ISSN 2664-9969

UDC 622.242.6; 666.97/.98
DOI: 10.15587/2706-5448.2023.286362

Tetiana Surzhko,
Maksym Knysh,
Yurij Kuzub,
Oleksandr Kruchkov,
Viacheslav Rubel

STUDY OF THE OPERATING PARAMETERS OF VIBRATIONS OF A VIBROSIEVE OF THE WASHING LIQUID PURIFICATION UNIT

The object of the research is elastic plates located across the movement of the solution on the vibrosieve. The problem of uniform distribution of material on the surface of the sieve is considered, which is solved with the help of the design proposed in the work.

Tensometry was used as a research method with subsequent processing of the results on an elector computer. In the course of the research, an analog-to-digital converter developed and manufactured at the Department of Mechanization of Construction Processes of the National University «Yuri Kondratyuk Poltava Polytechnic» (Ukraine) was used. As well as a computer with a free COM-1 port, «PROGRAM.EXE» software and a spreadsheet editor, strain gauges in the form of strain gauges with two pasted tensor resistors connected by a half-bridge circuit.

The paper proposes a fundamentally new scheme of a vibrosieve with additional working bodies in the form of elastic plates located across the movement of the solution on the sieve. The elasticity and mass of the plates are selected in such a way that their oscillations during the operation of the vibrosieve exciter are close to resonance. At the same time, the mode of vibration of the vibrosieve itself is far beyond resonance. As a result, a higher-quality and energy-efficient cleaning of the washing liquid will be obtained. This is due to the fact that the proposed cleaning method has a number of features, in particular, dispersion of drilling fluid over the entire surface of the vibrosieve and maximum loading of the entire working surface of the sieve to avoid dead zones. Thanks to this, it is possible to obtain resonant oscillations. In comparison with known analogs that work in a resonant mode, this provides advantages in the cleaning of drilling mud. The amplitude of oscillations of elastic plates reaches 1.2–1.5 mm, which is significantly greater than the amplitude of oscillations of a vibrating table.

In practice, it will be possible to use the proposed fundamentally new scheme of a vibrosieve with additional working bodies in the form of elastic plates that work in a resonant mode, as a way of supplementing vibrosieves that are in use or new when manufactured at manufacturers' factories.

Keywords: *vibrosieve, natural oscillation frequency, drilling fluid, drilled rock, working body, mechanical oscillations.*

Received date: 11.06.2023
Accepted date: 23.08.2023
Published date: 26.08.2023

© The Author(s) 2023
This is an open access article
under the Creative Commons CC BY license

How to cite
Surzhko, T., Knysh, M., Kuzub, Y., Kruchkov, O., Rubel, V. (2023). Study of the operating parameters of vibrations of a vibrosieve of the washing liquid purification unit. Technology Audit and Production Reserves, 4 (1 (72)), 34–39. doi: http://doi.org/10.15587/2706-5448.2023.286362

1. Introduction

The vibrosieve is the first stage of cleaning and removes sludge with a size of 100 microns and above. In fact, it separates 10–20 % of coarsely dispersed drilled rock. The cleaning and throughput capacity of vibrosieves is determined by the area of the sieve surface, the size of the cell of the sieve cassette and vibration acceleration. The problem that exists for manufacturers of vibrosieves is the uneven distribution of the drilling fluid on the surface of the screen. As a result of sieving, there are dead zones on which the solution does not fall, and the working surface of the sieve must be replaced after the end of its service life, although the dead zones do not wear out when replaced. This is the main reason why many manufacturers are looking for ways to use dead zones in their work, for more effective use of the screen's working surface, with minimal and reasonable costs. Let's consider this topic on the example of Ukrainian objects, namely manufacturers of domestic vibrosieves [1], studying the experience of scientists from other countries. Thus, in [2, 3], researchers, solving this problem, introduce various changes in the construction of vibrosieves, such as angles of inclination of the grid, different shapes of the grid itself. These factors for vibrosieves of different countries are practically identical, that is, their technological characteristics are close. For example, the LVS-1 vibrosieve (Fig. 1) (vibration acceleration – 5.5 g, screen surface area – 2.7 m^2) in terms of its technical and technological indicators corresponds to the Svako company's vibrosieve (vibration acceleration – 5.5 g, screen area surface – 2.6 m^2) [2, 4]. It is equipped with three-layer cassettes with a service life of 400 hours and above, and their stability depends only on proper operation.

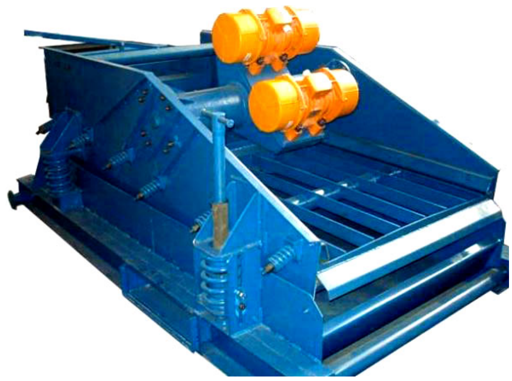

Fig. 1. Vibrosieve LVS-1M

Constructive, technological, operational measures are devoted to the purpose of increasing the efficiency of dispersion. In particular, the correct choice of the direction of movement of the vibrosieve can significantly affect the efficiency and energy consumption of scattering.

Under the action of the disturbing force of oscillations, depending on the design of the vibrator, the movement of drilling mud and particles of drilled rock on the surface of the grids can be linear, elliptical, circular or combined [2, 4, 5]. Similar studies also took place in works [3, 5, 6], but they did not take into account the specifics of the work of the vibrosieve and its parts.

Among other constructive measures that can be used to intensify sieving, a promising method was considered – the involvement of elastic plates 6 installed above the sieve 5 in advancing the material (Fig. 2). According to our assumption, these plates will oscillate with rather large amplitude and will distribute the material on the screen surface.

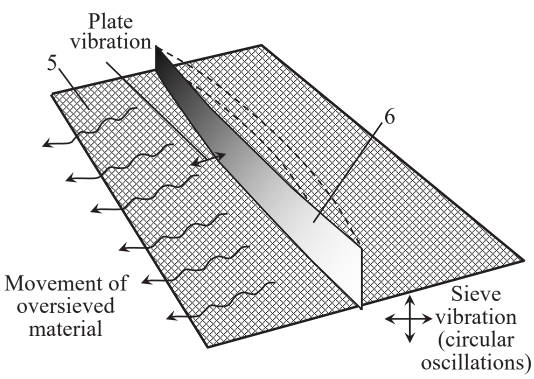

Fig. 2. Illustration of the vibrational movement of the elastic plate over the sieve – the active working body

The aim of research is to select the characteristics of elastic plates installed above the vibrosieve and experimental study of their oscillations, and to find out the possibility of realizing resonant oscillations.

2. Materials and Methods

The object of research is the promising method of activating the screening of drilling mud proposed in the work – the involvement of elastic plates installed above the screen in the advancement of the material.

For experimental research, an installation based on a vibrating field was created. At the department of industrial mechanical engineering and mechatronics of the National University «Yuri Kondratyuk Poltava Polytechnic» (Ukraine), a vibration platform with mechanical excitation from a mounted vibrator (vibrator exciter) is being studied (Fig. 3). A vibrating exciter with an asynchronous motor from the manufacturer «Honker» (position 4), model ZW-2.5 (single-phase motor; power 250 W; excitation force 2 kN; rotation frequency 2840 rpm) is used. Therefore, the frequency of forcing oscillations is 2840/60=47.3 cycles/s.

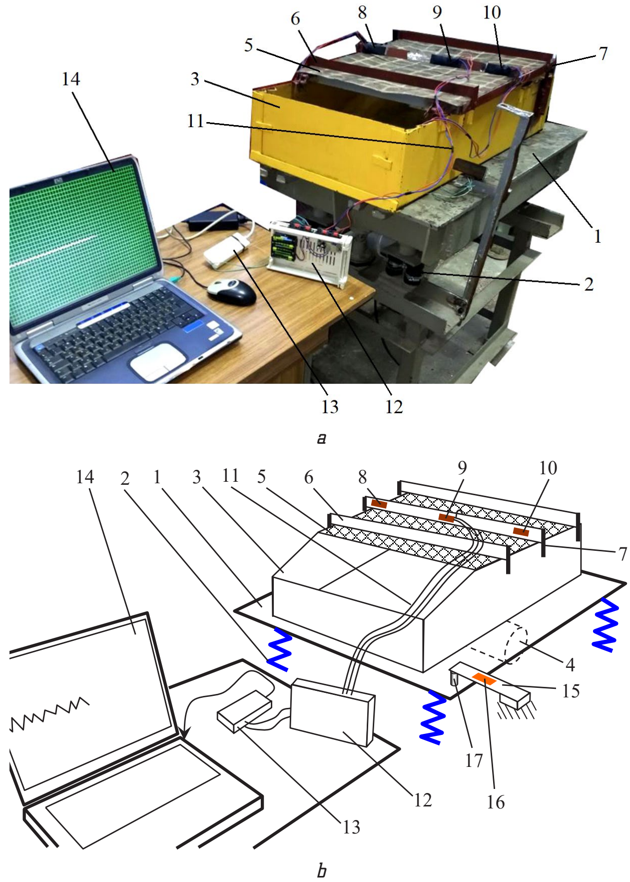

Fig. 3. Experimental setup for studying the vibrosieve: *a* – photo of the laboratory installation; *b* – scheme of the laboratory installation

The experimental setup with a vibrating platform (Fig. 3) is a table 1 mounted on eight elastic rubber elements 2 on a frame mounted on the concrete floor of the laboratory [7]. A vibration exciter 4 is attached to the bottom of the table 1. A box 3 is rigidly fixed on the table 1, on which a rigid sieve 5 is installed. Three identical steel plates 6 are fixed on the box 3. The fixing of the plates 6 on the box is not rigid. The longitudinal stiffness and mass of the plates are selected in such a way that their oscillations during the operation of the vibration exciter 4 occur in a near-resonance mode. Plates 6 are fixed on brackets 7. Tensor resistors 8, 9 and 10 are fixed on both sides of the middle plate; each pair is connected by a half-bridge circuit and wires 11 are connected to the strain amplifier 12. The signal from the strain amplifier 12 is transmitted to the analog-to-digital converter 13, and after it to the computer 14. The research methodology is described in detail in [8, 9].

To record the vibration parameters of the vibrating table 1 itself, a tension beam 15 is used, made of a steel locksmith's ruler, strain gauges 16 glued to the tension beam, and a pin 17 (in the form of a bolt screwed into the table 1) (Fig. 3 and Fig. 4).

Steel plate 18 (Fig. 4), plate loading system (load 19 and block 20) and caliper 21 were used to determine the stiffness of the plate, as well as for calibrating strain gauges 8, 9, and 10.

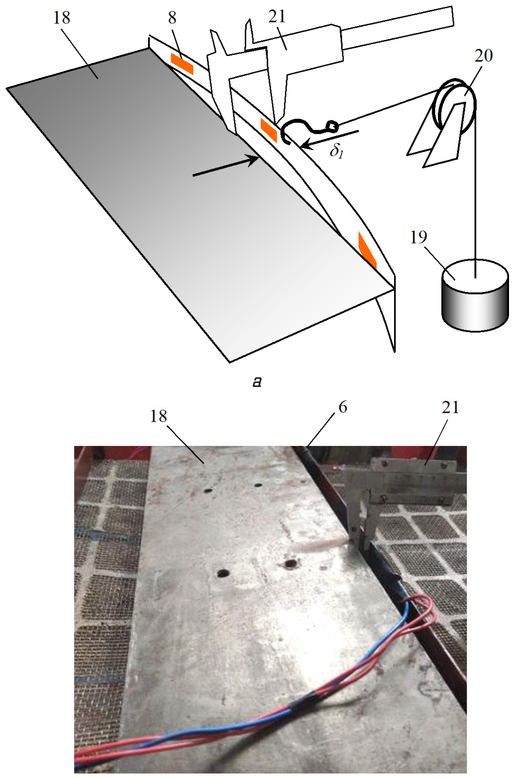

Fig. 4. Calibration of the system and determination of the plate stiffness: *a* – scheme of the laboratory installation; *b* – photo of the laboratory installation

The calibration of strain gauge 15 (with strain gauge 16) was carried out using a 2-mm-thick probe (a match was used) according to the diagram in Fig. 5.

Diagrams of strain gauges 16, 8, 9, 10 are shown in Fig. 6–9. In all cases, the deviation of the corresponding part of the tensor beam was 2 mm. The calibration made it possible to determine the transfer coefficients, thanks to which the diagrams recorded on the computer (electrical voltage, V) were reconstructed into diagrams of fluctuations of linear displacement (mm).

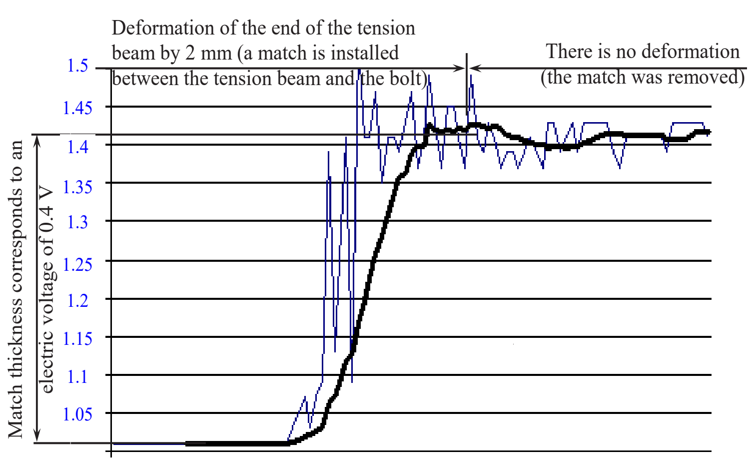

Fig. 5. Diagrams of strain gauge calibration 16 (Fig. 3)

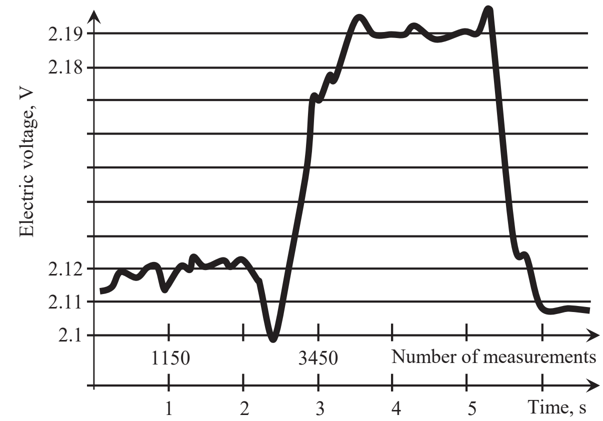

Fig. 6. Results of calibration of strain gauge 8 (Fig. 3) – the deformation of plate 6 in the area of strain gauge 8 is 2 mm

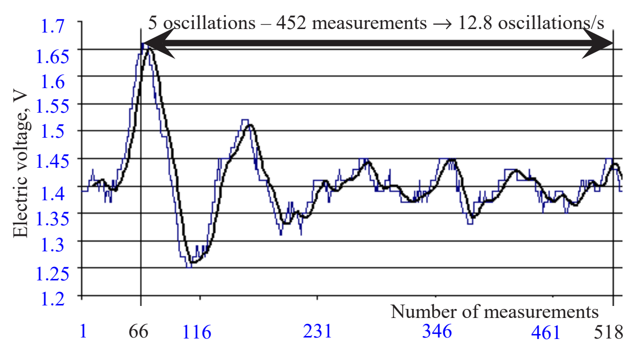

Fig. 7. Diagram of natural oscillations of the vibrating table (strain resistor 16 in Fig. 3)

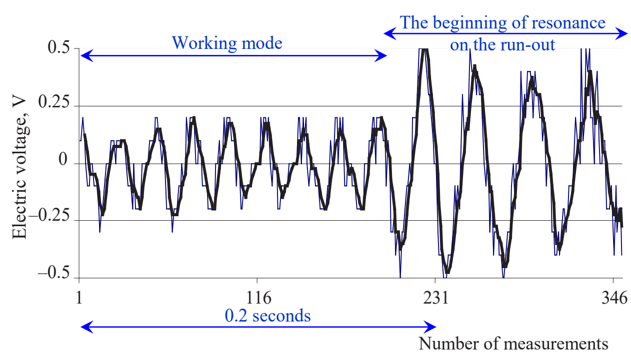

Fig. 8. Vibration table vibration diagram

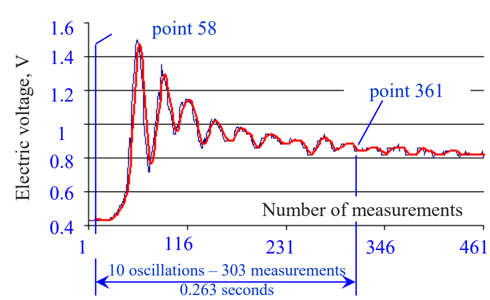

Fig. 9. Diagram of natural oscillations of the plate (tensor resistor 9 in Fig. 3)

A similar method of vibration research and methodology was applied earlier in the study of a drum-roll processor [10–12].

Tensor resistor 16, beam deflection 0.4 V. 2 mm/0.4 V = 5 mm/V – conversion coefficient.

Tensor resistor 8, beam deviation 2.19–2.12= =0.07 V. 2 mm/0.07 V = 28.57 mm/V – conversion coefficient. Tensor resistor 9, beam deviation 1.73–1.58= =0.15 V. 2 mm/0.15 V = 13.33 mm/V – conversion coefficient. Tensor resistor 10, beam deflection 2.765–2.65 = 0.115 V. 2 mm/0.115 V = 17.39 mm/V – conversion coefficient.

Time calibration was carried out by recording diagrams for a fixed period of time (for example, for 10 s). It was determined that the system processes (records) 1150 measurements in 1 second.

In addition to the operating modes of oscillations at the installation points of tensor resistors 16, 8, 9 and 10, diagrams of the system's natural oscillations at the installation points of tensor resistors 16 and 9 were also recorded. This made it possible to determine the proximity of the actual operating oscillation modes to the resonant frequency.

The self-oscillations of the vibrating table were recorded after a sharp force was applied to the surface of the vibrating table (hitting the surface of the table with a wooden board). The result is shown in Fig. 7. The natural oscillations of the plate with tensor resistor 9 were recorded after the plate was elastically deformed and then abruptly released (the plate was pulled with the fingers). The result is shown in Fig. 9.

3. Results and Discussion

The frequency of natural oscillations of the vibrating table, judging from the diagram in Fig. 7, was 12.8 oscillations/s. Taking into account that the frequency of forced oscillations (from the vibration exciter) is 47.3 cycles/s, it can be concluded that the vibration platform works far beyond the resonance mode: 47.3/12.8=3.7.

The post-resonance mode can be considered a certain standard for most vibration fields [11, 13, 14]. It ensures the stability of the process (even a significant change in mass will not lead to a noticeable change in amplitude) and a large excitation power of oscillations. In Fig. 8 – diagram of vibrations of the vibrating table in the working mode and at the beginning of run-out at a stop (amplitude of oscillations in the working mode up to 0.23 mm).

The natural frequency of oscillations of the active working body (plate 6; strain gauge 9) is 10/0.263 = 38 oscillations/s This is the frequency of resonant oscillations of the plate. The diagram in Fig. 10 – working mode; the frequency of oscillations is equal to the frequency of forcing oscillations (approximately 47 cycles/s). The amplitude of oscillations reaches 1.2–1.5 mm, which is significantly greater than the amplitude of oscillations of the vibrating table (0.23 mm; Fig. 8). This allows to expect that the plates will be able to provide a certain influence on the material, intensifying its sieving and movement along the sieve.

Thus, in the operating mode of the vibrating platform (with a frequency of 47.3 cycles/s), the plates 6 (Fig. 3), installed above the sieve, oscillate with the same frequency, and this frequency is very close to the frequency of the system's own oscillations – 38 cycles/ with. The difference is only 47.3/38=1.2 – these are close to resonant oscillations. The recorded oscillations of the resonant mode (Fig. 11) in frequency perfectly coincide with the frequency of the natural oscillations of the plates (Fig. 9).

Recorded oscillations of the tensor plate 10 in the operating mode are shown in Fig. 12.

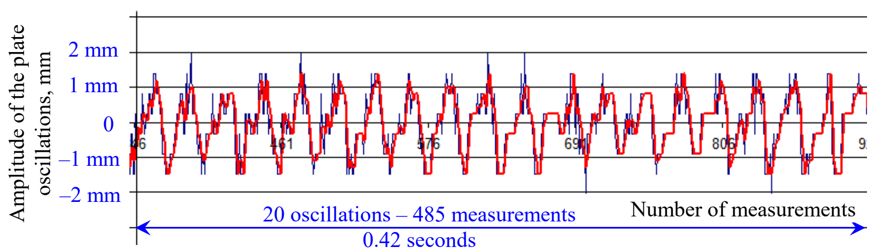

Fig. 10. Plate oscillation diagram (tensor resistor 8); working mode

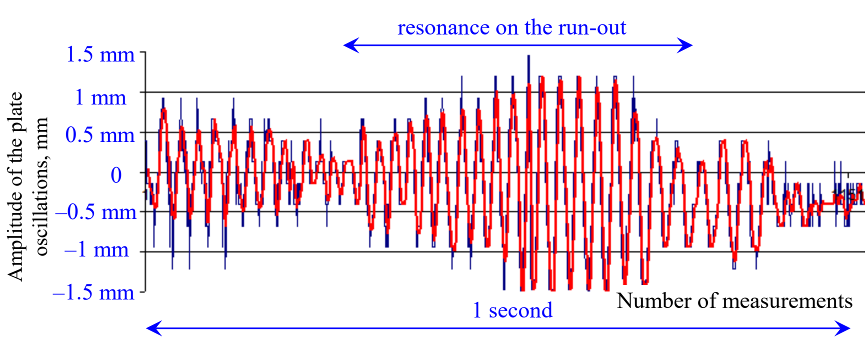

Fig. 11. Diagram of the plate oscillations (tensor resistor 9) near resonance

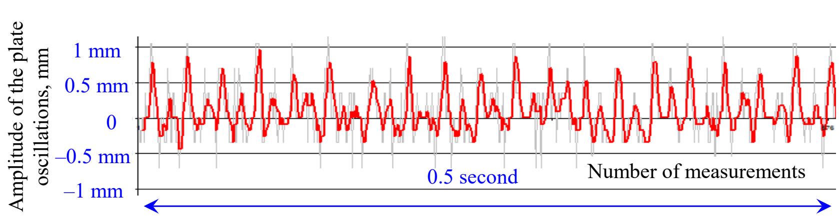

Fig. 12. Diagram of oscillations of the plate (tensor resistor 10) in working mode

Obviously, a more accurate selection of the mass of the plates 6 and their elasticity values $\left(\omega_0 = \sqrt{c/M},\ \text{rad/s}\right)$ will allow obtaining perfectly resonant oscillations of the plates. The near-resonance (or resonance) mode of vibration of the plates will have a positive effect on the cleaning of the drilling fluid and will allow reducing the energy consumption of the vibrosieve and increasing the speed of cleaning [15].

Practical meaning: In practice, the use of this design, the use of an active working body (plate), makes it possible to clean the drilling fluid better with lower energy costs.

Limitations of the study: In these experimental studies, the resistance of the environment in which the active working body (plate) will work was not taken into account.

The influence of martial law conditions: The conditions of the martial law in Ukraine affected the conduct of the research; they force us to look for ways of more rational use of energy carriers such as, for example, electricity.

Prospects for further research: In further research, it is recommended to take into account the resistance of the environment in which the active working body (plate) will work and to carry out the necessary calculations.

4. Conclusions

An experimental setup was developed and created to investigate the possibility of installing elastic plates as an active working body above the vibrosieve. The parameters of the forced oscillations of the vibrosieve and the elastic plates installed above it were determined experimentally. The forcing frequency of the vibrating table is 47.3 cycles/s, the amplitude of its oscillations is 0.23 mm. The amplitude of oscillations of elastic plates reaches 1.2–1.5 mm, which is significantly greater than the amplitude of oscillations of a vibrating table. This allows expecting that the plates will be able to provide a certain influence on the material, intensifying its sieving and movement along the sieve.

The frequencies of natural oscillations of the vibrating table and the elastic plates installed above the sieve were determined, they coincide with the frequencies of resonant oscillations of the corresponding elements of the vibrating system. The frequency of self-oscillations of the vibrating table was 12.8 cycles/s; elastic plates – 38 osc/s. Therefore, the frequency of forced oscillations of elastic plates (47.3 cycles/s) almost coincides with the frequency of their own oscillations (38 cycles/s). The difference is only 47.3/38=1.2 times; these are very near-resonance oscillations. This explains the significantly larger amplitude of plate oscillations compared to the amplitude of oscillations of the vibrating table itself (1.2–1.5 mm vs. 0.23 mm), and allows to expect a certain effectiveness of the influence of the plates on the movement of the material.

Therefore, without the use of an additional mechanism and an additional separate drive, but only by selecting the characteristics (stiffness and mass) of the elastic layers, their movement was ensured with amplitude significantly greater than the amplitude of oscillations of the vibrating table itself, which was the purpose of the research. This effect of the plates on the material can significantly improve the efficiency and reduce the energy intensity of scattering. Such a technical result allows expecting an improvement in the technical and economic indicators of the equipment, which opens up prospects for further research.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The research was performed without financial support.

Data availability

The manuscript has no associated data.

References

1. *Sito vibratcionnoe LVS-1M, LVS-2M, LVS-3M*. Available at: http://fluitech.com.ua/assets/files/odbu/lvs.pdf
2. Chen, Y., Tong, X. (2010). Modeling screening efficiency with vibrational parameters based on DEM 3D simulation. *Mining Science and Technology (China), 20 (4),* 615–620. doi: https://doi.org/10.1016/s1674-5264(09)60254-4
3. Dong, K., Esfandiary, A. H., Yu, A. B. (2017). Discrete particle simulation of particle flow and separation on a vibrating screen: Effect of aperture shape. *Powder Technology, 314,* 195–202. doi: https://doi.org/10.1016/j.powtec.2016.11.004
4. Raja, V., Chase, G. G., Jones, B. N., Geehan, T., Swaco, M. (2012). *Computational modeling and experiments on shale shaker performance*. AADE-12-FTCE-58.
5. Nesterenko, M., Nazarenko, I., Molchanov, P. (2018). Cassette Installation with Active Working Body in the Separating Partition. *International Journal of Engineering&Technology, 7 (3.2),* 265–268. doi: https://doi.org/10.14419/ijet.v7i3.2.14417
6. Lyakh, M. M., Savyk, V. M., Molchanov, P. O. (2016). Improving the efficiency of foamgenerating devices of pump-circulative systems of drilling sets. *Rozrobka rodovyshch korysnykh kopalyn. Naukovyi visnyk NHU, 3,* 23–30.
7. Liakh, M. M., Fedoliak, N. V., Reiti, O. O. (2016). Vyznachennia zhorstkosti vibroopor burovykh vibrosyt. *Aktualni zadachi suchasnykh tekhnolohii*. Ternopil: TNTU, 46–47.
8. Krot, O. Yu., Korobko, B. O., Krot, O. P., Virchenko, V. V. (2023). *Eksperymentalni metody doslidzhen*. Poltava: NUPP, 192.
9. Krot, A., Ruchka, A., Savchenko, A., Krot, O., Supryaga, D. (2018). Analytical Modeling of Oscillations of Movable Operating Elements of a Roll-Drum Activator. *International Journal of Engineering & Technology, 7 (4.3),* 58–63. doi: https://doi.org/10.14419/ijet.v7i4.3.19552
10. Nascentes, C. L., Murata, V. V., Oliveira-Lopes, L. C. (2022). Mathematical modeling of solids-drilling fluid separation in shale shakers in oil fields: A state of art review. *Journal of Petroleum Science and Engineering, 208*, 109270. doi: https://doi.org/10.1016/j.petrol.2021.109270
11. Sivko, V. Ya., Scubok, E. O. (1998). Motion of a dynamic system taking into account the internal resistance of the medium. Vibrotechnology – 98. Treatment of dispersed materials and media. *Theory, research. Technology and equipment*. Kyiv: NGO VOTUM, 16–21.
12. Banakh, L., Kempner, M. (2010). *Vibrations of Mechanical Systems with Regular Structure*. Berlin, Heidelberg: Springer. doi: https://doi.org/10.1007/978-3-642-03126-7
13. Nesterenko, M. P., Molchanov, P. O., Savyk, V. M., Nesterenko, M. M. (2019). Vibration platform for forming large-sized reinforced concrete products. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 5,* 74–78. doi: https://doi.org/10.29202/nvngu/2019-5/8
14. Surzhko, T. O., Savyk, V. M., Molchanov, P. O., Kaliuzhnyi, A. P. (2020). Pidvyshchennia efektyvnosti roboty obladnannia bloku ochyshchennia promyvalnoi ridyny. *Zb. nauk. prats Natsionalnoho universytetu «Poltavska politekhnika imeni Yuriia Kondratiuka» (haluzeve mashynobuduvannia, budivnytstvo), 2 (55),* 121–127.

15. Surzhko, T. O., Molchanov, P. O., Savyk, V. M., Aheicheva, O. O. (2020). Statychnyi rozrakhunok robochykh poverkhon obladnannia dlia ochystky burovoho rozchynu za metodom skinchennykh elementiv. *XIII Mizhnarodnoi naukovo-praktychnoi konferentsii «Akademichna y universytetska nauka – rezultaty ta perspektyvy»*. Poltava.

✉ ***Tetiana Surzhko,*** *Postgraduate Student, Department of Oil and Gas Engineering and Technologies, National University «Yuri Kondratyuk Poltava Polytechnic», Poltava, Ukraine, ORCID: https://orcid.org/0000-0001-8095-3984, e-mail: tanja_woman@ukr.net*

Maksym Knysh, *Postgraduate Student, Department of Oil and Gas Engineering and Technologies, National University «Yuri Kondratyuk Poltava Polytechnic», Poltava, Ukraine, ORCID: https://orcid.org/0000-0002-3516-4852*

Yurij Kuzub, *Postgraduate Student, Department of Mechanical Engineering and Mechatronics, National University «Yuri Kondratyuk Poltava Polytechnic», Poltava, Ukraine, ORCID: https://orcid.org/0009-0006-8463-3914*

Oleksandr Kruchkov, *Postgraduate Student, Department of Mechanical Engineering and Mechatronics, National University «Yuri Kondratyuk Poltava Polytechnic», Poltava, Ukraine, ORCID: https://orcid.org/0009-0009-7707-2874*

Vyacheslav Rubel, *Postgraduate Student, Department of Oil and Gas Engineering and Technologies, National University «Yuri Kondratyuk Poltava Polytechnic», Poltava, Ukraine, ORCID: https://orcid.org/0000-0002-5418-5595*

✉ *Corresponding author*