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PROSPECTS FOR INCREASING THE EFFICIENCY OF PNEUMATIC SEPARATION CHANNELS IN CLEANING GRAIN AND SEED MATERIALS

Kharchenko S. O.[1a], Lytvynenko V. A.[1b], Kovalyshyn S. Y.[2c]

[1]Poltava State Agrarian University, Skovorodi Street, 1/3, Poltava, 36003, Ukraine
[2]Lviv National Agrarian University, Volodymyra Velykoho Street, 1, Dublyany, 30831, Ukraine

Corresponding author's e-mail: kharchenko_mtf@ukr.net[a], stkovalyshyn@gmail.com[b], stkovalyshyn@gmail.com[c]

Abstract
The technological process of most universal grain and seed cleaning machines consists of the separation of components by aerodynamic characteristics on the pneumatic separation channels and the separation of components by size on the sieves. The restraining factor in further increasing the productivity of grain and seed cleaning machines is the imperfect design of pneumatic separation channels. The analysis carried out made it possible to determine the basic designs of pneumatic separating channels, their working elements and intensifying devices. This allowed creating a classification of pneumatic separation channels according to various structural, technological and functional features. The conducted system analysis established that one of the factors affecting the efficiency of cleaning grain or seed materials is the uniformity of loading of the pneumatic separation channel along its width. To determine the degree of significance of this factor, a research methodology has been developed. The description of conducting experimental researches is given, mathematical expressions for determining the uniformity of the supply of grain and seed materials are established. A list of design and technological parameters and properties of grain (seed) mixtures, which affect the efficiency of pneumatic separation channels, is presented.

Key words:
separation channel, cleaning, properties, grain, seeds, loading, channel width, efficiency.

Introduction

Increasing the productivity of grain cleaning separators affects the expenses and cost of post-harvest grain processing and seed preparation. The main technological indicators of separators for grain cleaning and calibration of seed materials are productivity and quality of separation of their components. These indicators are consistent with each other, but the quality is regulated by the standards of a particular country or international ISO, for example (ISO 605:1977, ISO 7970:2021).

Formulation of problem

In the technological process of most modern grain and seed cleaning machines, the first stage of material purification is the separation of components according to aerodynamic properties on pneumatic separation channels. After the separation of the components in the pneumatic separation channels, the grain or seed material is separated by size on the sieves. Increasing the productivity of sieves has a number of effective practical solutions, including parallel tiered or sequential cascade placement, the use of innovative sieves with increased screening capacity. Such solutions allow obtaining the maximum possible performance of sieve units. However, despite the increased productivity of sieve units, the constraining factor of the productivity of the entire cleaning machine is the performance of pneumatic separation channels.

Research of processes and methods of grain mixtures cleaning in air flows (Zaika *et. al* 1997; Burkov 1993; Andreev 2005; Kotov *et. al* 2010; Vasylkovskyi *et. al* 2006; Stepanenko 2017; Slipchenko 2012; Kharchenko *et. al* 2021).

Practical use of grain and seed cleaning machines is

the following. Scientists conducted research on the process of separation of bulk media by air flow, identified significant factors (Zaika *et. al* 1997; Burkov 1993; Andreev 2005; Kharchenko *et. al* 2021): specific loading of the pneumatic separation channel, uniformity of material distribution along its width; the initial speed and thickness of the layer of grain material particles, the speed and uniformity of the air flow in the working area.

The initial rate of input and uniformity of distribution of grain material in the PSC, the direction of movement affects the efficiency of separation. By analyzing the works (Kotov *et. al* 2010; Stepanenko 2017), technical means have been established to intensify the distribution of grain material along the width and the optimal parameters have been determined: the rate of introduction of grain material 0.3…0.4 m/s; the angle of inclination of the guide surface is taken to the angle of friction of the grain on the metal 25…35°.

In the work (Abduiev 2007), technical means for ensuring uniformity of the set speed of an air stream in a working zone of the pneumatic separation channel by means of system of blinds are also established.

Existing designs of pneumatic separation channels, taking into account the works (Abduiev 2007; Burkov *et. al* 2002; Yermak 2003), can be classified according to the following features: with open and closed airflow cycles; single-channel, sectional and non-channel; with vertical, inclined, horizontal, annular working channel.

Purpose of research

The purpose of the study is to determine promising ways to increase the efficiency of pneumatic separation channels of grain and seed cleaning machines and to substantiate the methodology of their research to optimize significant parameters.

Research results and discussion

As a result of the analysis of the researches, the designs of pneumatic separation channels are established:

– on the presence of channels: channelless (Fig. 1, a), channel (Fig. 1, b-k);

– on the principle of action: passive (Fig. 1, a-j), active (rotary) (Fig. 1, k);

– by location: single-channel (Fig. 1, b-g, i-k), sectional (Fig. 1, h);

– by the shape of the channel intersection: rectangular (Fig. 1, c, e, h, l), round (Fig. 1, e, f), ring (Fig. 1, i);

– in the direction of the channels: vertical (Fig. 1, b-f, h-j), horizontal (Fig. 1, a), inclined (Fig. 1, g);

– by type of air flow: injection (Fig. 1, a, b, g), suction (Fig. 1, c, e, f, h-k), suction-discharge (Fig. 1, d);

– by type of pneumatic system: machines with open (Fig. 1, a-c, e-k) and closed air flow cycles (Fig. 1, d).

The main disadvantages of the structures noted by researchers are: the lack of uniformity of air flow and distribution of grain material across the width of the channel; significant metal and energy consumption of machines; the size and complexity of structures; low quality cleaning and specific loading.

Also a negative factor, which is characteristic of most designs of pneumatic separation channels, is the supply of grain material in the middle part by means of self-flowing pipes. With a significant width of the pneumatic separation channel (more than 1000 mm) to ensure uniform feed of grain material, it is necessary to use additional switchgear.

Increasing the width of the channel can be used to increase the productivity of the pneumatic separation channels. This method leads to an increase in the size of the separators and to uneven loading across the width of the channel, which causes a loss of quality of separation of components of grain and seed materials.

The analysis made it possible to systematize and identify promising ways to improve the efficiency of pneumatic separation channels: optimization of technological parameters; preliminary preparation of grain materials and air flow; intensification of distribution of grain materials; using repeated cleaning; combining devices of different types of action.

Thus, a promising way to increase the efficiency of the process of pneumatic separation of grain and seed materials depends on the conditions of their introduction and distribution in the working areas of pneumatic separation channels.

To study the process of introducing grain materials into the working area of the pneumatic separation channel, the task was to establish an appropriate method.

To determine the speed of grain materials, when they are introduced into the working area, in the transverse and longitudinal sections of the channel must be divided into an equal number of sections. For experimental plots we use a set of rectangular trays.

Given the width of most grain and seed cleaning machines 1000 mm, which corresponds to the width (length) of the sieves, we accept 10 trays of 100 mm each.

For research we take a sample of grain material and pour it on the experimental sloping surface. Then we measure the time of the experiment. Next, we analyze the content of grain (seed) material in the trays-receivers, determine the weight. The experiments must be performed in triplicate and the values are averaged.

When conducting such experiments, attention should be paid to the established mode of operation of the pneumatic separation channel. Therefore, it is necessary to provide means to urgently enter the receiving trays into the working area in the steady state of channel loading. This will ensure the required accuracy in research.

For visual visualization, it is better to present the research results in the form of graphical dependence (Fig. 2). According to the test results, it is necessary to evaluate the efficiency of grain material distribution along the width of the channel.

Sampling time depends on the total specific feed

(productivity). Determine the average weight of grain material received on the *i*-th section of the width of the pneumatic separation channel during the experiment.

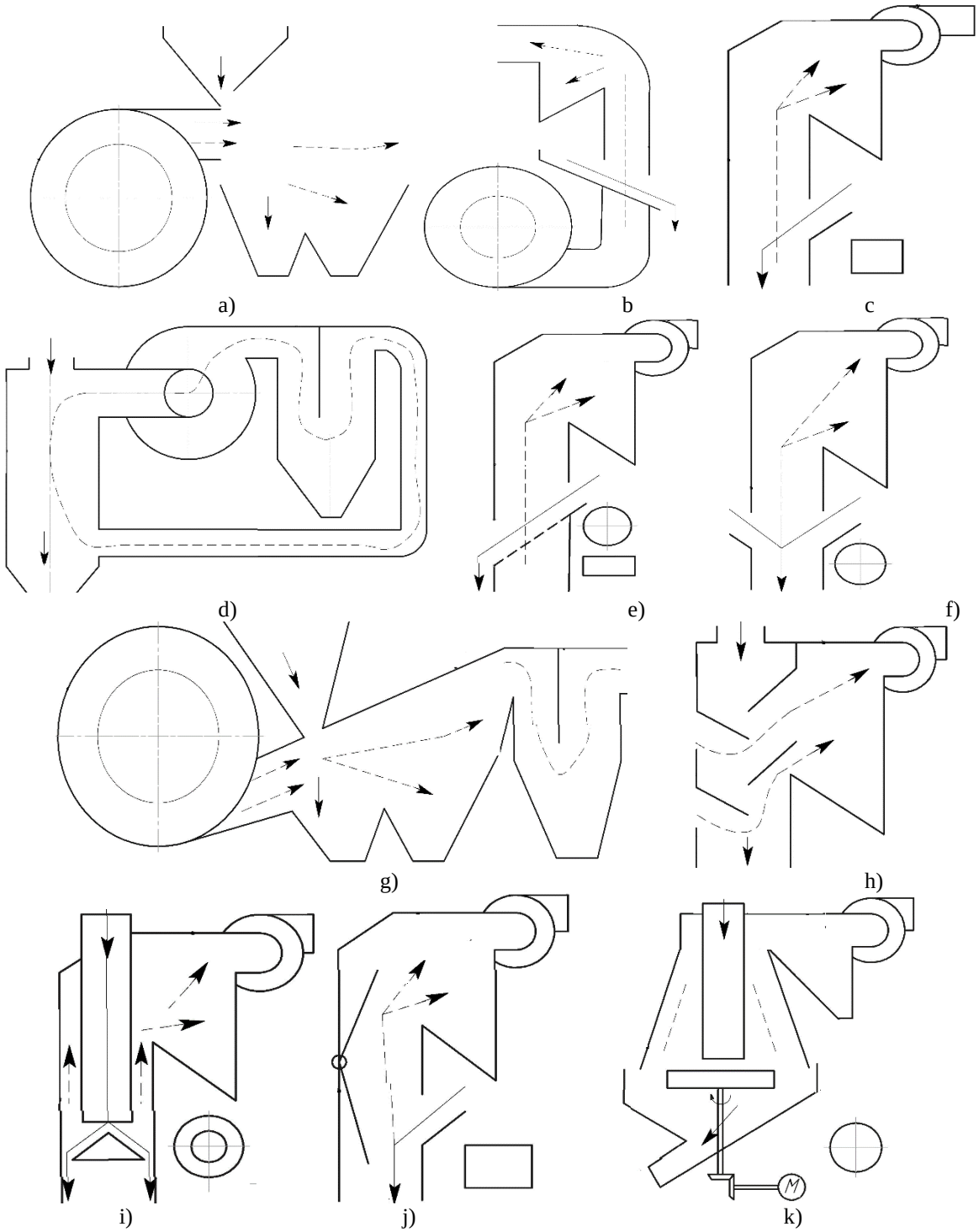

Figure 1. Schemes of pneumatic separators: a – injection channelless; b, c – injection and suction channel vertical; d – channel with a closed system; e – suction vertical with an inclined grid; f – suction vertical with perimeter supply; g – injection inclined; h – suction section; i – suction ring; j – suction with a variable working cross-section; k – suction disk rotary.

The average weight determines the supply of the *i*-th section of the pneumatic separation channel by the expression:

$$Q_i = \frac{q_{avi}}{t}, \text{ kg/s}, \quad (1)$$

where q_{avi} is the average weight of the grain material that fell on the *i*-th section of the width of the pneumatic separation channel;

t – duration of repetition of the experiment, sec.

The average supply of grain material in the area of the pneumatic separation channel is determined by the

expression:

$$Q_{av} = \frac{\sum_{i=1}^{n} Q_i}{n}, \text{ kg/s}, \quad (2)$$

where $\sum Q_i$ – total supply of grain material in the pneumatic separation channel, kg/s;

n – the number of sections (trays) across the width of the pneumatic separation channel.

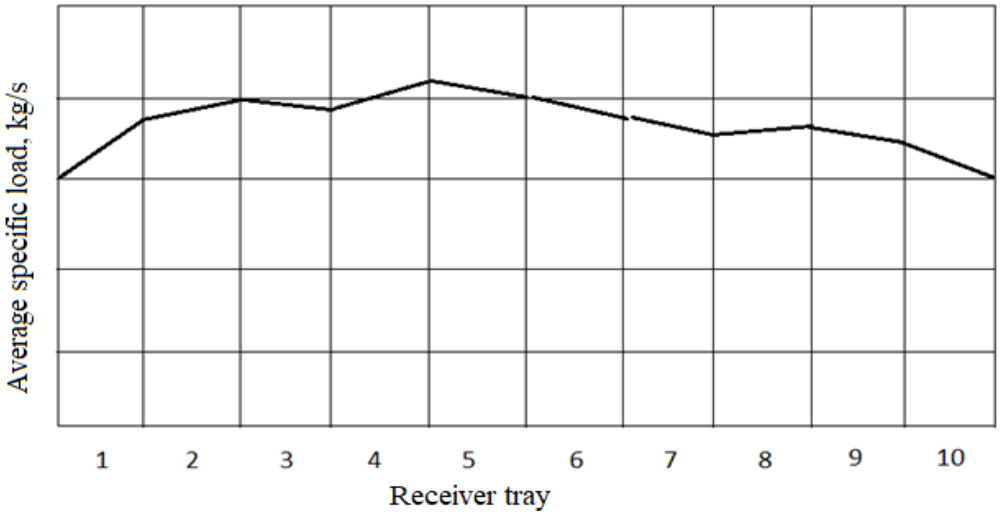

Figure 2. Dependence of grain material distribution on the width of the pneumatic separation channel of the grain cleaning machine.

The numerical indicator of the characteristic of uniformity of distribution of grain material on width of the pneumatic separation channel is found through coefficient of non-uniformity (k_n):

$$k_n = \frac{\sigma}{Q_{av}}, \quad (3)$$

where σ – the standard deviation of the average material feed of the material across the width of the channel:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (Q_i - Q_{av})^2}{n-1}}, \quad (4)$$

where Q_{av} – the average feed of the material in the area of the channel width, which is determined by the expression (2).

It should be noted that the determination of the uniformity of the feed depends not only on the design and technological parameters of the channel, but also on the properties of the grain (seed) material.

The design and technological parameters of the channel should include: the angle of inclination of the sloped surface, its length, the amount of grain material supply, the width and thickness of the channel.

The properties of grain (seed) mixtures include: clogging, moisture, density of components and mixtures; coefficients of friction and natural bevel, particle size, porosity of the material.

Conclusions

The analysis of the technological processes of grain and seed cleaning machines, the designs of their pneumatic separating channels made it possible to determine promising ways to increase the efficiency of their work. Among similar methods, it is necessary to highlight the uniform distribution of grain material along the width of the channel.

A methodology for studying the uniformity of distribution of grain or seed material in pneumatic separation channels has been developed, which provides a description of the research, the expression of the main performance indicators, a list of factors affecting its value.

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