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The theoretical justification for the fractionation of bulk materials during separation

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Abstract. In separating lines at different stages of the technological process is carried out fractionation of the bulk material. These different quality streams subsequently processed on the working bodies or machines that are more suited for a specific faction. Fractionation can increase productivity, reduce costs, reduce the amount of material being processed through the working bodies of the passes. Criteria for selection of the working body for fractionation and its place in the production line depends on many factors and insufficiently developed. The aim of this work is to determine the criteria for evaluating the effectiveness of the working body for the fractionation of the raw material on the basis of a possible increase productivity throughout the production line. The curves obtained by calculation, allow us to estimate the total increase in line speed. Obtained dependence can be used for calculations of separation processes of granular mixtures in the production of building materials, food industry, powder metallurgy, pharmaceutical and other.

1. Introduction

In various branches of industry in the preparation of raw material, intermediate, or bring the final product to the applicable regulatory requirements separation of bulk materials.

In the construction industry for the classification of the particle size of sand, loose construction mixtures vibrating screens are widely used [1- 10]. Similar equipment used in the mining industry [11, 12], industry [13], food [14, 15]. For separation of fine materials used air separation [16- 27], which is very often used in conjunction with the sieve by separation [28].

The problem of quality of separation exists in the preparation of seed in agricultural production [29- 31] and the allocation of hazardous contaminants in the milling and grinding industry. For example, biological or chemical composition when components like mixture can be separated by means of a mechanical action only when it is accompanied by various physical and mechanical properties. The difficulty lies in the fact that the shared components have very similar physic-mechanical properties. Therefore, there is a need for separation of aggregate material separation characteristics.

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In this regard, the bulk separation of mixtures in most cases it is necessary to use the largest number of separation characteristics, use separating the working bodies where the combined effect of using these features [28, 32, 33].

For proper selection of the working bodies in the preparation of technological lines required information about the numerical values of the quantities characterizing the properties of the components to be separated, as well as their concentration [34].

The organization of the process promising avenue is the use of fractional separation technologies [28, 32, 35]. The essence of these technologies is to separate the source of the bulk material of different quality in its composition fraction (part). Further processing of these fractions is carried out separately. Fractions obtained processing technology must take into account their quality composition.

Due to the necessity of using a starting material for separation of various features in traditional separation flowsheets all the material is passed through a non-specified number of working bodies successively for various

purposes. Impurity phases allocated to each operating element and the purified material is obtained at the outlet of the production line.

Actual performance separating lines in the real world can be 1.5 - 3.0 times lower than the rating. The main reasons for this is underutilization of the performance of individual machines and equipment as a result of their consistent connection and incompleteness in quality cleaning process. It requires multiple separated material pass through the working bodies. Depending on the specific conditions to limit the performance of the entire line can be any actuator. For example, the lower sieve [36].

Incomplete utilization of separating machines and working bodies because of their rigid technological communication with each other causes the lower separating capacity in general of the whole line. The main reasons for the above-mentioned drawbacks of the existing production lines is a discrepancy between the required time separation of the material to the actual time of its location on your body. The excess of the required time separation valid necessitates re-treating the material and determines their ratio multiplicity processing.

2. Methods

The required separation time is determined by the physical and mechanical properties of the raw material components, the required quality of the finished material, its interest yield, specific load, kinematic parameters of working bodies. Improving the ability of a separating process lines for the separation of bulk materials by increasing the number of working bodies of the same type or set of parallel rows of leads to an increase in the cost parameters.

Improving the quality of the separation process and performance improvement, ceteris paribus is possible due to the pre-redistribution component cereal mixture between the factions.

When the sieve separators increase the specific load leads to an increase in the efficiency of a large selection of light impurity at a two-tier arrangement of sieves. This is due to impurities in the floating layer of light moving over the screen material selection and it is similar to the upper screen. Increased pressure on the lower or main sieve leads to difficulty small components pass through the layer of separated material [37, 38, 39]. As a result of this process, separation efficiency is reduced.

Sub-optimal loading of separating individual working parts may occur when changing the percentage of impurities in the starting material. Therefore, before supplying the source separated material to the main separating machine is necessary to ensure a stable percentage of the material.

Divide the source material on the grain fractions mind of impurities or highlight individual fractions in pure form is very difficult due to the greater number of its constituent components, imperfections separating bodies are constantly changing the composition of the starting material.

In most cases, a fraction containing the same components as the starting material, but in different proportions. Therefore, separation is necessary to use all the major types of working bodies (air channel, a sieve, Trier). For optimum loading of each of these working elements must simultaneously fractionation flexible regulation resulting volume fractions and their quality according to the state of the starting material. The need for such a regulation is dictated by constantly changing the composition of the starting material.

Fractionation of great importance should be allocated to the choice of the division attribute at fractionation, sequence location and layout of the working bodies in the process line. Versatility separating machines with combined working bodies reduces their range, but it limits the possibilities of separating the individual working bodies due to their rigid connection with each other.

Comparative analysis of the ability of the pitch separating the working bodies in the separation on the basic features (aerodynamic properties, thickness, width, length) shows that in real terms the worst of all possible uses of the air flow. Process air flow efficiency can be as little as 15 - 30%.

The reasons for the low efficiency of the air flow of the work are the design features of the use of the air channelas an additional operating element in the sieve separating machines. This leads to uneven loading airflow velocity unevenness of its fields, the high concentration of components in the separation zone, setting process complexity. Maximum capacity of separating the air flow is achieved when the constructive development of air channels of individual working bodies. In this case, you can use the optimum cross-section of the air channel, providing the most qualitative separation.

When choosing the location of the sequence separating the working bodies in the process lines in the first stage should be preferred to air flow, i.e. In. Air flow performance is less dependent on humidity and contamination of the starting material.

When working on the production lines fractional schemes recommended to allocate to various waste from 5 to 30% of the components of the main product [32, 28]. Isolation of a fraction in the first stages of processing can improve the ability of separating the following working bodies and unload process line.

From the above analysis that the raw material be fractionated using a sieve or an air flow, taking into account the physical-mechanical properties of its components. Possibly also two-step fractionation: first step - the air flow, the second - sieve. Fractionation should be a preparatory operation before the material by separation in the subsequent working bodies in order to enhance their ability to pitch. It is necessary to carry out a flexible regulation of quality and volume of fractions to reduce the influence of the changing composition of the starting material.

To study the effectiveness of a fractionation process of reception, enhancing the ability of separating working bodies, it is necessary to consider theoretically the process of separating the starting material of different quality fraction. For comparison we will base the parallel operation of two similar screens having the width S and the length L_1 (Fig. 1). The starting material stream is divided into two equal in scope and quality parts. Each sieve is Q_0 performance. Total capacity of the two screens is Q_1. The original content of impurities in the feed to the sieve starting material denoted D_0.

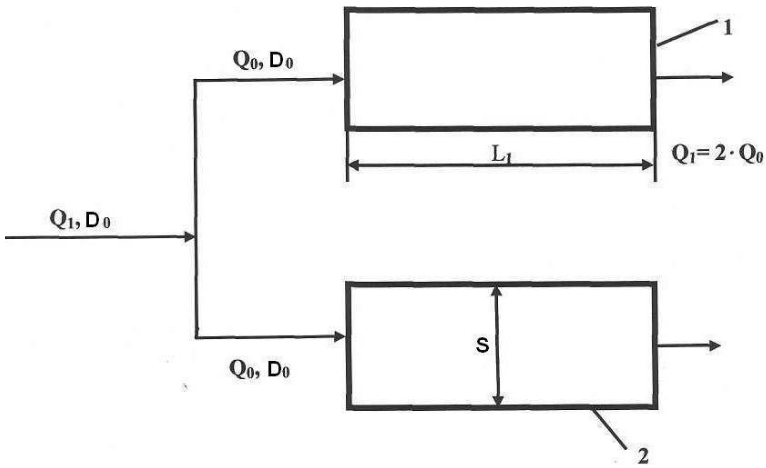

Fig. 1. Schematic of the location of the working bodies in the base case: 1, 2 - screens

When working on a fractional scheme (Fig. 2) in-line included a working body for fractionation. Performance for input on this body is Q' with the same source material debris D_0. At the exit from the working member to fractionate the starting material is divided into two fractions and applied to is the same as in the basic embodiment of sieve. The amount of starting material fed to the sieve 1 is $Q'{\cdot}\varphi$. On the sieve 2 - $Q'{\cdot}(1-\varphi)$. The magnitude φ It is determined by the proportion of the output of the first main fraction, which has a contamination D_{01}. Infestation of the second fraction is equal to the value of D_{02}.

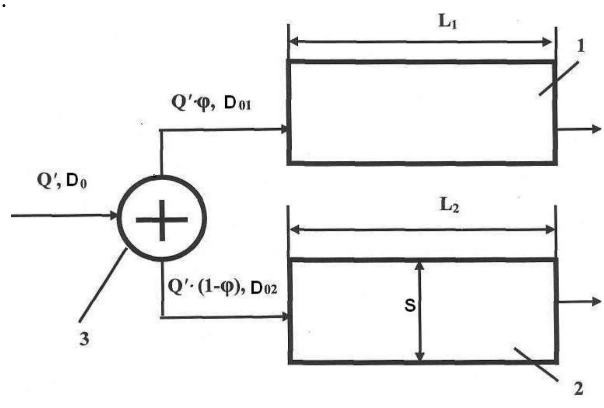

Fig. 2. Scheme of the location of the working bodies in the fractionation: 1, 2 screens, 3- fractionating working body

Assume that redistributes fractionating actuator impurity of the first fraction to the second so that the clogging of the first fraction is proportional to its output. Then

$$D_{01} = D_0 \cdot \varphi \quad (1)$$

$$D_{02} = D_0 \cdot (1-\varphi) \, . \quad (2)$$

3 Results and discussion

Let the total amount of impurities extracted from the screen area during the separation unit, both processing lines are equally well and Q_R. In this case, a more rational use of the working bodies of technological lines by fractionation will increase their relative performance. Specific performance sieves first production line (Fig. 1) will be determined by the formula:

$$G_{u0} = Q_0 / S \cdot L \ . \tag{3}$$

The second line (Fig. 2) - using the formula:

$$G_u = Q' / (S \cdot L_1 + S \cdot L_2) \ . \tag{4}$$

Factor increasing the production rate of the second line with the first [14]:

$$\eta_Q = G_u / G_{u0} \ . \tag{5}$$

Self-sorting time (time sifting through a small layer of material components located on the screen (Fig. 3)) is given by [14]:

$$t_0 = (h - \Delta h) / W_z \ , \tag{6}$$

where h - the height of the layer of material on the sieve, *m*;
Δh - the height of the elementary layer one particle in *m*;
Wz - vertical movement speed of the fine particles in the layer of material *m/s*.

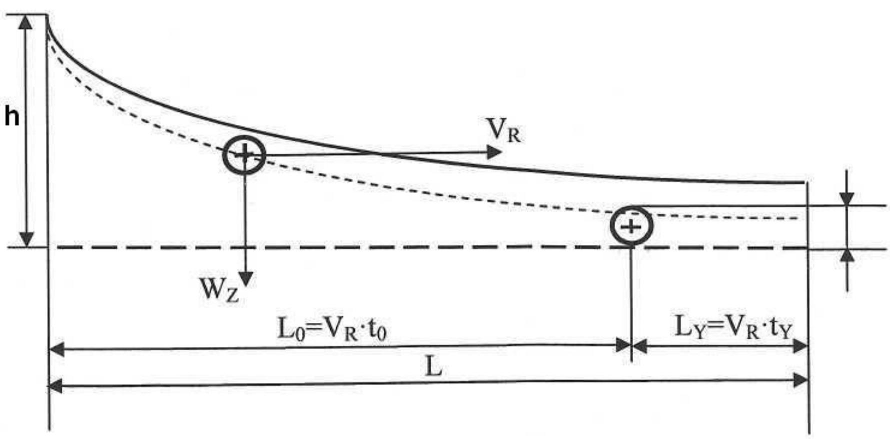

Fig. 3. Scheme of movement of small component in a layer of material being separated on the sieve: L0 -the length of the screen, on which the screening of small components through the material layer; LY - the length of the screen, on which there is sifting through a fine mesh sieve component

$$W_z = r \cdot \omega (m_0 (\Delta - 1) g) \cdot F_V^{-1} \left[(m_0 (\Delta - 1) / m_1 (1 - \delta)^{1/2}) - (F_h / (m_1 \cdot r \cdot \omega^2))^2 \right]^{1/2} \tag{7}$$

where r - the radius of the trajectory of the medium point, *m*;
ω - the frequency of the oscillation sieve, rad/s;
m_0 - the mass media in an amount equal to the volume of the particle, *kg*;
$\Delta = \rho/\rho_0$ - the ratio of the small component and density of the surrounding environment;
Fv - the power of immersion resistance in the vertical direction, *N*;
Fh - the power of immersion resistance in the horizontal direction, *N*;

$m1 = m + m'$ - the effective mass of the particles consisting of particle mass and added mass in *kg*;
δ - dimensionless parameter showing which part of the drag force is the difference in the forces of gravity and the particle medium in the volume of the particle.
Performance of the first line (Fig. 2) with the expression (6), subject to the screening of small components through a layer of Material having a sieve at the beginning of the thickness *H*, is defined as

$$Q_1 = \left(W_z \cdot L_1 / V_R + \Delta h\right) \cdot S \cdot V_R \cdot \rho \ , \tag{8}$$

where V_R - the rate of separated material along the sieve, *m/*s.
ρ - bulk density of the separated material, kg/m^3. Performance of the second line, if all fines sieving through sieve material layer 1 (Fig. 2)

$$Q^{'} = \left(W_z^{'} \cdot L_1 / V_R + \Delta h\right) \cdot S \cdot V_R \cdot \rho_0 / \varphi \, , \tag{9}$$

Where W'_z - vertical movement speed pattern for the small particles in the material layer shown in Fig. 3 *m/s*.
2 on the sieve (Fig. 2) enters the starting material with a high content of small components. Therefore, for more efficient separation of impurities therefrom intake material to a sieve 2 must be carried out in one elementary layer. Minor impurities sieve sieved 2 begin after contact with a sieve. Therefore, the length of the screen 2 can be represented as

$$L_2 = t_2 \cdot V_R \, , \tag{10}$$

where t_2 - residence time of the material on the sieve with.
Time t_2 is determined from the relationships obtained in [14]

$$t_2 = -\ln\left(1 - Q_{R2} / F_{N2}\right) / C_{Y2} \ . \tag{11}$$

Where F_{N2} - The impurity concentration in the lower sieve layer 2 (Figure 2).
C_{Y2} - Intensity factor screening, *1/s*.
Impurities extracted from both sieves unit area during separation, equal to the sum of impurities with the first and second sieves:

$$Q_R = Q_{R1} + Q_{R2} \, . \tag{12}$$

In view of the initial content of impurities (D_0) and the regulatory process efficiency (*N*)

$$Q_R = N \cdot D_0 \cdot Q_1 / \left(S \cdot V_R\right). \tag{13}$$

The impurity concentration in the second elementary layer the sieve

$$F_{N2} = D_{02} \cdot \Delta \cdot \rho_0 \, , \tag{14}$$

In view of (12) - (14) the expression (11) takes the following form:

$$t_2 = -C_{Y2}^{-1} \cdot \ln\left[1 - \left(N \cdot D_0 \cdot Q_1 / \left(S \cdot V_R\right) - Q_{R1}\right)\left(D_{02} \cdot \Delta \cdot \rho_0\right)^{-1}\right]. \tag{15}$$

The amount of Q_{R1}, a member of the expression (12), according to [14] is defined as

$$Q_{R1} = D_{01} \cdot \rho_0 \left[W_z^{'} \cdot L_1 / V_R + \left(\Delta h - W_z^{'} / C_Y\right) \cdot \left(1 - exp\left(-C_Y \cdot L_1 / V_R\right)\right)\right] \tag{16}$$

In view of the above expression for determining dependency ratio increased productivity (5) takes the following form:

$$\eta_Q = \left[\left(W_z^{'} \cdot L_1 / V_R + \Delta h\right) L_1\right]\left[\varphi\left(L_1 + t_2 V_R\right)\left(W_z \cdot L_1 / V_R + \Delta h\right)\right]^{-1} . \text{ 17)}$$

Conclusions

Expressions (12) - (17) are sufficient conditions for determining the appropriateness of a working body in technological lines for fractionation. The resulting expression is possible to determine depending on the initial state of the material being separated, size of the sieve surfaces speed sieve material.

The feasibility of using a specific working body for fractionation will also be determined by the share of redistribution of impurities between fractions (φ), which provides the working body.

When changing the qualitative composition of the starting material with flexible processing schemes can be implemented traditional streaming technology and technology fractional fractionation on one or more of its stages.

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