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EXPERIMENTAL STUDY IN A PNEUMATIC MICROBIOCATURE SEPARATOR WITH APPARATUS CAMERA

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Abstract: *In the article the analysis of existing designs of flat-row separators is carried out. Hypotheses are put forward, which allow to eliminate existing disadvantages of constructions. Their essence is reduced to the feeding of grain perpendicular to the direction of air flow. This is provided by the slope of the walls of the aspiration canal at an angle close to 45°, so that the aspiration channel acquires the shape of a truncated hollow cone, coaxially inside a scattered installed, in the form of a truncated cone, which is turned with a larger base upward. The equation of regression of efficiency and clarity of the process of pneumatic separation from the regime parameters of the aspiration chamber is obtained. The regression equation of the purification and precipitation of light impurities has been obtained by an improved aspiration chamber.*

Keywords: *flat-panel separator, aspiration chamber, efficacy, air separation, deposition.*

1. Introduction

In today's conditions of a market economy of Ukraine there has been a tendency to change the ownership of land and change the structure of crop areas [3]. This contributed to the emergence of farms that cultivate small areas of grain crops. For the processing of cereal streams coming from these crops, farms use mobile grain cleaning machines that perform preliminary and basic purification. It is mainly mobile flat-panel machines with productivity from 10 t / h to 30 t / h.

The disadvantages of their work include the allocation of grain dust and light impurities in the working space around the machine, which complicates its operation and worsens ergonomic performance [4].

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Therefore, the search for new technical solutions for the utilization of grain dust and light impurities on mobile flat-panel machines is an urgent task.

Universal pneumatic centrifugal grain separators are widely used in farms of Ukraine as machines of preliminary and primary purification due to their high specific productivity and insignificant specific material content. Their use allows to reduce the need for production space three times as compared with traditional separators.

As a rule, universal pneumatic centrifugal separators consist of two parts: pneumatic centrifugal and vibration center-resonator. With high productivity and compactness, the work of these separators showed an inadequate purification of the grain mixture from light impurities (floor, parts of stems, etc.), which is due to the disadvantages of the design of the pneumatic centrifugal part. Therefore, the actual scientific and technical task is the further technical improvement of the pneumatic centrifugal part of the pneumatic centrifugal grain separator.

Most foreign firms (Miag (Germany), Buhler (Switzerland), Hept-Carter (USA), etc.) do not install aspiration chambers on their separators, and the separation and concentration of light impurities from separators are performed centrally in a separate device. With such a system, it is difficult to tailor the isolation individually to each separator [2]. In addition, this allocation system is possible when the farm has a certain system of cleaning machines, which in the conditions of the farm is not always acceptable.

Aspiration chambers of two types are most often installed on mobile flat-row separators: in the form of a bunker with a partition for changing the direction of air flow - a chamber of gravitational type; centrifugal chamber with a central tube and a spiral or inclined cavity for the east of the isolated admixtures. Studies have shown [6] that chambers of the centrifugal type have the same efficiency with cameras of gravity type and when installed on mobile grain cleaning machines shift the center of gravity, which increases the probability of a turning over when driving. No significant studies have been carried out on the use of gravity aspiration chambers on mobile flat-row separators, which makes the research relevant.

Studies [5] found that the reason for poor cleaning of the grain mixture from light impurities is the inappropriate feeding of grain into the ascending air flow by the spreader. During the process, the spreader feeds the grain mixture with a dense layer in the air stream. Since the blades are installed in the lower part of the serial spreader, this contributes to the uneven (perimeter) feeding of the grain to the aspiration channel due to the fact that the blades guide the grain in the form of "jets", thereby providing zones with increased grain density. Another disadvantage of the pneumatic separating part of the pneumatic centrifugal separator is the swing in the duct connection zone with the upper cylindrical part of the aspiration chamber, which reduces the air flow velocity in certain areas of the chamber.

In [1], hypotheses were put forward to eliminate these shortcomings. Their essence is reduced to the feeding of grain perpendicular to the direction of air flow. This is ensured by the slope of the walls of the aspiration channel at an angle close to 45°, so that the aspiration channel acquires the shape of a truncated hollow cone, coaxially inside a scattered installed, in the form of a truncated cone, which is reversed with a larger base upward.

Theoretical studies [7] substantiated the basic parameters of the operating mode of the pneumatic separating part of the pneumatic centrifugal separator. However, most provisions require experimental confirmation.

The purpose of the research is to detect and evaluate the influence of the regime parameters of the improved air separation part on the qualitative parameters of purification of the grain mixture.

2. Material and Method

2.1. Design of Advanced Aspiration Chamber with Spreaders

According to the hypotheses and the theoretical propositions put forward in [7], there were developed 2 clatterers (Figure 1 a, b). The first one is a truncated cone, which is backed up by a larger base, up to a diameter of 720 mm. Moreover, much of the side surface of the spreader is made of rubber and has a distribution cone in the center (Figure 1 a). The second spreader, unlike the first one, has a narrow rubber upper part of the lateral surface, which is attached to a conical metal part having a blade (Figure 1 b) but does not contain a distribution cone in the center. The third spreader is similar to a serial design (Figure 1 c).

a *b* *c*

Fig. 1. *The general view of the spreaders, which carried out experimental research: a – conical scoop without blades; b – conical spreader with shoulder blades; c – serial spreader*

Experimental studies of the described scatterers were carried out in an improved aspiration chamber (Figure 2 a).

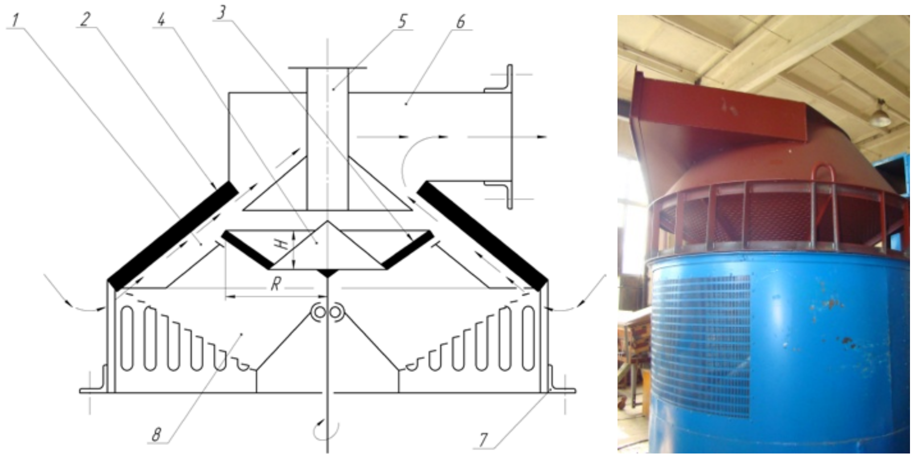
It is a design consisting of a ring channel 1 formed by two conical walls. In the center of the aspiration chamber there is a spreader 4 over which the dispenser 5 is located. The connector 6 is connected to the upper part of the ring channel 1. A flange 7, representing a cylindrical ribbed surface and an air gap 8, representing the louvre cone, is attached to the bottom of the annular channel.

To carry out experimental studies, the aspiration chamber was improved on an experimental installation (Figure 2 b).

Technological process on the advanced aspiration chamber is as follows. Grain material is fed through the dispenser 5 to the spreader 4, where, under the action of centrifugal force, it moves to the edge of the inner surface of the grain thrower 3 and is introduced at an initial rate into the air stream passing through the annular channel 1. Light impurities, under the influence of aerodynamic force, are captured by air flow and through the air line 6 are removed outside the aspiration chamber. The purified grain, reflecting from the inner wall of the channel 2, falls on the aerosol hole 8. When leveled along the air deflector 8, the grain is further purified by air jets blowing from the louver openings and supplied for additional purification.

Experimental studies were carried out on the subject of the influence of the regime parameters of the aspiration chamber: *q* — supply of grain material; *υ* — speed of ascending air flow; *n* — frequency of rotation of the spreader on qualitative parameters of air separation: efficiency of separation *E* and clarity of *Z* separation.

The efficiency and clarity of separation of the improved aspiration chamber were determined by the degree of discharge of garbage impurities, that is, the relative content of the passage fraction.



a *b*

Fig. 2. *The design scheme is suited to the aspirating camera (a) and the illegal camera at the warehouse of the experimental installation (b):*
1 – ring channel; 2 – internal channel surface; 3 – the inside of the grain spreader; 4 – grain spreader; 5 – dispenser; 6 – pipe; 7 – flange; 8 – aero-cleansing

To achieve the determination of the influence of the above-mentioned regime parameters on qualitative parameters of air separation, the method of a multivariate experiment was applied. A three-factor experiment was conducted on the D-optimal Boxx-Benick plan.

Guided by the earlier theoretical studies of the process of air separation of grain, it is possible to establish the most influential factors and determine the limits of their variation. These factors include: the rate of ascending air flow *υ*, the grain supply *q*, the spin speed *n*. The values of the proposed factors are given in Table 1.

For the optimization parameter, the efficiency of separation in percent *E* and the clarity of the pneumatic separation *Z* are accepted. Experimental studies were carried out on wheat grains.

Levels of independent factors of experimental research Table 1

Name, designation and dimension of influential factors	Levels of variation of factors			Variable interval
	Upper (+1)	Zero (0)	Lower (-1)	
The rate of ascending air flow, *υ* [m/s]	9	7	9	2
Feeding grain material, *q* [t/h]	25	15	5	10
Frequency of rotation of the spreader, *n* [rpm]	160	130	100	30

2.2. The Design of the Modernized Aspiration Chamber of the Flat-Radiator Separator

In order to improve the effect of purification from light impurities and their concentration for an experimental flat-line separator, an aspiration chamber was created as a result of the research carried out, the general appearance of which is shown in Figure 3.

It is a structure consisting of a hull, a bunker, pit latches, guiding channels, a siege chamber, shells, cleaning shelves, a fan, a screw and output channels.

The camera was installed above the lattice states of the experimental sample of the flat-line separator.

The technological process of work on it was carried out as follows. Grain mixture was driven from the bunker to pods.

Slipping down the shelf, the grain with light impurities falls into the sloping air flow created by the fan. Due to its weight and small coefficient of aerodynamic resistance, the grain falls down to the subsequent purification by sieve, and light impurities captured by air flow, due to a higher coefficient of aerodynamic resistance, are fed along the guide channel to the siege chamber.

In the siege chamber there is a turning of the air flow due to the shape of the shell, resulting in a decrease in the flow rate in the zone of rotation of the air stream. When the speed of air flow decreases, aerodynamic force decreases, therefore, light impurities are deposited and collected in the harvesting shelves to the screw, which they are transported to the outlet channel.

To verify the operation of the aspiration chamber, a one-factorial experiment was conducted on the effect of the performance of the flat-panel separator q on the efficiency of purification *E*, % and precipitation *Ek*, % of light impurities.

An overweight of 60 kg with litter with light impurities of 3% was passed through an aspiration chamber. The valve on the bunker regulated the productivity of the flat-rust separator in the range of 0.4-9.6 t / h. To account for the light impurities that were captured by the fan impeller, a 2-meter-long sack was put on the fan feed line.

The efficiency of cleaning E was calculated by the formula:

$$E = \frac{m_1 + m_2 - m_3}{m \cdot \varepsilon} \quad (1)$$

where:

m is a lot of weightlessness [kg];

ε – turbidity [%];

m_1 – mass of light impurities allocated aspiration chamber [kg];

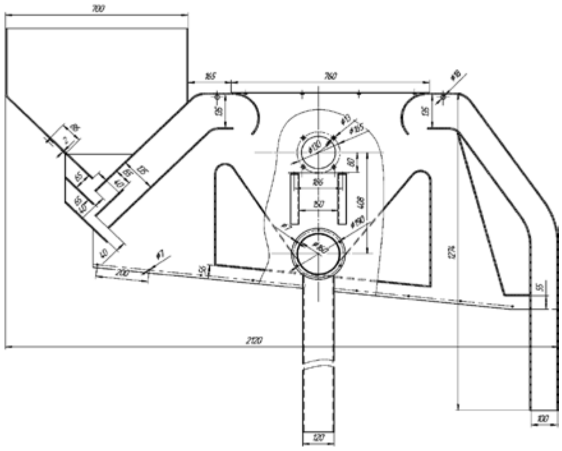
m^2 – mass of light impurities in the bag [kg];

m_3 – the mass of grain in the segments separated by a bag and aspiration chamber [kg].

The efficiency of precipitation of light impurities *Ek* was calculated by the formula:

$$Ek = \frac{m_1}{m_1 + m_2} \qquad (2)$$

The plan for implementing the experiment is presented in Table 1.



a

b

c

Fig. 3. *Design scheme (a) of the modernized aspiration chamber of the flat-radiator separator and its general appearance (b, c)*

3. Results and Discussion

3.1. Experimental Study of Advanced Aspiration Chamber with Scatterers

After analyzing the significance, reproducibility and adequacy, the following regression equations for efficiency and clarity of pneumatic separation for the 3 types of spreaders were obtained.

Equation for separation efficiency (3, 4):

$$\begin{aligned} E1 &= -68.79 - 0.2\cdot n - 2.29\cdot q + 44.6\cdot v + 0.063\cdot q^2 - 2.56\cdot v^2 \\ E2 &= 22.38 + 7.38\cdot v - 0.011\cdot q\cdot n + 0.027\cdot q^2 \\ E3 &= -49.75 - 0.43\cdot n - 0.41\cdot q + 36.45\cdot v + 0.053\cdot n\cdot v - 2.53\cdot v^2 \end{aligned} \quad (3)$$

$$\begin{aligned} Z1 &= 73.83 + 9.31\cdot v - 0.83\cdot v^2 \\ Z2 &= 68.9 - 0.49\cdot q + 11.49\cdot v + 0.083\cdot q\cdot v - 1.07\cdot v^2 \\ Z3 &= 72.12 + 0.285\cdot n - 0.001\cdot n^2 + 3.64\cdot v - 0.006\cdot n\cdot v - 0.27\cdot v^2 \end{aligned} \quad (4)$$

Analysis of the data of the regression equations shows that the rate of ascending air flow υ has a significant effect, less importance is the supply of grain *q* and the influence of the spin rotation frequency n is negligible.

On the basis of the regression equations (1) graphic dependences (Figure 4) of separation efficiency *E* from the air flow velocity *υ* (at *n* = 130 rpm, *q* = 15 t/h) and from the feed grain material *q* (at *n* = 130 rpm, *υ* = 7 m/s).

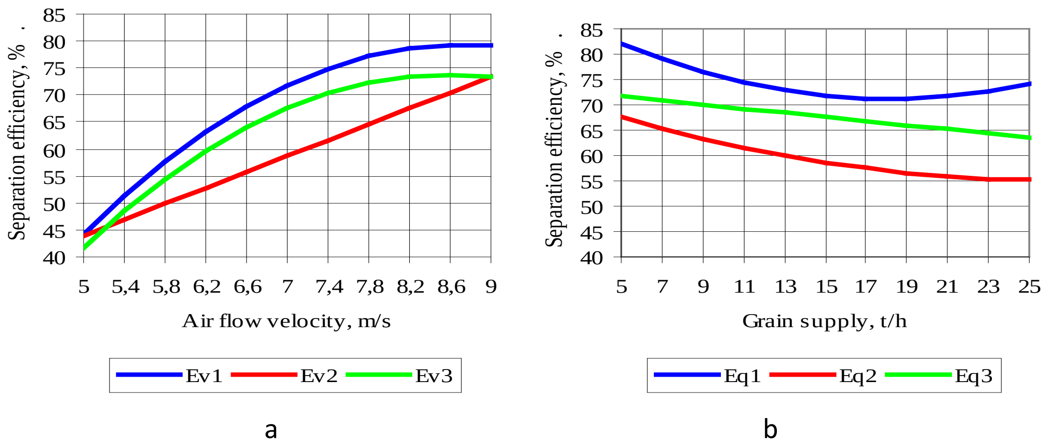


Fig. 4. *Graphic dependences of separation efficiency E on air flow velocity υ (a) and grain supply q (b): 1 – conical scatterer without vanes; 2 – conical spreader with shoulder blades; 3 – serial spreader*

The analysis of dependency data shows that the increase in the air flow rate υ increases the efficiency of the process of pneumatic separation *E* (Figure 4 a) and reduces the efficiency of the process of pneumatic separation *E* with an increase in the supply of grain *q*. The greatest efficiency is achieved when using a conical spatula without blades. This is due to the fact that this spreader does not create so-called "jets" zones of local grain condensation. Thus, this is confirmed by theoretical hypotheses. The highest efficiency of 80% is achieved at an air flow velocity of *υ* = 8.7 m/s and a feed of grain material *q* = 6 t/h by a conical scoop without blades. The serial spreader showed the lowest efficiency, since it does not provide perpendicular input of grain into the air stream.

On the basis of the regression equations (2) graphic dependences (Figure 5) of the separation *Z* on the air flow velocity *υ* (at *n* = 130 rpm, *q* = 15 t /h) are constructed.

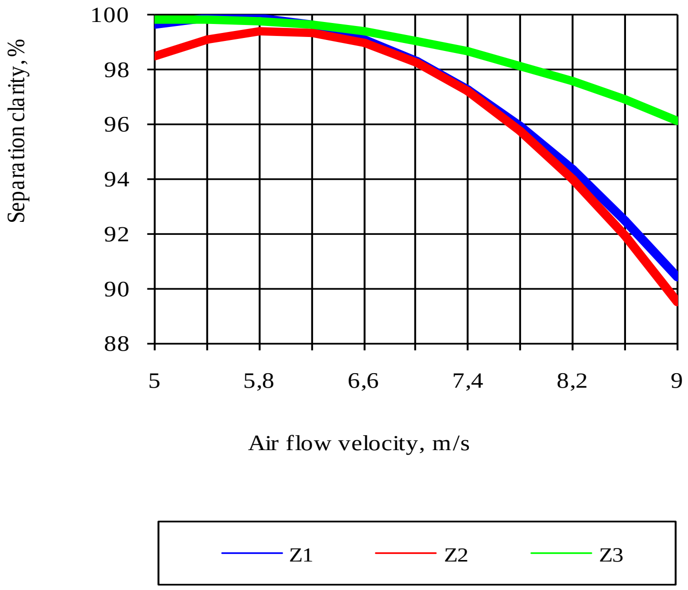


Fig. 5. *Graphic dependencies of separation clarity Z on air flow velocity υ: 1 – conical scatterer without blades; 2 – conical spreader with shoulder blades; 3 – serial spreader*

These dependences show that with increasing airflow separation υ decreases clarity *Z* greatest clarity separation shows conical spreader with blades. This is due to the fact that the spreader with a significant diameter 720 mm and thanks to the effect of "jets" that cause the conditions set blades capture airflow grain particles much worse than when grain is introduced into the airflow serial spreader (smaller diameter 540 mm) or conical scoop without blades (Figure 1). Graphic dependencies shown in Figure 5 shows that the conical spreader without blades and serial spreader provide almost the same clarity separation *Z*, because they create the same conditions for capturing particles of grain airflow, serial spreader at the expense of smaller diameter than the tapered spreaders, increasing the movement of particles of grain air flow; a conical scraper without blades due to the absence of the effect of "jets".

Summarizing the graphic dependencies shown in Figures 4-5, we can conclude that the most rational design is a conical scraper without blades. In order to establish a rational velocity was built comparative graph, which built on two axes *Z* clarity and separation efficiency *E* for n = 130 rpm, q = 15 t/h (Figure 6).

As a result, the intersection of the *Z*-graphs and the separation efficiency *E* gives the optimum point, which has the highest efficiency and the highest degree of separation. The highest separation efficiency *E* = 71.8 % and the highest separation clarity *Z* = 98.3 % can be achieved simultaneously at air flow velocity υ = 7 m/s.

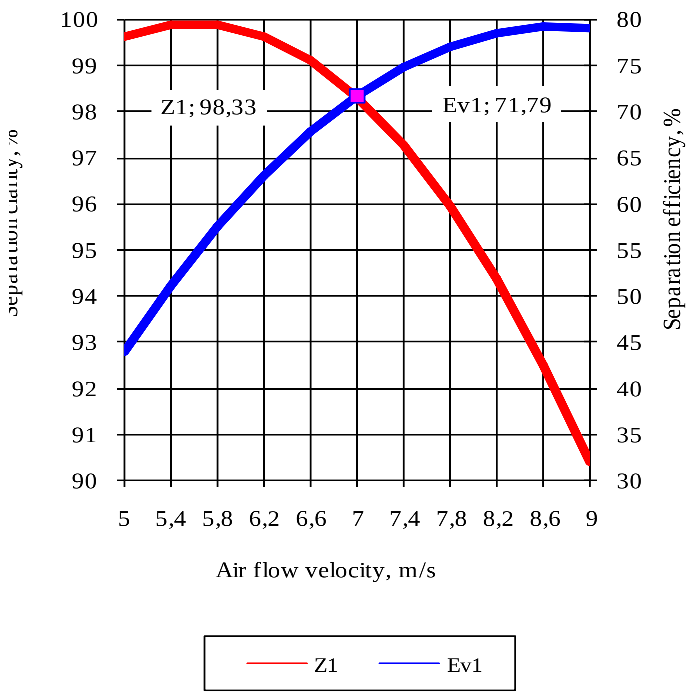


Fig. 6. *Comparative graph of Z-resolution and separation efficiency E from the air flow velocity υ for a conical scoop without blades*

3.2. Experimental Study of Modernized Aspiration Chamber of a Flat-Ridge Separator

The experimental data of the modernized aspiration chamber were amalgamated by a polynomial of the second degree. The equation of regression for the efficiency of cleaning *E* and the efficiency of precipitation of light impurities by an aspiration chamber from the performance of a flat screen separator *q* took the form:

$$E = 72.223 - 7.1473 \cdot q + 0.2641 \cdot q^2 \quad (5)$$

$$Ek = 68.473 + 3.9712 \cdot q - 0.5033 \cdot q^2 \quad (6)$$

On the basis of equation (5) and data Table 2 a plot of the dependence of the purification efficiency from light impurities E on the separator q efficiency (Figure 7) was constructed.

The graph shows that with increasing productivity q the effectiveness of pneumoconference is reduced, which is explained by the deterioration of the conditions for the allocation of light impurities. The maximum separation efficiency of 70% can be achieved with minimum performance values.

Table 2

Levels of independent factors of experimental research

Separator productivity, t/h	Efficiency of cleaning from light impurities,%	Efficiency of precipitation of light impurities,%
0,4	69,3	70,0
4	49,6	76
4,4	44,2	76,5
9,6	28	60,2

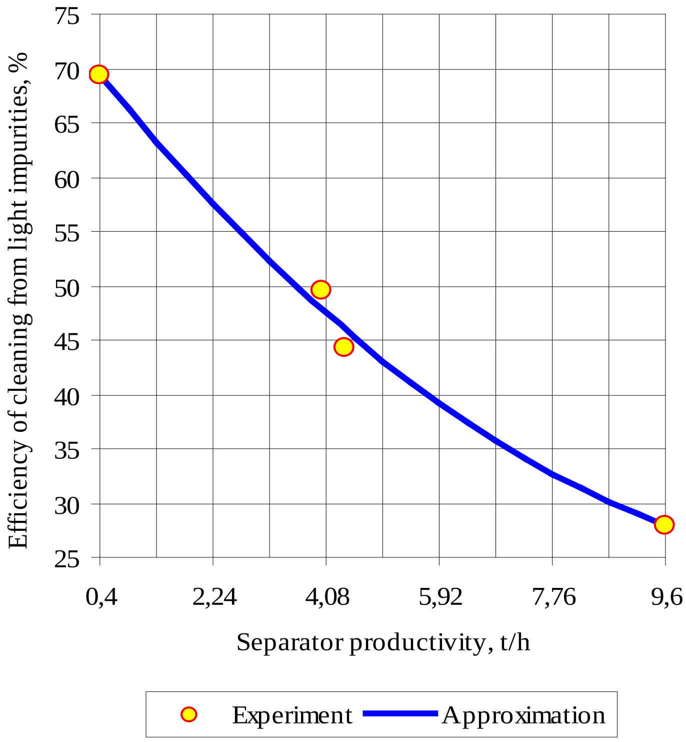


Fig. 7. *Graph of the dependence of the technological efficiency of the air separation E, % of the modernized aspiration chamber on the performance of the separator q*

On the basis of equation (6) and data table 2 a plot of the dependence of the precipitation efficiency of the light impurities Ek on the separator productivity q (Figure 8) was constructed.

An analysis of this graph shows that the function has an extremum at 3.95 t/h. This value of productivity corresponds to the highest value of precipitation efficiency of 76.26 %. This zone can be explained by the fact that when the productivity of the flat-line separator q increases, the amount of isolated light impurities is decreased, that is, their concentration (Figure 8). Reducing the concentration of light impurities improves the conditions of deposition, but with increased concentration of light impurities in the air stream, the air flow velocity between the particles increases and as a consequence of the decrease of the air flow rate at the turning in some zones is inadequate. Further lowering of the concentration of light impurities in the air stream also negatively contributes to precipitation, as at a small concentration of light impurities in the air stream, the dynamic pressure, which limits the lower boundary of the air flow velocity at the turning point, increases.

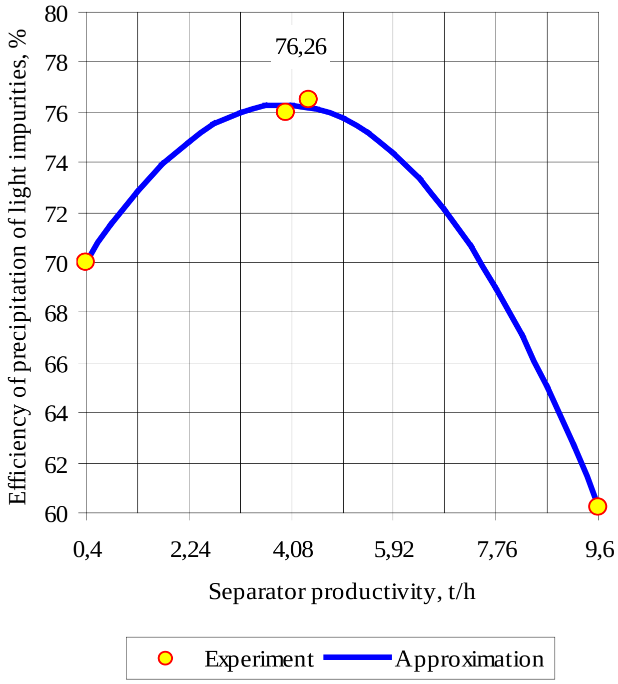


Fig. 8. *Graph of the dependence of the technological efficiency of precipitation of light impurities Ek, % aspiration chamber of the flat-line separator on the efficiency of the separator q*

4. Conclusions

1. The experimental researches of the advanced aspiration chamber using various types of scatterers have been confirmed by theoretical researches and hypotheses. New equations of regression of efficiency and clarity of the separation process, as well as their graphical interpretation, are obtained. The rational use of a conical spatula without blades has been proved experimentally. It was established that the optimal mode parameters of the aspiration chamber, which increase the separation efficiency (76-78%) and the separation severity (98,0-98,8%), are within:
   - air flow velocity υ = 7,2 – 7,4 m/s;
   - grain delivery q = 6 – 7 t/h;
   - frequency of rotation of the spreader n = 100 – 130 rpm.
2. As a result of the experimental research of the modernized aspiration chamber of the flat-line separator, the regression equation of the efficiency of

purification and deposition of light impurities and their graphical interpretation was obtained. It has been established that maximum purification efficiency can be achieved with minimum productivity values and maximum efficiency of precipitation of light impurities 76.26 % - at a productivity of 3.95 t/h.

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