on the mathematical models proposed in the scientific literature for the distribution of the material sifted on sieve with oscillatory motion, we propose an exponential distribution assuming that the frames of a package would be willing one after another.

It is possible that this distribution follows another law but this requires experimental determination on the material flow of any plansifter compartment.

Also, for frames with different fabrics, we considered that the percentage of sifted material is proportional to the size of sieve apertures, which is not far from reality.

The mathematical model proposed and applied to a real case of plansifter compartment of the passage Break 1, shows a high degree of correlation between the values determined by calculation with those experimentally determined.

Knowledge of calculation methods for these coefficients of extraction is important for the milling industry specialists for rapid appreciation of sifting yield of plansifter, as well as for designers.

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