THE INFLUENCE OF BASIC PARAMETERS OF SEPARATING CONVEYOR OPERATION ON GRAIN CLEANING QUALITY
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ВПЛИВ ОСНОВНИХ ПАРАМЕТРІВ РОБОТИ ТРАНСПОРТЕРА-СЕПАРАТОРА НА ЯКІСТЬ ОЧИЩЕННЯ ЗЕРНА

Prof. Ph.D. Eng. Vasylkovskyi Oleksii[1], Lect. Ph.D. Eng. Vasylkovska Kateryna[1], Lect. Ph.D. Eng. Moroz Serhii[1], Prof. Dr. Eng. Sc. Sviren Mykola[1], Dr. Agric. Sc. Storozhyk Larysa[2]
[1] Central Ukrainian National Technical University / Ukraine;
[2] Institute of Bioenergy Crops and Sugar Beet National Academy of Agricultural Sciences of Ukraine / Ukraine
Tel: +380667103625; E-mail: vasilkovskakv@ukr.net

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ABSTRACT

The rational succession of technological operations of all-purpose grain cleaning machines was substantiated at the Department of Agricultural Engineering at Central Ukrainian National Technical University. The original design of a separating conveyor used in the first stage of the proposed cleaning scheme was created. The experimental separating conveyor allows extracting large impurities before feeding the grain mass to aspiration, reducing the resistance of the system and creating optimal conditions for air cleaning.

The objective of our research was to identify rational parameters and operating modes of the suggested separating conveyor. The objective was achieved by studying the influence of the basic parameters of the conveyor: the inclination angle α, sieve hole diameter d, buckets velocity v, as well as the specific loading of the sieve width unit q_B *on one of the most important qualitative indicators which is grain separation fineness. The fineness is characterised by the content of full-value grains in fodder waste.*

The experimental device and methodology for laboratory research were developed to identify the most influential factors on the separation fineness. During the research, the matrix of the full factorial experiment of the 2^4 *type was implemented. The basic level and intervals of factors variation were chosen based on the analysis of theoretical studies results and experimental research preliminary data.*

The obtained regularities confirmed the efficiency of the suggested design and allowed identifying the rational parameters of the separating conveyor to ensure acceptable separation fineness of grain.

РЕЗЮМЕ

На кафедрі сільськогосподарського машинобудування Центральноукраїнського національного технічного університету було обґрунтовано раціональну послідовність технологічних операцій в зерноочисних машинах загального призначення і створено оригінальну конструкцію транспортера-сепаратора, що використовується на першому етапі запропонованої схеми очищення. Дослідний транспортер-сепаратор дозволяє виділити крупні домішки перед подачею зернової маси до аспірації, зменшуючи опір системи і створюючи оптимальні умови для повітряного очищення.

Метою наших досліджень було встановлення раціональних параметрів і режимів роботи запропонованого транспортера-сепаратора. Досягнення поставленої мети здійснювалося шляхом вивчення впливу його основних параметрів: кута нахилу α, діаметра твірних решета d, швидкості переміщення ковшів v, а також питомого завантаження одиниці ширини решета q_B*, на один з найбільш важливих якісних показників – чіткість сепарації зерна, що характеризує вміст повноцінного зерна у фуражних відходах.*

Для встановлення найбільш впливових факторів на чіткість сепарації було розроблено експериментальну установку і складено методику лабораторних досліджень. В ході проведення досліджень реалізовано матрицю повного факторного експерименту типу 2^4*. Основний рівень та інтервали варіювання факторів обрані на основі аналізу результатів теоретичних досліджень та попередніх даних експериментальних досліджень.*

Одержані закономірності дозволили підтвердити ефективність запропонованої конструкції і встановити раціональні параметри транспортера-сепаратора для забезпечення допустимої чіткості сепарації зерна.

INTRODUCTION

The market of agricultural machines constantly develops and is updated with new models of machines. The vast majority of the national manufacturers often copy best models of the well-known international brands. A small number of the Ukrainian machine builders develop their own designs, test them and eliminate failings. A smaller number of manufacturers create original designs of machines and mechanisms on the basis of scientific research. However, this category of manufacturers has long-term prospects for creating truly competitive products for the world market.

MATERIALS AND METHODS

Several designs of all-purpose grain-cleaning machines were created at the Department of Agricultural Engineering of Central Ukrainian National Technical University through the conduct of scientific research. One of the main operating elements of each design is a separating conveyor (*Moroz S. M., 2014; Moroz S. M., 2011*) which is installed at the beginning of the technological cycle of the machine and allows the grain to be cleaned from large impurities at the stage of loading.

The experimental device (Fig.1, 2) consists of the frame *1*, to which the housing of the separating conveyor *2* with the drive mechanism is fixed on the joint *10.* The sieve with circular longitudinal baffles *3* and upper (driving) and lower (driven) drums *4* and *5* on bearing spherical supports are fixed to the sides of the housing inside the separating conveyor. The grain comes from hopper *11*, equipped with dispenser *12* and slide gate *13* in the grain pipe *8*. Under the sieve, there is a receiver for grain fraction pass-through 7. The separating conveyor is actuated by the electric motor *14* with the help of a V-belt drive and the six-speed gearbox *15* that provides the change of the buckets velocity v from 0.5 to 2.83 m/s.

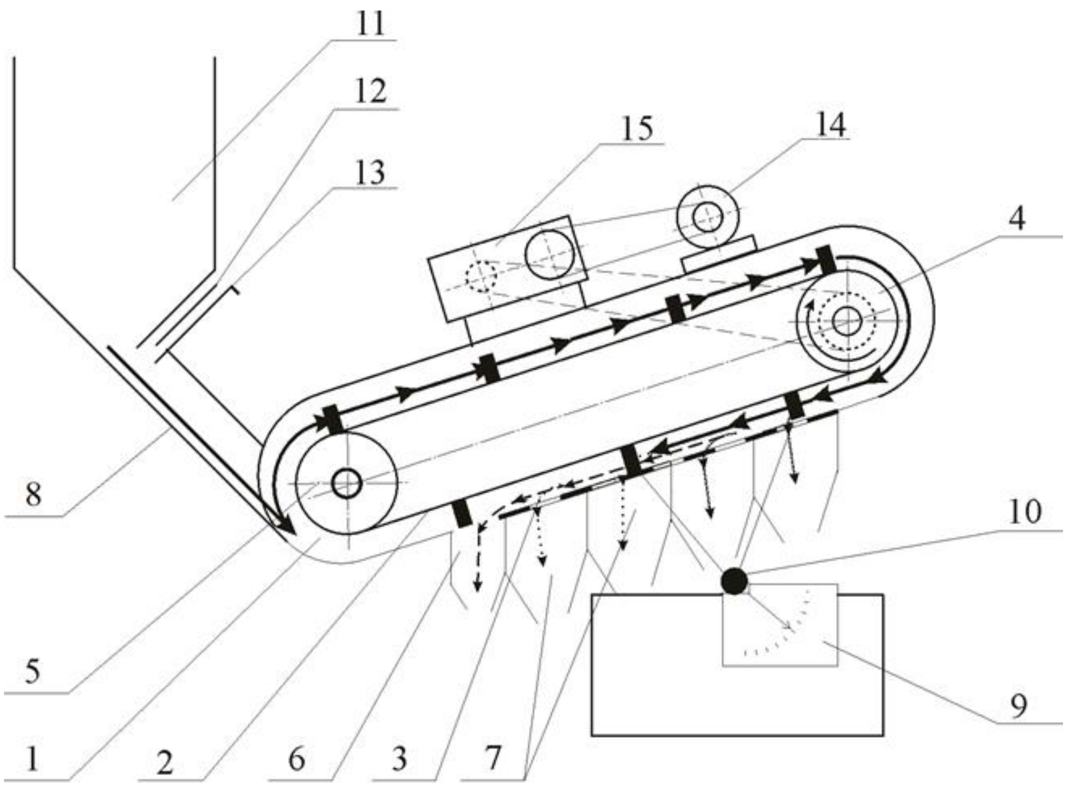


Fig. 1 - Schematic layout of the experimental device

The change of the housing inclination angle α of the separating conveyor relatively to the horizon was carried out by its rotation relatively to the joint *10* with the fixation in the required position. The control and measurement of the conveyor inclination angle relatively to the horizon was carried out using angle gauge *9*.

The sieves with longitudinal baffles of round shape with the diameters of 1.3 and 5 mm (Fig. 3, 4) serve as surfaces for the separation.

Fig 2 - General view illustration of the experimental device

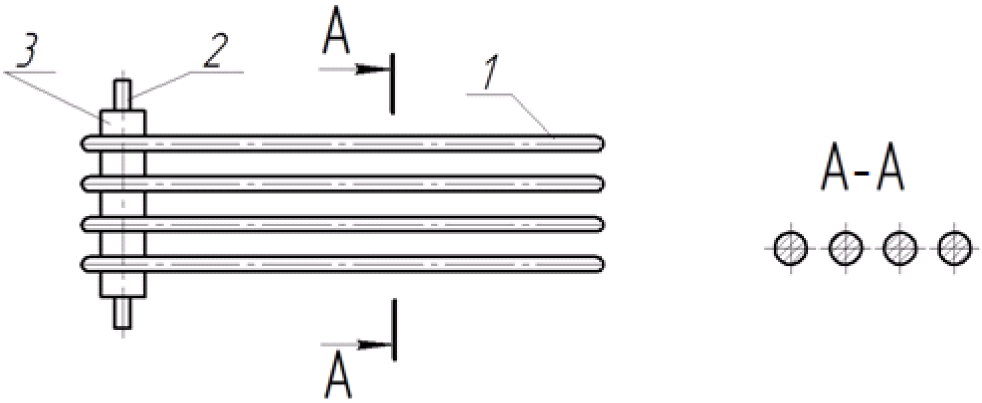


Fig 3 - Schematic view of the sieve

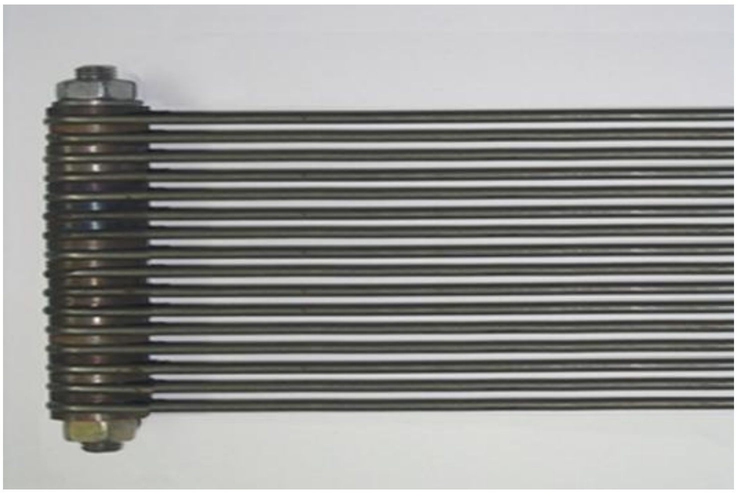


Fig 4 - General view of the sieve

During theoretical and experimental studies, the dependences of the influence of its constructive parameters values and operation modes on the grain separation completeness were established (*Dryncha VM, 2006; Kotov BI, 2017; Kroulik M., 2016; Levdanskiy EI, 2008; Piven M., 2015; Stepanenko S., 2017; Tishchenko L., 2014; Tishchenko L., 2016*). However, the separation fineness, which characterizes the content of the full-value grain in large impurities, has not been studied in details.

The objective of the research is to determine the influence of the design parameters and the operating mode of the suggested separating conveyor on the separation fineness. The research will give grounds for identifying rational values on conditions that the agro-technical requirements regarding the content of the full-value grain in the fodder waste are provided.

Separation fineness *Y* – the relative content of full-value grain in the waste was determined by sieving and weighing. To identify the influence of the investigated factors on the separation fineness and to determine the direction of motion to the part of the response surface, where the conditions of the process were optimal, the matrix 2^4 was applied (*Borovikov V.P., 2003*). Independent variables, variation intervals, and planning matrix are presented in Table 1.

Table 1

Planning of the experiment while studying the separation process

Investigated factor	**Angle of inclination of a sieve, α, deg.**	**Diameter of the cross-cut baffle of the sieve, d, mm**	**Speed of scrapers, v, m/c**	**Specific productivity, q_B, kg/(m×c)**		
Basic level	**30**	**3**	**1**	**11**		
Variation interval	**±10**	**±2**	**±0,5**	**±3**		
Code designation	x_1	x_2	x_3	x_4	Y_u	S_u^2
Experiment 1	+	+	–	+	16.10	0.012
Experiment 2	+	–	+	–	3.91	0.012
Experiment 3	–	+	–	–	1.03	0.0031
Experiment 4	+	–	+	+	8.95	0.0052
Experiment 5	–	–	–	+	4.13	0.0031
Experiment 6	+	+	+	–	6.05	0.0043
Experiment 7	–	–	+	+	6.08	0.011
Experiment 8	+	+	+	+	20.10	0.280
Experiment 9	–	–	–	–	0.15	0.0019
Experiment 10	–	–	+	–	1.50	0.0013
Experiment 11	–	+	+	+	11.2	0.317
Experiment 12	–	+	+	–	4.90	0.210
Experiment 13	+	+	–	–	4.10	0.0077
Experiment 14	–	+	–	+	7.80	0.0067
Experiment 15	+	–	–	+	9.10	0.280
Experiment 16	+	–	–	–	1.85	0.0037

The basic level and intervals of factor variations were selected based on the analysis of theoretical studies results and experimental research preliminary data.

RESULTS

After conducting experiments, the regression equation was obtained. This equation describes the local area of the response surface, which characterizes the separation fineness:

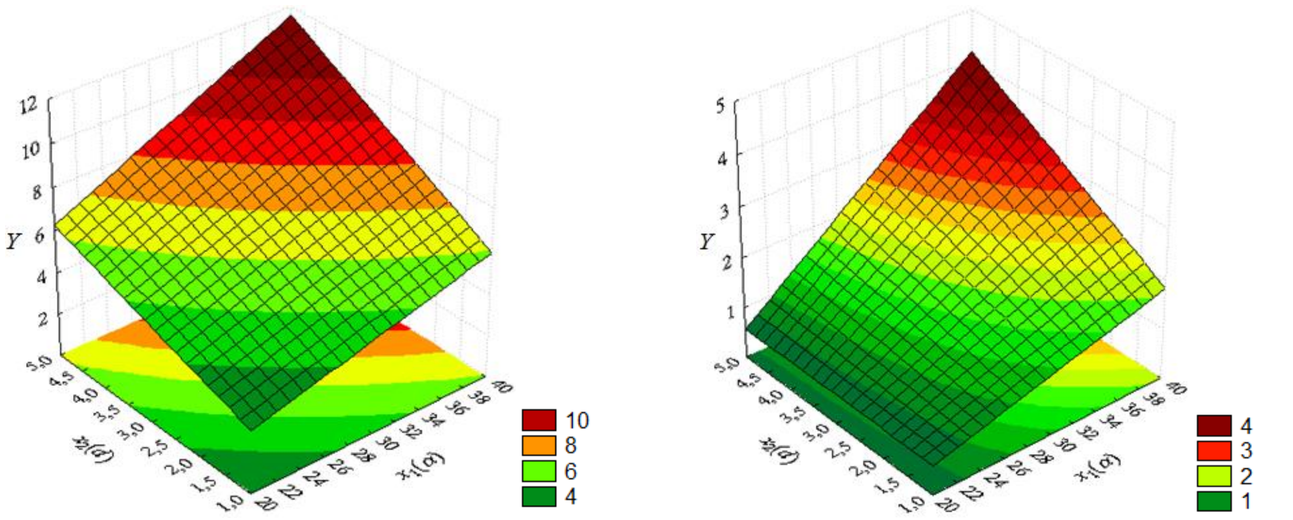
$$Y = 6.864 + 2.08x_1 + 2.006x_2 + 1.152x_3 + 3.748x_4 + 0.592x_1x_2 - 0.169x_1x_3 + \\ + 1.044x_1x_4 + 0.501x_2x_3 + 1.142x_2x_4 - 0.002x_3x_4 \quad (1)$$

The verification of the obtained model adequacy (Table 1) was carried out according to Fisher's criterion (F-criterion). The calculated value of the *F*-criterion, which is *F*=0.211, is less than the value in the Table F_t=2.561 (selected for *p*=0.95; $f_{aд}$=11; f_y=32) (*Vasylkovskyi O., 2016*). Thus, the hypothesis of the linear equation adequacy is confirmed and can be used to describe the process.

The significance of the obtained coefficients was checked by Student's criterion (t-criterion) to ensure the reliability of the assessment – 0.95 and the number of degrees of freedom f_t=15. The analysis of the confidence interval shows that in the studied interval there are statistically insignificant regression coefficients b_1b_2, b_1b_3, b_2b_3 and b_3b_4.

The statistically significant coefficients include all the coefficients except for the coefficients b_1b_2, b_1b_3, b_2b_3 and b_3b_4.

The response surfaces and maps of lines of equal output (fig. 5-10) allow not only to reveal the coherent influence of factors on the separation fineness, but also to determine the direction of movement to rational design and technological parameters of the investigated operating element.



a) b)

Fig 3 - Dependence of the separation fineness on the sieve inclination angle and diameter of the sieve cross-cut baffle

a – basic level of factors; b – lower level of factors

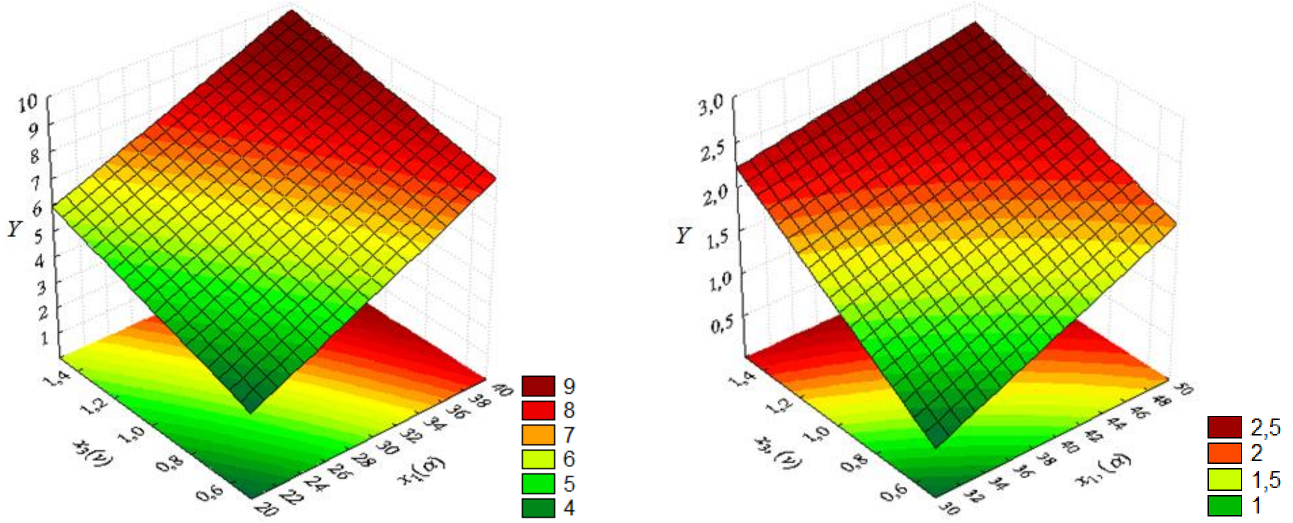


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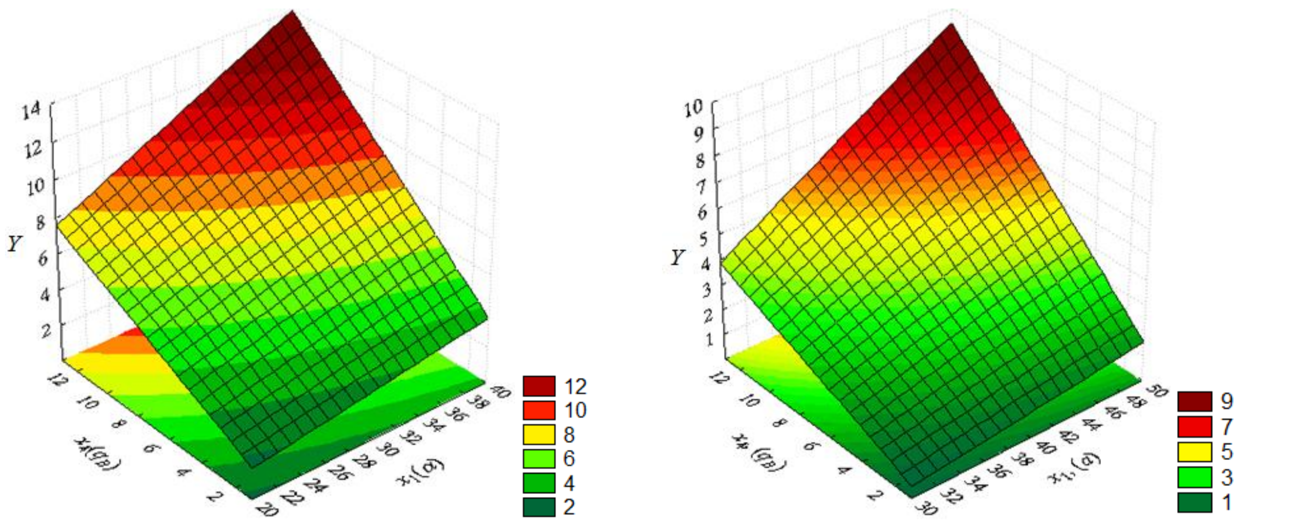
Fig. 4 - Dependence of the separation fineness on the sieve inclination angle and the initial velocity of the material motion

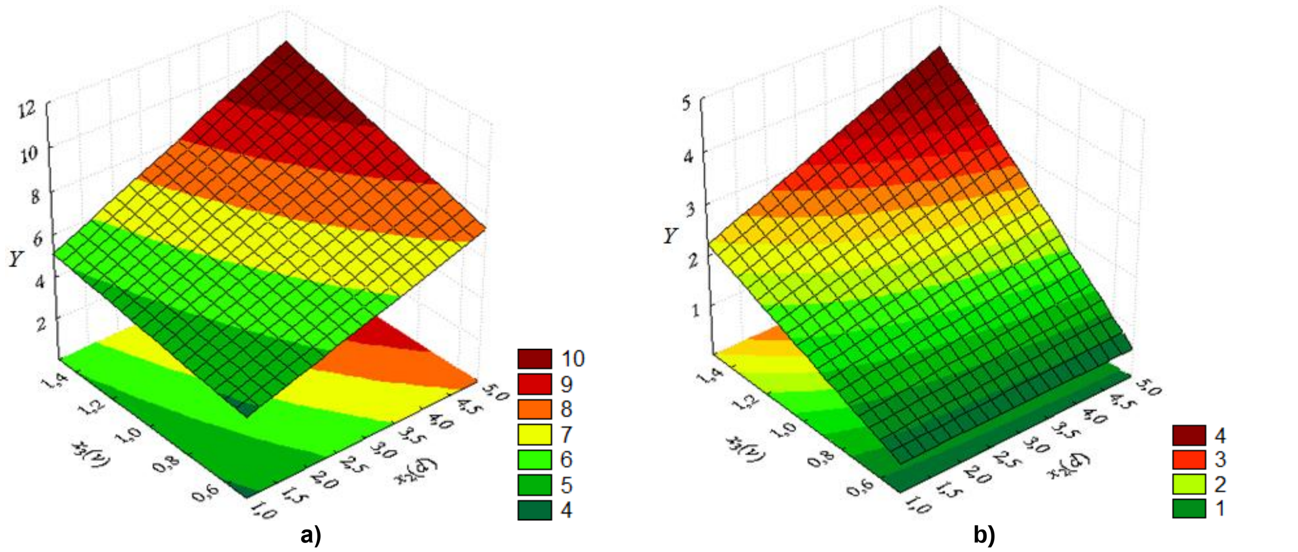
a – basic level of factors; b – lower level of factors



a) b)

Fig. 5 - Dependence of the separation fineness on the sieve inclination angle and material feeding

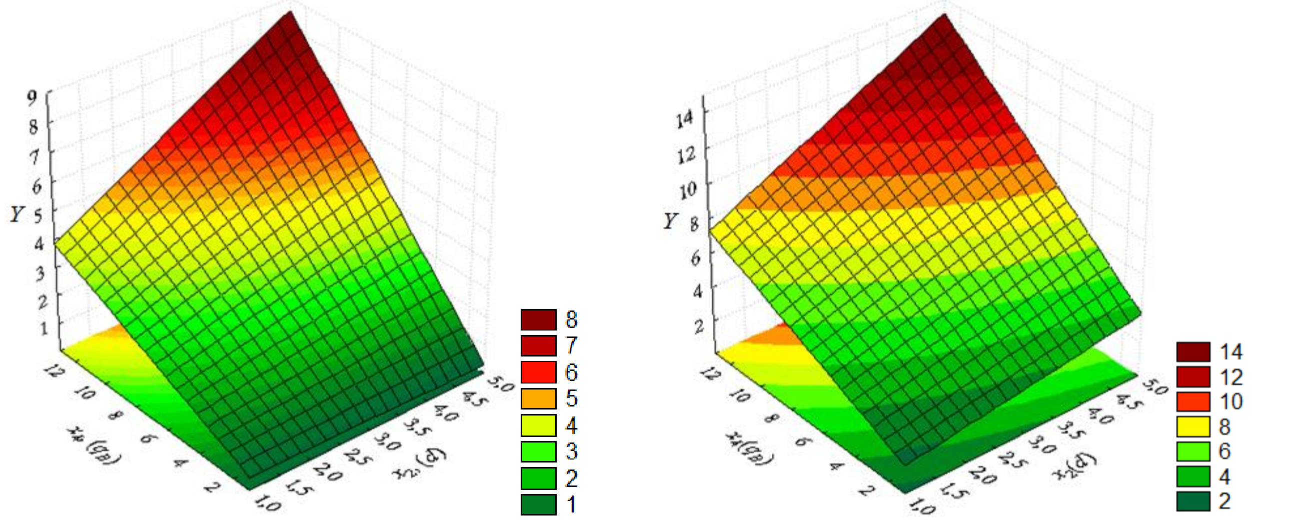
a – basic level of factors; b – lower level of factors



a) b)

Fig. 6 - Dependence of the separation fineness on the diameter of the sieve cross-cut baffle and the initial velocity of the material motion

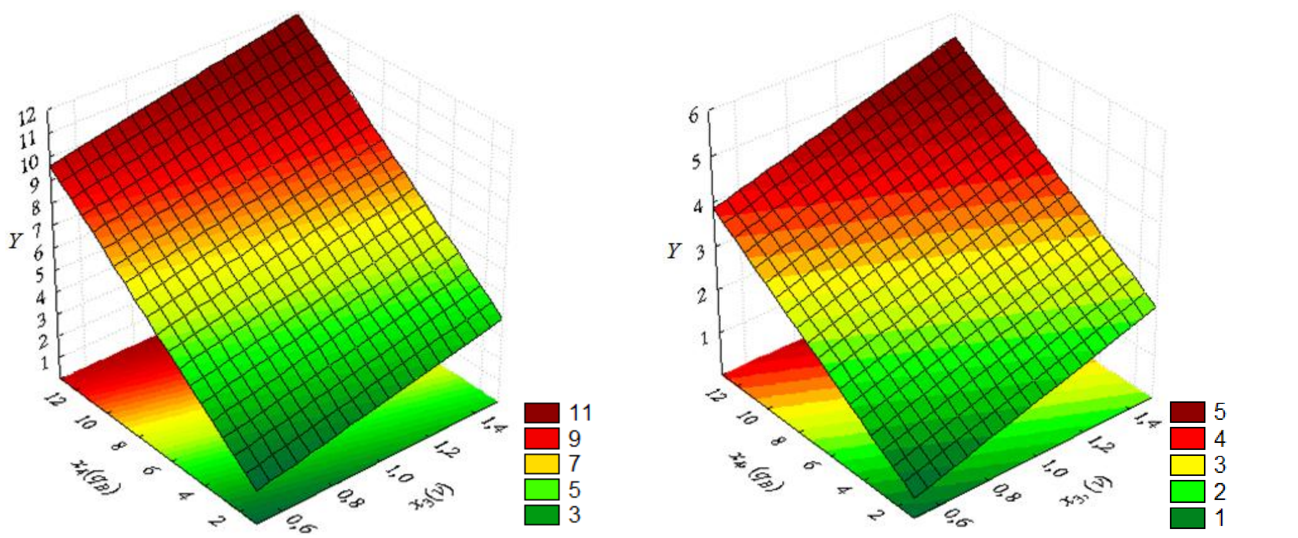
a – basic level of factors; b – lower level of factors



a) b)

Fig. 7 - Dependence of the separation fineness on the diameter of the sieve cross-cut baffle and material feeding

a – basic level of factors; b – lower level of factors



a) b)

Fig. 8 - Dependence of the separation fineness on the initial velocity of the material motion and material feeding

a – basic level of factors; b – lower level of factors

In the experiments, a natural heap of winter wheat with a moisture content of 14.6% and a total contamination of 12.2% was used.

The analysis of the results allows the following as a whole to be argued. The increase in the angle of inclination (x_1), the diameter of the sieve cross-cut baffle (x_2), the speed of the scraper (x_3) and the specific productivity (x_4) increase the degree of separation clarity. This is observed in experiments where the remaining factors are at the main level of variation (fig. 3a-8a). In the case where the remaining factors are at the lower level, the pattern is slightly different. In particular, it turns out that the diameter of the sieve transverse cross-sections does not affect the clarity of separation (fig. 3b, 6b). This pattern can be explained by the increased time on grain sifting as a result of a small specific feed and speed of movement.

After analyzing the Pareto-cards (fig. 11), we can conclude that all factors influence the separation fineness ε. In addition, the interaction of factors was also influential: the inclination angle and the feeding x_1x_4; diameter and feeding x_2x_4. The feeding x_4 has the greatest influence and the initial velocity of the chaff motion x_3 has the smallest influence.

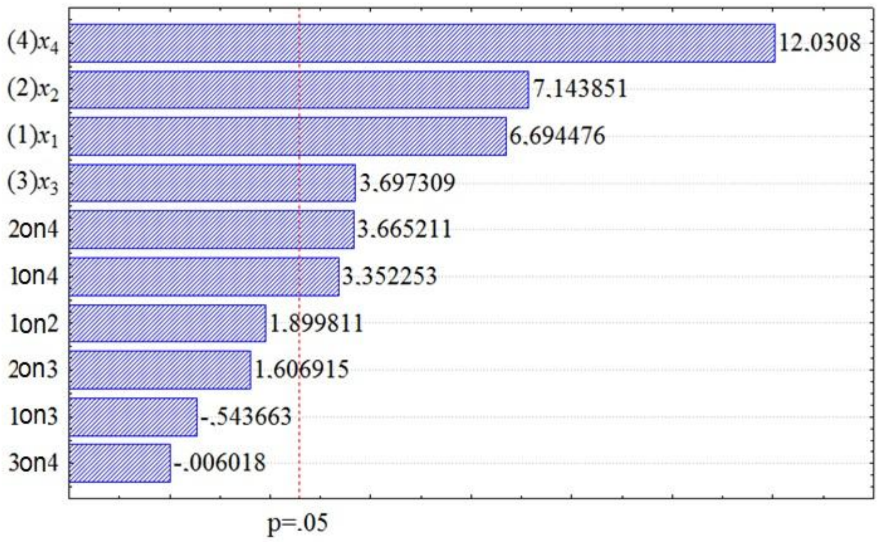


Fig. 11 - Standardised Pareto-card for separation fineness *Y*(ε)

CONCLUSIONS

The analysis of experimental data made it possible to identify the nature of the change of factors and to analyse their mutual influence on the optimization criterion. With an increase in the specific grain loading x_4 (*qB*), the separation fineness decreases proportionally. It was found that increasing the inclination angle of the sieve x_1 (α), the diameter of its baffles x_2 (*d*), and the initial velocity of the grain material motion x_3 (*v*) cause a decrease in separation fineness.

It has been identified that the specific grain loading x_4 (*qB*) should not exceed 7 kg/(m·s), the initial velocity of the grain material x_3 (*v*) is at the level of 0.5-1.2 m/s and the inclination angle of the sieve x_1 (α) ranges within 20-30º. According to the above-mentioned factors, the rational diameter of the sieve baffles x_2 (*d*) should not exceed 1-3 mm. By these parameters, it is possible to achieve separation fineness at the edge limit of 2%.

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