Study of operation of four-screen shoes of grain-cleaning separators

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Abstract. Screen shoes with three layout schemes of sieve arrangement were studied. There are separation and head screens installed in the upper tier in the first and third schemes, and in the lower one respectively there are two cleaning and two sorting screens, and in the latter between the tiers there is a rolling surface placed in the opposite direction of grain material movement. The second scheme involved the sequential installation of a sorting screen in the upper tier, and a cleaning and sorting screen in the lower tier. These schemes are used for preliminary, primary and secondary cleaning of grain material. The experimental studies made it possible to obtain the dependence graphs of the identified grain fractions on its supply to the beginning of the screen shoe, as well as the influence of grain supply on the quality indicators of winter wheat grain, such as the thousand-kernel weight of the main and forage fractions and the completeness of the fodder fraction extraction. The use of a screen shoe with a third layout scheme can provide seed cleaning with a supply of 0.38 kg/(s·m), commercial – with a supply of 1.05 kg/(s·m) and preliminary – with a supply of 3.94 kg/(s·m).

1 Introduction

Currently, post-harvest treatment is essential for maintaining high cleaning qualities of cereal seeds. It includes a set of sequential technological operations. Post-harvest treatment is one of the main and final stages in grain production, without which it is impossible to obtain seeds that meet the GOST R 52325-2005 requirements.

Post-harvest treatment of grain is primarily aimed at increasing the storage duration of the obtained material. Secondly, the quality of the grain should meet the regulatory requirements for sown material, food grain or forage.

Various grain cleaning units are used for post-harvest treatment. The efficiency of grain cleaning is one of the main criteria for evaluating the operation of the grain cleaning unit. The improvement of cleaning efficiency is achieved due to coordinated operation of all grain cleaning machine units, such as switchgear, a screen shoe, an air system, etc.

Currently, a wide variety of air-sieve grain cleaners is used in the world. Various screen shoes can be installed depending on the purpose of the grain cleaner. Screen shoes can differ in the number of installed sieves, number of tiers in a screen shoe, working surface area of a screen. The screens are installed with various types of holes: round, rectangular [1–5].

The purpose of this study is to improve grain cleaning using four-screen shoes of grain-cleaning separators.

The objects of the study were the patterns of change in the quality indicators of grain depending on the cleaning scheme of a screen shoe.

2 Materials and Methods

Winter wheat grain of Bezenchukskaya 38 variety was used for experimental studies, the harvesting of which was carried out by direct combining with ACROS 580 harvesters. Table 1 shows the parameters of the initial grain mass.

Table 1. Parameters of winter wheat grain.

Average grain diameter b_{av}, mm	Root-mean-square deviation σ, mm	Thousand-kernel weight, g
2.556	0.299	32.4

The study was carried out in the laboratory of the Department of Agricultural Machines, Tractors and Cars of Voronezh State Agrarian University using an experimental unit, which layout is shown in Figure 1.

The experimental unit operates as follows. The initial grain is filled into a tank 7, then through a dosing flap 16 it is supplied by gravity to a screen 8 installed on a screen shoe 15, which oscillates with constant amplitude. The screen shoe is driven by an electric motor 1 by V-belt transmission, a variator 2 and a crank mechanism 3. Screens are cleaned from clogging by rubber balls 9. The grain passing through the screen holes, which has dimensions smaller than those of the screen holes along a slide surface 12, enters the receiver for grain material passage 13. The grain coming from a screen 8 along the tray of a slide surface 11 is directed to the receiver for

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grain material output 14. With the help of an adjustment screw, the required capacity was set and the dosing flap 16 was opened. The screen shoes were replaced depending on the study of the accepted schemes. The screen shoe was installed in the laboratory unit in turn according to the layout of a screen (Figure 2) in the screen shoe: at the beginning of the screen of the upper tier, then the screen of the lower tier. The screenings from screens installed in the upper tier were supplied to the beginning of the subsequent screen. Passages according to the scheme – on the screen of the lower tier [6–8].

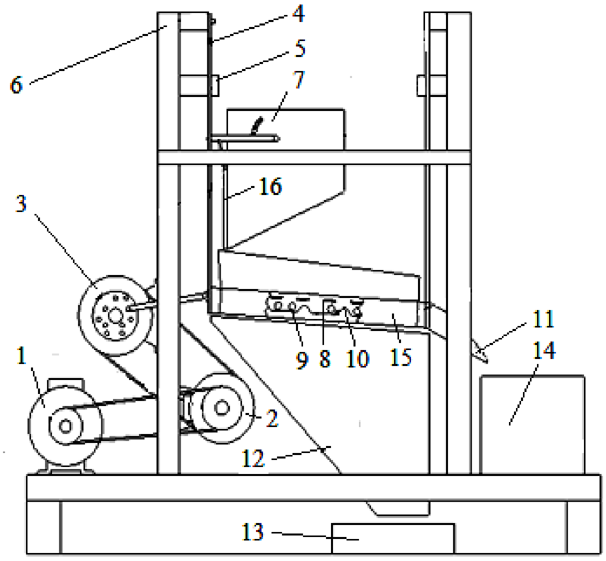

Fig. 1. Experimental unit layout: 1 – electric motor; 2 – variator; 3 – crank mechanism; 4 – screen shoe suspension; 5 – adjustment brackets; 6 – frame; 7 – tank; 8 – screen; 9 – rubber balls; 10 – reflective surface; 11 – slide surface for grain material output; 12 – slide surface for grain material passage; 13 – receiver for grain material passage; 14 – receiver for grain material output; 15 – screen shoe; 16 – dosing flap

The unit was adjusted for the following operation parameters: screen inclination angle to the horizon – 6°; oscillation amplitude of a screen shoe – 0.0075 m; speed of a drive shaft – 420 min^{-1}; screen length (8) – 0.79 m; screen width – 0.2 m.

The experiments were carried out at the following feeds to the screen shoe: 0.38, 1.05, 2.06, 3.94 and 5.07 kg/(s·m) and its corresponding productivity 2.0; 5,6; 11,0; 21,0; 27.0 t/h on the basis that its working width is 1.48 m.

Screen shoes with three layout schemes were studied during the experiments. The schemes are shown in Figure 2.

The first scheme represents a sequentially installed separation screen B_1 and a feeder screen B_2 in the upper tier, and two cleaning screens C in the lower tier, the dimensions of the holes of which are equal to B_1 = 3.0 mm; B_2 = 3.6 mm, C = 2.0 mm. This scheme makes it possible to extract only large and small impurities from grain, so it can only be used for preliminary or primary cleaning [9–13].

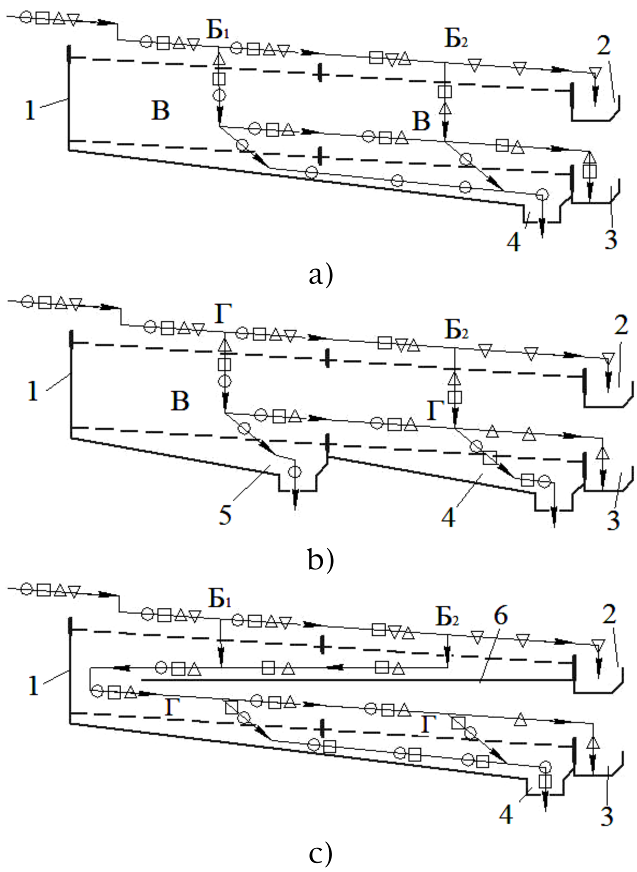

Fig. 2. Studied layout schemes of screen arrangement in a screen shoe: a) first scheme; b) second scheme; c) third scheme; B1 – separation screen; B2 – feeder screen; C – cleaning screen; D – sorting screen; □ – forage fraction; ○ – fine impurities; ▽ – coarse impurities; △ – main fraction; 1 – frame; 2 – tray for large impurities; 3 – tray for the main fraction; 4 – forage tray; 5 – tray for fine impurities; 6 – slide surface

In the second studied scheme of screen arrangement, a sorting screen D and a feeder screen B_2 are sequentially installed in the upper tier, and in the lower tier – the cleaning screen C and the sorting screen D are installed, the sizes of holes of which are equal to B_2 = 3.6 mm, D = 2.6 mm, C = 2.0 mm, respectively. This scheme allows the extraction of large and small impurities from the grain, as well as its separation into the main and forage fractions, so it is recommended to use it for primary and secondary cleaning [14–18].

In the third studied scheme of screen arrangement in the screen shoe there are separation B_1 and feeder B_2 screens sequentially installed in the upper tier, in the lower one – two sorting screens D. In this screen shoe there is a slide surface installed between the upper and lower tiers, which supplies passages from the separation B_1 and feeder B_2 screens to the beginning of the lower tier. The dimensions of the holes of the used screens are equal to B_1=3.0 mm; B_2=3.6 mm, D=2.6 mm. The third analyzed scheme allows extracting only large impurities from grain, and then to separate it into two fractions: main and forage, including small impurities. Most rationally this layout will be used in secondary cleaning.

During the experimental studies, the following indicators were determined, such as the qualitative composition of grain regulated by the rules according to GOST 30483-97, thousand-kernel weight according to GOST 10842-89 and the completeness of the fodder fraction ε according to expression 1.

$$\varepsilon = \frac{m_\phi}{m_\phi + m_{\phi+o\phi}} \tag{1}$$

where ε – completeness of fodder fraction; m_ϕ – weight of forage; $m_{\phi+o\phi}$ – weight of forage in the main fraction.

In order to determine the completeness of the fodder fraction ε, the main fraction obtained after cleaning was further sieved on the sorting screen, the passage was weighed, the obtained data were substituted into expression 1 [19].

3 Results and Discussion

The experimental studies made it possible to build the dependence graphs of the identified grain fractions on its supply to the beginning of the screen shoe (Fig. 3).

With increased productivity, the proportion of grain sent to the main fraction increases with the use of all the tested layout schemes in the screen shoe (Fig. 3, a). The largest amount of grain in the main fraction remains in the first studied scheme, the smallest – in the third scheme. The yield of the purified material varies from 96.80 to 98.84 and from 77.13 to 90.56%, respectively, in the second scheme – from 96.80 to 98.84% with an increase in supply at the beginning of the screen from 0.36 to 5.07 kg/(s·m). In the screen shoe with the layout of screens according to the first scheme, the sorting screens *D* were not installed, in connection with this, the grain of the forage fraction, with the exception of small impurities, remained in the main fraction. The minimum amount of grain sent to the main fraction during the operation of the screen shoe with the third scheme is explained by the installation of sequentially two sorting screens in the lower tier with the supply of grain material from the upper tier to their beginning, which ensured a greater completeness of the extraction of forage fractions [20].

The analysis of graphic dependencies in Fig. 3, b shows that the separation of the forage fraction during the study of the screen shoe with the first scheme did not occur due to its design features. In other cases, with an increase in productivity from 2 to 27 t/h, the yield of the forage fraction decreased in the second scheme – from 10.95 to 4.05%, in the third scheme – from 22.80 to 9.12%. The area of sorting screens is the same in the second and third schemes of the screen shoe. However, the specific load on the upper tier sorting screens in the second scheme is higher than in the third scheme and, as a result, a smaller amount of the separated forage fraction compared to the third scheme.

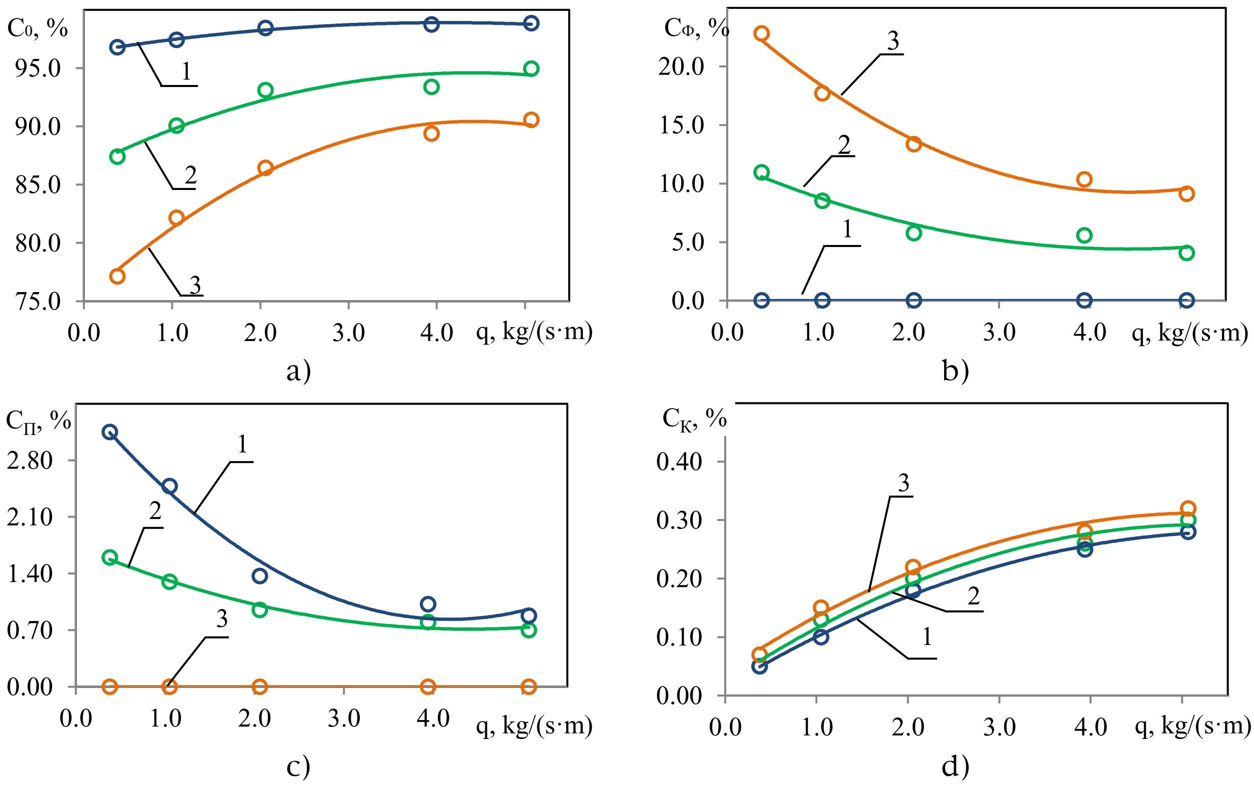

Fig. 3. Effect of grain supply on fraction output in a screen shoe: a) main fraction output (CO); b) forage fraction output ($C_Ф$); c) fine impurities output ($C_П$); d) descent from the feeder screen ($C_К$); 1 – first scheme; 2 – second scheme; 3 – third scheme.

The largest fodder release at all tested performance of the screen shoe was observed in the third scheme. This is due to the fact that two sorting screens are installed sequentially in this screen shoe in the lower tier. Fine impurities were isolated into a separate tray during the operation of screen shoes with the first and second scheme, in the third case they were collected together with the forage fraction. During the operation of the screen shoe according to the first scheme, the amount of isolated fine impurities is the largest and amounts to 3.15% with its capacity equal to 2 t/h, this is due to the fact that two cleaning screens are sequentially installed in the lower tier (Figure 3, c). With an increase in the specific supply of grain, the amount of the separated waste fraction decreases, this is due to the fact that the specific load on cleaning screens increases sharply, while part of fine impurities located on their surface did not have time to spill through the holes [21].

According to Figure 3, the output of large impurities with an increase in productivity increases during the study of all layout schemes, but in neither three cases the grain loss from screen shoes did not exceed the permissible values, i.e., more than 0.5%.

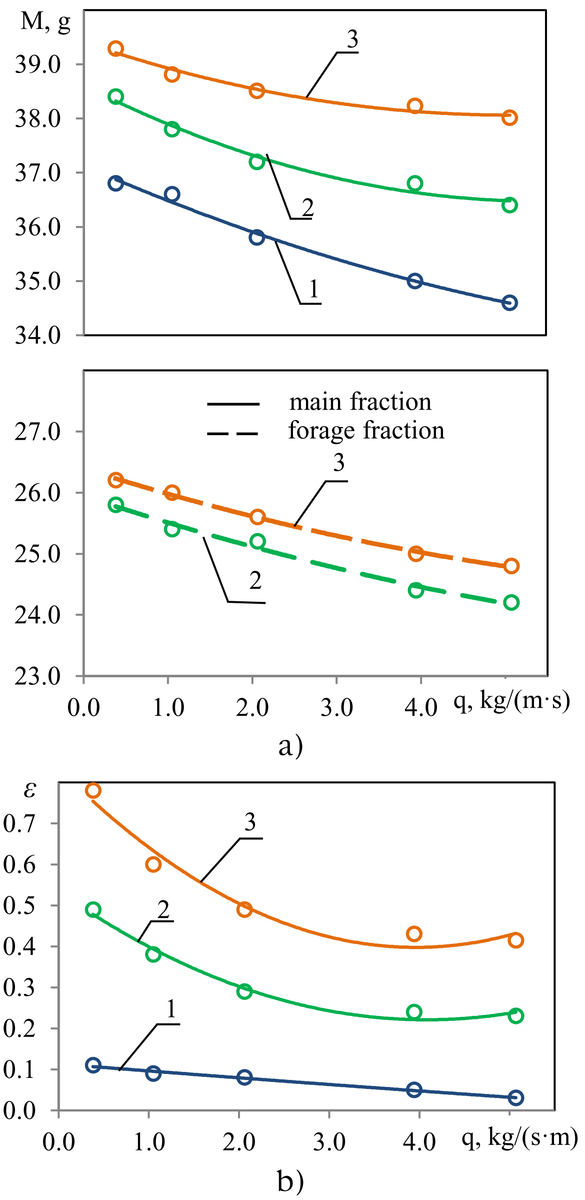

Fig. 4. Influence of grain supply on quality parameters of winter wheat grain: a) thousand-kernel weight of main and forage fractions (M); b) completeness of fodder fraction (ε); 1 – first scheme; 2 – second scheme; 3 – third scheme

Figure 4 shows the results of studies to determine the thousand-kernel weight in the main and forage fractions, as well as the completeness of the separation of the forage fraction depending on the capacity of the screen shoe. The thousand-kernel weight of the main fraction with increase of grain material supply up to 5.07 kg/(s·m) decreased in all cases, since in the first scheme this indicator decreased from 36.80 to 34.60 g, in the second scheme – from 38.40 to 36.40 g, in the third scheme – from 39.29 to 38.23 g, since more fodder fell into the main fraction and did not have time to pass through sorting and cleaning screens.

The thousand-kernel weight of the main fraction of winter wheat obtained during grain cleaning according to the third scheme is slightly higher than when using the first and second scheme and amounts to 39.29 g at a productivity of 2 t/h. The lowest thousand-kernel weight of the main fraction was observed during the operation of the first screen shoe and did not exceed 36.80 g. This is due to the fact that there is also forage in the purified material, which was not separated into a separate fraction. It is worth noting that the thousand-kernel weight of the main fraction is higher in all studied schemes of the screen shoe than in the forage screen. This indicates that the main fraction contains better quality winter wheat grains [22–23].

The smallest completeness of the separation of the waste fraction was observed in the screen shoe with the first layout and did not exceed 0.12, while the forage fraction represented small grains separated on cleaning screens installed in the lower tier. Therefore, it is reasonable to use this screen shoe to remove fine impurities from incoming harvester grain waste during prefractionation. The completeness of fodder fraction extraction in the screen shoe with the second layout will vary from 0.23 to 0.49, the maximum value of this indicator corresponds to lower and the minimum – to higher productivity. This screen shoe ill can be used in preliminary and primary cleaning according to the requirements. The most complete isolation of the forage fraction was observed during the third scheme (Fig. 4, b), this is due to the fact that this screen shoe has two sorting screens sequentially installed in the lower tier, and the supply was carried out at its beginning, which provided higher separation capacity. At the same time, the completeness of the forage fraction extraction changed from 0.78 to 0.42 with an increase in productivity from 2 to 27 t/h. In this regard, the use of a screen shoe with a third layout scheme can provide seed cleaning when supplied up to 0.38 kg/(s·m), commercial – when supplied from 0.38 to 1.05 kg/(s·m) and preliminary – when supplied from 1.05 kg/(s·m) to 3.94 kg/(s·m), which corresponds to the productivity of 2, 5, 6 and 11 t/h. Therefore, when increasing the productivity during wheat grain seed cleaning, it is necessary to increase the separation surface area of sorting screens [24].

4 Conclusion

With increased productivity, the proportion of grain sent to the main fraction increases with the use of all the studied schemes for placing screens in the screen shoe. With an increase in productivity from 2 to 27 t/h, the output of the forage fraction decreased in the second scheme from 10.95 to 4.05%, in the third scheme – from 22.80 to 9.12%. During the operation of the screen shoe according to the first layout, the amount of separated fine impurities is the largest and amounts to 3.15% with its productivity equal to 2 t/h. The output of large impurities with an increase in productivity increases during the study of all layout schemes, but in none of the three schemes the grain loss from screen shoes did not exceed the permissible values, i.e. more than 0.5%.

The thousand-kernel weight of the main fraction is higher in all studied schemes of the screen shoe than in the forage screem, which indicates the content of higher quality winter wheat grains in the main fraction. The thousand-kernel weight of the main fraction of winter wheat obtained during grain cleaning according to the third scheme is 39.29 g at a productivity of 2 t/h, which is slightly higher than when using the first and second schemes.

The most complete isolation of the forage fraction was observed during the third scheme of the screen shoe. The use of the screen shoe with a third layout scheme can provide seed cleaning when supplied up to 0.38 kg/(s·m), commercial – when supplied from 0.38 to 1.05 kg/(s·m) and preliminary – when supplied from 1.05 to 3.94 kg/(s·m).

The results of the study make it possible to conclude that in order to obtain better grain after cleaning, it is most promising to use the third layout scheme of a screen shoe with the installation of a slide surface between the upper and lower tiers.

References

1. A. Butovchenko, A. Dorochenko, I. Kotelnikova, Graph model development in the context of the grain cleaning machine, MATEC Web of Conf. **224**, 141807 (2018)
2. A. Butovchenko, A. Doroshenko, A. Kol'Cov, V. Serdyuk, Comparative analysis of the functioning of sieve modules for grain cleaning machines, E3S Web of Conf. Innov. Technol. in Environ. Sci. and Ed. **135**, 01081 (2019)
3. V.E. Saitov, V.G. Farafonov, A.V. Saitov, Experimental substantiation of the effective height of a grain falling by a stream of liquid in an ergot release device, IOP Conf. Ser.: Earth Environ. Sci. **341**, 012123 (2019)
4. V. Saitov, V. Farafonov, A. Saitov, Parameters of the seed output device of the ergot isolation machine, E3S Web of Conf. **244**, 03015 (2021)
5. S. Kharchenko, Y. Borshch, S. Kovalyshyn, M. Piven, M. Abduev, A. Miernik, E. Popardowski, P. Kiełbasa, Modeling of aerodynamic separation of preliminarily stratified grain mixture in vertical pneumatic separation duct, J. Appl. Sci. (Switzerland) **11(10)**, 4383 (2021)
6. I. Dudarev, V. Olkhovskyi, S. Panasyuk, S. Khomych, Study of small-size inertial louver-countercurrent dust collector, Lecture Notes in Mechan. Eng. 218–227 (2021)
7. A. Saitov, R. Kurbanov, V. Saitov, Taring the unloading of grain material from the loading hopper, Lecture Notes in Civil Eng. **130**, 382–390 (2021)
8. K. Astanakulov, Parameters and indicators of the longitudinal-transverse oscillation sieve, IOP Conf. Ser.: Mater. Sci. and Eng. **883(1)**, 012151 (2020)
9. R. Aipov, A. Linenko, I. Badretdinov, M. Tuktarov, S. Akchurin, Research of the work of the sieve mill of a grain-cleaning machine with a linear asynchronous drive, J. Mathem. Biosci. and Eng. **17(4)**, 4348–4363 (2020)
10. M.K. Kharitonov, A.M. Gievsky, V.I. Orobinsky, A.V. Chernyshov, I.V. Baskakov, Studying the design and operational parameters of the sieve module of the grain cleaning machine, IOP Conf. Ser.: Earth and Environ. Sci. **488(1)**, 012021 (2020)
11. V.I. Orobinsky, V.A. Gulevsky, A.V. Chernyshov, Improving the technology of post-harvest seed treatment, IOP Conf. Ser.: Earth and Environ. Sci. **723(3)**, 032018 (2021)
12. A.E. Balanovskiy, M.G. Shtaiger, V.V. Kondratyev, A.I. Karlina, Determination of rail steel structural elements via the method of atomic force microscopy, CIS Iron and Steel Rev. **23**, 86–91 (2022)
13. D. Podoprigora, R. Byazrov, J. Sytnik, The Comprehensive Overview of Large-Volume Surfactant Slugs Injection for Enhancing Oil Recovery: Status and the Outlook, Energies **15**, 8300 (2022), Retrieved from: https://doi.org/10.3390/en15218300
14. E.F. Denisov, M.Z. Yamilev, E.A. Tigulev, V.V. Pshenin, Analysis of the current level of technologies for determining the location of non-metallic underground services, Oil Industry, **2022(9)**, 121–125 (2022), DOI: 10.24887/0028-2448-2022-9-121-125
15. V.V. Kondrat'ev, V.O. Gorovoy, A.D. Kolosov, R.V. Kononenko, V.Y. Konyukhov, Description of the complex of technical means of an automated control system for the technological process of thermal vortex enrichment, J. of Phys.: Conf. Ser. **1661(1)**, 012101 (2020)
16. Yu.M. Strelkov, L.S. Sabitov, S.V. Klyuev, A.V. Klyuev, O.V. Radaykin, L.A. Tokareva, Technological features of the construction of a demountable foundation for tower structures, Construct. Mater. and Prod. **5(3)**, 17–26 (2022), Retrieved from: https://doi.org/10.58224/2618-7183-2022-5-3-17-26

17. E.N. Pashkov, N.V. Martyushev, A.V. Ponomarev, An investigation into autobalancing devices with multireservoir system, IOP Conf. Ser.: Mater. Sci. and Eng. **66(1)**, 012014 (2014), DOI: 10.1088/1757-899X/66/1/012014
18. N. Chernykh, A. Mikhalev, V. Dmitriev, V. Tynchenko, E. Shutkina, Comparative Analysis of Existing Measures to Reduce Road Accidents in Western Europe, *INFOTEH-JAHORINA, INFOTEH 2023*, 22nd Int. Symp. (2023), DOI: 10.1109/INFOTEH57020.2023.10094192
19. V.L. Tatarintsev, L.M. Tatarintsev, S.K. Makenova, M.M. Shostak, Geoecological assessment of landscapes as the basis for organizing sustainable agricultural land use, Sustainable developm. of mountain territ. **13(4)**, 485–497 (2021), DOI: 10.21177/1998-4502-2021-13-4-485-496
20. Y.V. Daus, I.V. Yudaev, Estimation of solar energy potential under conditions of urban development, In: *Actual Issues of Mechanical Engineering (AIME 2017)*, *Advances in Engineering Research* (Atlantis Press, 2017), Vol. 133, pp. 156–161, DOI: org/10.2991/AIME-17.2017.26/
21. Shutaleva, N. Martyushev, Z. Nikonova, I. Savchenko, S. Abramova, V. Lubimova, A. Novgorodtseva, Environmental Behavior of Youth and Sustainable Development, Sustain. **14**, 250 (2022), DOI: 10.3390/su14010250
22. K. Yelemessov, L.B. Sabirova, N.V. Martyushev, B.V. Malozyomov, G.B. Bakhmagambetova, O.V. Atanova, Modeling and Model Verification of the Stress-Strain State of Reinforced Polymer Concrete, Mater. **16**, 3494 (2023), DOI: 10.3390/ma16093494
23. L.S. Malyukova, N.V. Martyushev, V.V. Tynchenko, V.V. Kondratiev, V.V. Bukhtoyarov, V.Y. Konyukhov, K.A. Bashmur, T.A. Panfilova, V. Brigida, Circular Mining Wastes Management for Sustainable Production of Camellia sinensis (L.) O. Kuntze, Sustain. **15**, 11671 (2023), DOI: 10.3390/su151511671
24. D.V. Kuznetsov, S.V. Klyuev, A.N. Ryazanov, D.A. Sinitsin, A.N. Pudovkin, E.V. Kobeleva, I.V. Nedoseko, Dry mixes on gypsum and mixed bases in the construction of low-rise residential buildings using 3D printing technology, Construct. Mater. and Prod. **6(6)**, 5 (2023), DOI: 10.58224/2618-7183-2023-6-6-5