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Calculation of the effective separation of light impurities in the inertial jalousie-countercurrent dust collector

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Abstract. It is developed a I -shaped inertial dust collector which contains alternately located of jalousie separator and countercurrent separator for the separation of light impurities from the exhaust air. The initial section of the jalousie separator is horizontal, the final section is vertical. It is proposed the technique allows calculating the effect of light impurities separation from the exhaust air by the dust collector quite accurately depending on its design parameters and fractional composition of grain dust particles. The dust collector which has a height of inlet branch pipe $H_o = 0.16$ m, the angle of the jalousie grate $\alpha = 7^\circ$, the angle of the jalousie in the grate $\beta = 30^\circ$, a height of the outlet of the jalousie separator $h_j = 0.04$ m, a height of the outlet of the countercurrent separator $h_c = 0.04$ m, a length jalousie grate $L = 1.0$ m, the height of the camera for dust precipitation $H = 0.6$ m is installed in the air system of seed cleaning machine that functioned on seed cleaning of barley variety Abava. The effect of the separating of light impurities from the exhaust air by the air system was an average value $E_o = 98.9\%$.

1. Introduction

Devices based on different principles are used to purify the removed air. To isolate large and heavy particles of impurities sedimentary chambers are most often used, and for more fine particles of impurities – cyclone, fabric or jalousie dust collectors [1, 2].

Cyclone dust collectors very effectively separate light impurities from the removed air, but they have large dimensions and a great hydraulic resistance, significantly change the movement of the air flow in the aspiration channels of grain cleaning machines.

Fabric dust collectors also effectively separate light impurities from the removed air, but have large dimensions, require devices for shaking the filter cloth and often require replacement of the fabric.

Jalousie dust collectors have the efficiency of light impurities extraction less in comparison with cyclone and fabric dust collectors, relatively large overall dimensions, but due to a number of advantages are increasingly used. They are well combined with air systems of grain cleaning machines because of the flat and parallel movement of air in them, have a small hydraulic resistance.

G. Yu. Stepanov, I. M. Zicer gave recommendations [4] for the calculation of the constructive-technological parameters of the inertial jalousie dust collectors. For example, an algorithm for calculating the jalousie separator is given and the following parameters of the jalousie grating are recommended: the angle of inclination of the front surface of the grating to the direction of air flow $\alpha = 6...7^\circ$; the angle of inclination of the plates in the jalousie grating $\beta = 25...30^\circ$; the step S of the



plates should be taken as minimum possible; the length l of the plates is equal to the step S at the recommended α and β ; the average air velocity at the inlet to the dust collector should be $V_O = 9 \dots 15$ m/s.

The suction coefficient q equal to the ratio of the amount of air Q_I which is withdrawn together with the separated dust to the amount of air Q_J which passed through the jalousie grate should be values

$$q = Q_I / Q_J = 0,1 \dots 0,2. \quad (1)$$

The effect of the release of light impurities by the jalousie dust collector (%) from the removed air:

$$E_J = \left(\frac{q}{1+q} \right)^{\varepsilon_{01}} \cdot 100, \quad (2)$$

where ε_{01} – the dust transmission coefficient for one channel of the jalousie grating (in fractions from one) with characterized the amount of separated dust to its total amount and can be calculated on a computer using the described algorithm.

2. Methods and materials

The Γ -shaped inertial dust collector with a flat parallel movement of air in it is developed [5, 6], in which the jalousie separator of light impurities from the exhaust air and countercurrent separator are located after each other (figure 1).

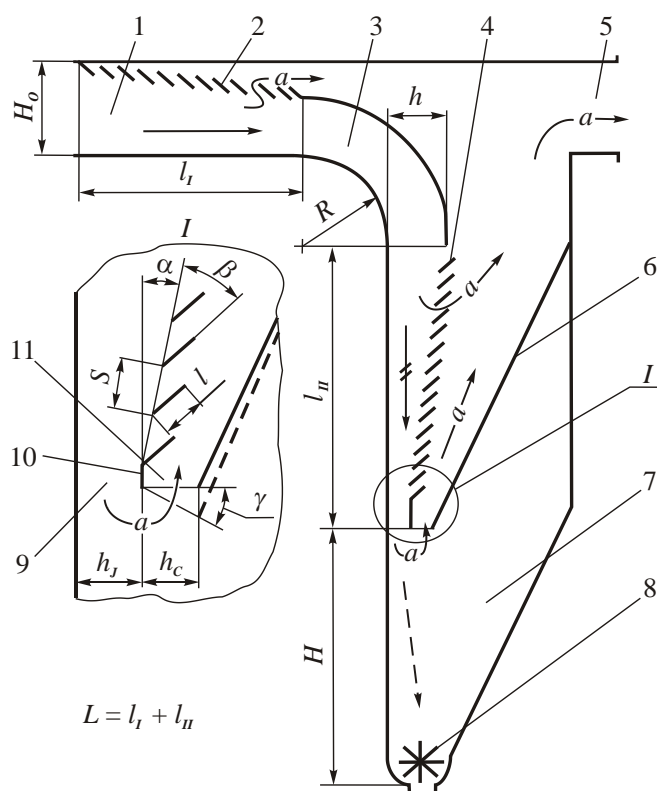


Figure 1. Scheme of Γ -shaped inertial jalousie-countercurrent dust collector: 1, 5 – inlet and outlet pipes of the dust collector; 2, 4 – initial and final sections of the jalousie grate; 6 – dividing wall; 7 – dust-settling chamber; 8 – sluice valve; 9, 11 – outlet pipes of jalousie separator and countercurrent separator; 10 – adjacent wall of outlet pipes of separators; \longrightarrow – air with light impurities; $\longrightarrow a$ – purified air; \dashrightarrow – separated light impurities.

The initial part 2 of jalousie separator with a length l_I is positioned horizontally, and the end part 4 with a length l_{II} is vertical. The initial 2 and final 4 parts are connected by a channel with a radius R and a height h . The total length of the jalousie grating is L . To the final part 4 jalousie separator sequentially connected countercurrent separator formed by the outlet pipe 9 of the jalousie separator, an adjacent wall 10, an outlet 11 of countercurrent separator and a dividing partition 6. In the lower part of the dust collector is a dust chamber 7 depth H . The height of the output pipe of the jalousie separator 9 is the value h_J , the output pipe of the countercurrent separator 11 is the value h_C . The position of the separation wall 6 was determined by the height of the outlet pipe 11 countercurrent separator and

an angle $\pm \gamma$ relative to the horizontal, passing the lower edge of the adjacent wall 10.

The separation of impurities from the exhaust air is as follows. The air with light impurities from the air system of the grain cleaning machine enters the inlet pipe 1 with a height H_O , moves along the initial section 2 of the jalousie grate, rotates by 90° in the channel 3 and passes along the final section 4 of the jalousie grate. In this case the air flow over the entire width of the dust collector remains flat and parallel.

The particles of light impurities under the action of inertia forces move along the jalousie grate, and the purified air passes between the plates length which is l , the are located in the jalousie grate with a step S and at an angle of inclination β .

When moving to the outlet pipe 9 of the jalousie separator the concentration of light impurities in the dust mixture increases, and the air speed almost does not change, since the jalousie grate is installed at an angle α to the wall of the dust collector housing.

In countercurrent separator the flow of dust-air mixture turn at an angle of almost 180° . Light impurities under the action of inertia and gravity settle in the dust chamber 7 and are removed by means of a sluice gate 8, and the purified air through the outlet 11 of the countercurrent separator is directed to the outlet pipe 5.

3. Results and discussion

Calculation of the efficiency of the allocation of light impurities by a jalousie-countercurrent dust collector of the exhaust air has its own peculiarities.

The parameters of the inertial jalousie-countercurrent dust collector are the height H_O , the area F_O of the cross section of the inlet pipe, the length L and the area F of the surface of the jalousie grate, the height H of the dust collector, the heights h_J , h_C and the areas F_1 , F_2 of the cross sections of the output holes of the jalousie separator and countercurrent separator, the angle γ , which determines the position of the dividing wall 6 relative to the horizontal passing through the lower edge of the adjacent wall 10.

The height H_O (m) is determined by the total air flow Q_O (m³/s) passing through the dust collector and the air inlet velocity V_O :

$$H_O = \frac{Q_O}{B \cdot V_O}, \quad (3)$$

where B – the width of the dust collector equal to the width of the air system of the grain cleaning machine, m.

The suction coefficient at the same width B in the dust collector and the jalousie grate is equal to:

$$q = \frac{Q_1}{Q_J} = \frac{V_1 \cdot h_J}{V' \cdot b' \cdot z}, \quad (4)$$

where V_1 , V' – the average air velocity in the outlet of the jalousie separator and the air jet passing between the plates of the jalousie, m/s;

b' – the height of the air jet passing between the plates, m;

z – number of channels in the grate.

$$L = \frac{H_O - h_J}{\sin \alpha}, \quad z = \frac{L}{S}, \quad (5)$$

and for "dense jalousie grate" [4], when $S \leq l$, the expressions are valid

$$\frac{V'}{V_1} = \frac{\sin(\alpha + \beta/2)}{\sin(\beta/2)}; \quad (6)$$

$$\frac{b'}{S} = \frac{\sin \alpha \cdot \sin \beta}{\sin \alpha + \sin(\alpha + \beta)}; \quad (7)$$

then is the height of the outlet of jalousie separator

$$h_J = \frac{H_O}{1 + \frac{\sin(\beta/2) \cdot [\sin \alpha + \sin(\alpha + \beta)]}{q \cdot \sin(\alpha + \beta/2) \cdot \sin \beta}}. \quad (8)$$

To estimate the impact of the design and technological parameters of the countercurrent separator on the efficiency of its operation we will use a simplified flowing air model that takes into account the basic laws of the real process. The air jet at the flow rotation is modeled by a ring with internal R_1 and external R_2 radiuses (figure 2).

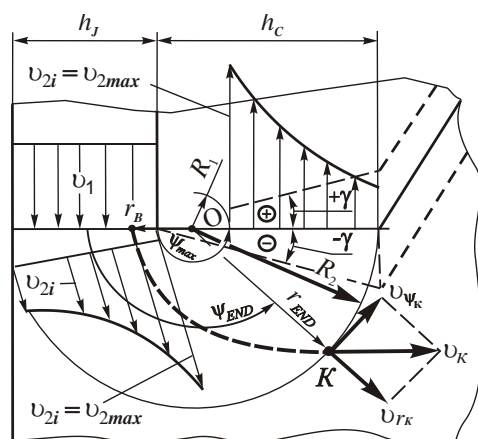


Figure 2. Scheme of flowing air and solid particle motion in countercurrent separator.

Then the height h_C of the outlet of the countercurrent separator is determined by the radius R_1 of the turn of the annular jet:

$$h_C = h_J + 2 \cdot R_1. \quad (9)$$

The radiuses R_1 and R_2 are determined from the continuity condition of the flow:

$$B \cdot h_j \cdot V_1 = \int_{R_1}^{R_2} B \cdot V_{2i} \cdot dr, \quad (10)$$

where V_{2i} – the flowing air velocity in the i -section of the annular jet, m/s.

When the jet is rotated the air velocity depends on the radial coordinate r_i and changes according to the law of the potential circular flow [4]:

$$V_{2i} = V_{2\max} \cdot \frac{R_1}{r_i} , \quad (11)$$

where $V_{2\max}$ – the air velocity at the inner boundary of the jet, m/s.

According to the research of I. E. Idelchik [7] when the air jet turns 180° near the edge of a continuous adjacent wall the expression is rightly:

$$\left(\frac{V_{2\max}}{V_2}\right)^2 = 4, \quad (12)$$

where V_2 – the average air velocity in the annular jet of the countercurrent separator, m/s.

$$h_J = (R_2 - R_1) \cdot \cos \gamma; \quad (13)$$

$$\psi_{max} = \pi \pm \gamma, \quad (14)$$

From the condition of continuity of the annular jet

$$V_1 = V_2. \quad (15)$$

$$h_J = 2 \cdot R_1 \cdot \ln \frac{R_2}{R_1}. \quad (16)$$

$$R_2 = R_1 \cdot \exp \frac{h_J}{2 \cdot R_1}. \quad (17)$$

Then the turning radius of the jet is equal to

$$R_1 = \frac{h_J}{[\exp(h_J/2 \cdot R_1) - 1] \cdot \cos \gamma}. \quad (18)$$

This equation is solved by iteration method [4, 8].

The depth of the dust-reducing chamber H is determined using the theory of G. N. Abramovich on a turbulent jet that gets into a dead end [9]:

$$x = 6 \cdot (h_J + h_C). \quad (19)$$

Then the height of the dust chamber, taking into account the diameter of the sluice gate d_{SG} :

$$H = 6 \cdot (h_J + h_C) + d_{SG}. \quad (20)$$

The velocity at the outlet of the jalousie separator V_1 necessary to determine the efficiency of the countercurrent separator determined from the condition of continuity of the flow:

$$Q_O = Q_1 + Q_J. \quad (21)$$

$$V_O \cdot F_O = V_1 \cdot F_1 + V' \cdot B \cdot b' \cdot z. \quad (22)$$

When the width of the jalousie separator and dust collector is rightly the expression

$$V_O \cdot H_O = V_1 \cdot h_J + V' \cdot b' \cdot L / S. \quad (23)$$

Given the formulas (6), (7) and (23), we obtain:

$$V_1 = \frac{V_O \cdot H_O}{h_J + L \cdot \frac{\sin(\alpha + \beta/2) \cdot \sin \alpha \cdot \sin \beta}{\sin(\beta/2) \cdot [\sin \alpha + \sin(\alpha + \beta)]}}. \quad (24)$$

The trajectories of the grain dust particles which are necessary for calculating the efficiency of the countercurrent separator are determined in polar coordinates: r_i – the radius where the particle is located and ψ_i – the angle of rotation of the particle.

The deposition of particles of light impurities in the dust-settling chamber is determined from the following considerations. If according to the results of calculations the particle has reached the radius R_2 and the angle $\psi_i < \psi_{max}$, then we believe that this particle further moves by inertia and settles in the dust chamber.

The calculation of the trajectory of the particle with a diameter δ_i produce, given the values of the initial coordinate r_i starting from R_1 until at a certain coordinate r_B particle is not released from the flowing air. Assuming that the particles of this diameter δ_i are uniformly distributed in the flowing air, we determine the dust transmission coefficient by the formula

$$\varepsilon_{Ci} = \frac{r_B - R_1}{h_J}. \quad (25)$$

Calculation of the coefficients of dust passing $\varepsilon_C = f(\delta)$ through a countercurrent separator depending of the particle size δ_i produced using computer algorithm G. Ju. Stepanov, I. M. Zicer [4] for the jalousie separator with the following changes: the dust separation conditions in the countercurrent separator differ from those given there so the formulas (13), (14) and (17) are used to determine the radiuses R_1 , R_2 and the angle ψ_{max} ; the calculating velocity of the flowing air V_{2i} over the cross section of the annular jet is used the formula (11); the determining average flowing air velocity at the inlet to the countercurrent separator V_1 the formula (24) is applied.

Figure 3 presents the results of calculations of the coefficients of the dust passage ε_{Ci} in the counter-

current separator depending on the size of the light impurities particles δ_i at the angles $\psi_{max} = 160^\circ; 170^\circ; 180^\circ; 190^\circ; 200^\circ$ and of the heights of the output holes of jalousie separator $h_J = 0.02; 0.04; 0.06$ m.

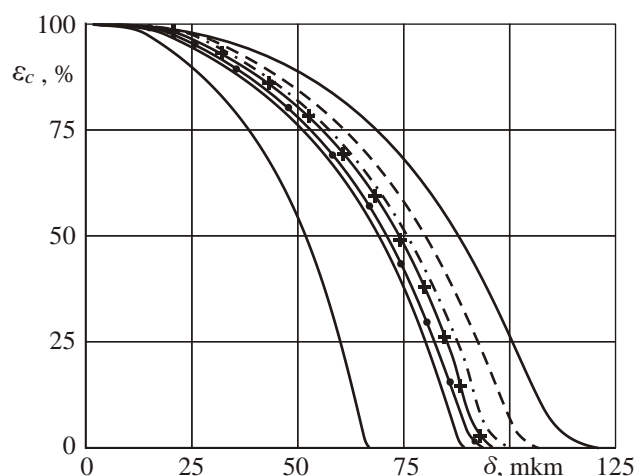


Figure 3. The coefficients of passing dust through a countercurrent separator ε_c from the size of particles δ_i (micrometers): 1 – $h_J = 0.02$ m; 2 – $h_J = 0.04$ m; 3 – $h_J = 0.06$ m; — — — — — $\psi_{max} = 160^\circ$; — · — · — — $\psi_{max} = 170^\circ$; — — — — — $\psi_{max} = 180^\circ$; — · — · — · — $\psi_{max} = 190^\circ$; — × — × — $\psi_{max} = 200^\circ$.

The effectiveness of the capture of light impurities by the countercurrent separator is improved with a decrease of the heights h_J , h_C , and with the angle $\gamma = 0^\circ$. But reducing the height of h_J reduces the effectiveness of the capture of light impurities by the jalousie separator.

There are calculated effects of the capture of light impurities from the exhaust air in the countercurrent separator with the heights $h_J = h_C = 0.02; 0.04; 0.06$ m and the angle $\psi_{max} = 180^\circ$ using the published N. A. Revenko [10] the density P of the distribution of light impurities depending on the particle diameter. The effects are respectively had the values $E_C = 98.5; 96.8$ and 95.4% .

Ignoring the change in the fractional composition of the particles during the separation of impurities in the jalousie separator we obtain a formula for determining the effect capture of light impurities (%) from the exhaust air by an inertial jalousie-countercurrent dust collector as a whole:

$$E_O = \left(\frac{q}{1+q} \right)^{\varepsilon_{01}} \cdot \left(100 - \int_{\delta_{min}}^{\delta_{max}} \varepsilon_{Ci} \cdot P(\delta) \cdot d\delta \right). \quad (26)$$

where $P(\delta)$ – is the particle size distribution density of light impurities.

It is installed Γ -shaped inertial jalousie-countercurrent dust collector with constructional parameters $H_O = 0.16$ m, $\alpha = 7^\circ$, $\beta = 30^\circ$, $h_J = 0.04$ m, $h_C = 0.04$ m, $L = 1.0$ m, $H = 0.6$ m in the air system of seed cleaning machine that functioned on the cleaning of barley seeds of Abava variety. The effect of capture of light impurities from the exhaust air in the pneumatic system as a whole was $E_O = 98.9\%$.

The developed methodology allows the determining effect of light impurities separation from the exhaust air by the Γ -shaped inertial jalousie-countercurrent dust collector quite accurately depending on its design parameters and fractional composition of grain dust particles.

4. Conclusion

It is developed a Γ -shaped inertial dust collector, which contains alternately located of jalousie separator and countercurrent separator for the separation of light impurities from the exhaust air.

The initial section of the jalousie separator has a length l_I and is horizontal, the final section has a length l_{II} is vertical.

It is installed Γ -shaped inertial jalousie-countercurrent dust collector with a height of inlet branch pipe $H_O = 0.16$ m, the angle of the jalousie grate $\alpha = 7^\circ$, the angle of the jalousie in the grate $\beta = 30^\circ$, a height of the outlet of the jalousie separator $h_J = 0.04$ m, a height of the outlet of the countercurrent separator $h_C = 0.04$ m, a length jalousie grate $L = 1.0$ m, the height of the camera for dust precipitation $H = 0.6$ m in the air system of seed cleaning machine that functioned on seed cleaning of barley variety Abava. The effect of the separating of light impurities from the exhaust air by the air system was an average value $E_O = 98.9\%$.

The developed methodology allows to determine the effect of light impurities separation from the exhaust air by the Γ -shaped inertial jalousie-countercurrent dust collector quite accurately depending on its design parameters and fractional composition of grain dust particles.

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