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1 ASSESSMENT OF THE CURRENT STATE OF PARAMETERS AND OPERATING MODES OF TECHNOLOGICAL TECHNICAL SYSTEMS

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ABSTRACT

The classification features of technological technical systems, the further development of the theory of the working process are given. The classification features are determined. Only the classification features that determine their purpose and the nature of the work they perform are considered. An assessment of the design and technological parameters of the existing technical systems of industrial engineering has been carried out. New and improved evaluation criteria have been used. Reliable assessment and analysis made it possible to formulate more reasonably methods for solving the problem. Continuously improving, the technology leaves a reflection on the directions of development of technical system designs. On the basis of this, working hypotheses were formulated, the essence of which lies in modeling the medium and technical system as a single system with their own dynamic individuality. The system «technical system – medium» is represented by a complex hybrid (mixed) dynamic system, in which the technical system is a system with discrete parameters, and the medium is with distributed parameters, and this system is reduced to the calculated one in the form of a system with discrete parameters.

KEYWORDS

Technical system, medium, classification, criteria, assessment, analysis, modeling, discrete, distributed parameters, hypotheses.

1.1 DETERMINATION OF THE CLASSIFICATION CHARACTERISTICS OF TECHNICAL SYSTEMS AND PROCESSING MEDIUMS IN THESE STUDIES

Technical systems can be processes and objects, depending on the nature of the connections between the elements of the system. The main goal of the development of technical systems is to eliminate the contradiction between the growing needs of society and the capabilities of today's technical systems. Any technical system is primarily a physical object. And the correct choice of fundamental, that is, physical, foundations of functioning will lead to its viability and efficiency. The dialectic of the development of technical systems lies in the fact that new and well-known technical solutions are effectively combined in a newly created or improved system.

The technical systems of industrial engineering include machines (equipment), which include a number of elements, devices designed to perform certain technological operations and functions (**Fig. 1.1**).

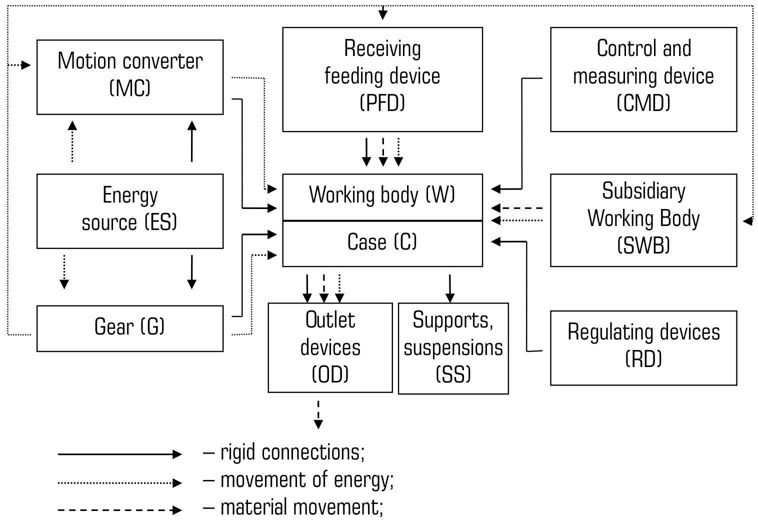


Fig. 1.1 Structural diagram of the machine

For the development of general principles for the creation of machines, for the further development of the theory of their working process, the classification features of these machines have been determined. The classification signs take into account the fundamental and design features of the structure of vibration machines, their purpose and the nature of the work they perform.

In this work, the most significant two classifications of machines are used: constructive-technological and structural. Structural and technological classification implies the determination of the use of a machine for performing a particular work process (crushing, sorting, compaction, etc.) with a note of the design features of their working bodies.

Structural classification characterizes the general fundamental features of the structure of machines of dynamic action and the nature of the interaction of their working bodies with the processed medium. This classification creates the necessary prerequisites for the development of a unified theory of machines, guides and facilitates their further development.

The parameters of work (the magnitude of the amplitude and the type of trajectory of oscillations of the working body) of dynamic machines are determined by the nature of the working forces, the frequency of oscillations, a feature of elastic links and the ratio of the masses of individual parts of the system. Therefore, the structural classification in the monograph is determined by the signs of the degree of freedom of the dynamic scheme of the machine, the nature of its drive, the characteristics of elastic links.

The type of work performed by machines and the peculiarities of the interaction of their working bodies with the processed medium determine, on the one hand, the fundamental structure of the machine, and on the other hand, put them in an equivalent relationship in assessing the working conditions. In this regard, one of the main classification features of a machine is the nature of the work it performs (features of the interaction of its working body with the medium being processed and the type of overcoming different types of resistance).

All machines are divided into several groups that are fundamentally similar in structure and nature of interaction with the processed medium.

The following operations, which are homogeneous with respect to the nature of external resistance to the working bodies, can be noted: the transfer of energy to different media during their processing.

In the classical theory of oscillations, all dynamical systems are usually divided into systems with one, two, three, *n* and an infinite number of degrees of freedom (systems with distributed parameters). Such a distribution of dynamical systems presents certain conveniences with regard to their theoretical study. Dynamical systems with an equal number of degrees of freedom are described by the same number of differential equations solved by similar methods.

By the type of drive, which is the third classification feature, the monograph examines vibration machines with a power drive. Currently, machines with a kinematic drive have little application and are not used in research.

The fourth classification feature is based on the characteristics of elastic links, which determine the nature of the restoring forces and internal resistances of the vibration machine. According to the characteristics of elastic connections, all investigated vibration machines are divided into machines with linear and nonlinear characteristics of stiffness [1].

A feature of these studies is taking into account the conditions of interaction with the processing medium [2], as a result of which there is a need to determine the classification features of such mediums. Such information is necessary for the justified direction of the formation of the algorithm and methods of technical systems of dynamic action. In such conditions, the key features of the classification are the state of the medium, the nature of the qualitative behavior of the medium, rheological properties and dynamic parameters. Depending on the ratio of the yield point τ at pure shear to atmospheric pressure p_a, the process medium in its state can be [3]:

– hard plastic $\tau/P_a \geq 1$;
– liquid-plastic $\tau/P_a = 1$; (1.1)
– liquid at: $\tau/P_a \leq 1$.

By the nature of the qualitative behavior under dynamic load in the medium (1.1), wave phenomena may appear or these phenomena are absent. Accounting for wave phenomena in the working medium can be estimated from the ratio of the wave propagation time $t_{\min}$ and the oscillation period T [4] under the following conditions:

$$\left.\begin{aligned} \tau < T \\ \tau > T \end{aligned}\right\}. \tag{1.2}$$

Under the first condition (1.2), the process of oscillation of the medium can be considered slow and the elastic wave can be neglected. In this case, accelerations and deformations are determined exclusively by forces that are constant and unchanged in the direction of the action of external forces on such a medium.

When the second condition (1.2) is satisfied, the motion of the medium is determined not only by forces, but also by elastic waves. Movement, speed and acceleration along the majestic change and depend not only on time, but also on the coordinate in the direction of which external forces act on such a medium.

So, in the first case, inertial forces dominate, and in the second, elastic ones. In most cases, real mediums to be investigated fall between these conditions (1.2). That is, as a rule, it is necessary to take into account the elastic, inertial and dissipative properties, which is accepted in this work.

1.2 ASSESSMENT OF DESIGN AND TECHNOLOGICAL PARAMETERS OF EXISTING TECHNICAL SYSTEMS OF INDUSTRIAL ENGINEERING

The design and technological parameters are assessed using functional criteria according to the appropriate method [5]. The methodology is based on the principles of parameter assessment (**Fig. 1.2**) of the same type of machines using the technical characteristics of existing technological technical systems. Subsequently, depending on the purpose of the technical system, the numerical values of the criteria are determined (**Table 1.1**) and, on their basis, conclusions are drawn on the formulation of research tasks for certain processes.

The application of the above criteria, fulfilled for machines for crushing, sorting, mixing and compaction, are taken into account in the corresponding sections of the monograph. Their analytical form is shown in **Table 1.1**.

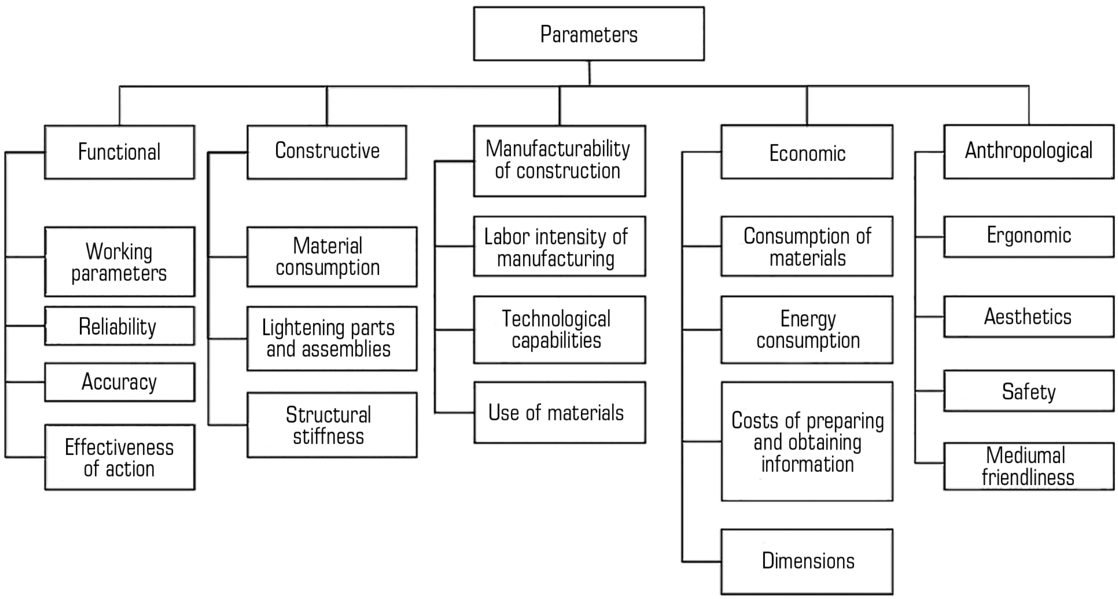
Table 1.2 shows the numerical values of the main parameters of vibration crushers.

Calculations according to this **Table 1.2** obtained numerical criteria for evaluating the parameters of vibration crushers, confirming significant differences (**Table 1.3**).

The main parameters of resonant technical systems for sorting materials are presented in **Table 1.4**.

As follows from **Table 1.4,** resonant screens, having a one-two-mass structure according to the screening scheme, are three and four-mass. The screen parameters are also different: the vibration amplitude (**Table 1.4**) has a wide range from 0.6 to 10 mm, foreign production – 5–14 mm. They are also excellent in vibration frequency, which is reflected in one of the main indicators – vibration acceleration. In terms of the power of a foreign-made rotor for such parameters (amplitude and frequency of oscillations), they have lower values, which indicates a possible greater oscillation amplification factor, and therefore greater efficiency.

Technical characteristics of gravity concrete mixers are given in **Tables 1.5, 1.6**.



⬡ **Fig. 1.2** Classification of technical system parameters

Table 1.1 Criteria for evaluating technological and design parameters of technical systems for dynamic processes of processing technological media

No.	Criterion	Analytical dependence
1	Effect of mass on performance	$K_m=P/m$
2	Impact of energy consumption on performance	$k_e=P/R$
3	Effect of power on ground	$k_p=P/m$
4	System synergy factor (efficiency)	$K_s=E_s/E_{p.k.}$
5	The rate of change in the stress state of the medium in time	$\upsilon_{s.s} = d\sigma/dt$
6	Speed	$k_s = X_0 \cdot \omega$
5	Acceleration	$k_a = X_0 \cdot \omega^2$
6	Dynamism of the system	$k_d = a/g$
7	Mixing drum volume ratio	$K_z=V_s/V_g$
8	The ratio of the mass of the medium to the mass of the technical system	$K_m=m_m/m_{t.s.}$

Table 1.2 Numerical values of the main parameters of vibration crushers

Type	Productivity, m³/h	Mass, kg	Power, kWt	The largest size of the input material, mm	The smallest size of the source material, mm	Machine volume, m³
VSHCHD 440×800 (REC «Mechanort-tekhnika)	22	1 500	60	350	40	10.92
VSHCHD 65×400 2 chambers (REC «Mechanort-tekhnika)	2.5	1 400	14	50	10	3.6
VSHCHD 130×300 (REC «Mechanort-tekhnika)	1	1 500	22	110	20	2.89
VSHCHD 600×150 (Mining Academy in Krakiw)	1.56	1 082	7.5	120	15	1.35
VSHCHD 600×800 (REC «Mechanort-tekhnika)	47	2 500	60	5 00	70	17.95
VSHCHD 1200×1500 (REC «Mechanort-tekhnika)	188	5 400	110	1 000	100	59.2
SVDA-1000 (Skochinsky Institute of Mining)	938	8 116	480	1 000	300	–

Table 1.3 The value of the criteria for evaluating the parameters of vibration crushers

Type	K1	K2	K3	K4	K5
VSHCHD 440×800 (REC «Mechanort-tekhnika)	0.0015	0.3667	250.00	8.75	2.0147
VSHCHD 65×400 2 chambers (REC «Mechanort-tekhnika)	0.0018	0.1786	100.00	5.00	0.6940
VSHCHD 130×300 (REC «Mechanort-tekhnika)	0.0007	0.0455	68.18	5.50	0.3460
VSHCHD 600×150 (Mining Academy in Krakiw)	0.0014	0.2080	144.27	8.00	1.1556
VSHCHD 600×800 (REC «Mechanort-tekhnika)	0.0019	0.7833	416.67	7.14	2.6184
VSHCHD 1200×1500 (REC «Mechanort-tekhnika)	0.0035	1.7091	490.91	10.00	3.1757
SVDA-1000 (Skochinsky Institute of Mining)	0.0116	1.9542	169.08	0.01	–

Table 1.4 Parameters of resonant technical systems for sorting materials

Type	Scheme	Amplitude of vibrations, mm	Vibration frequency rad/i	Power, kWt	Maximum acceleration, m/s^2
VR-50	One-mass unbalanced	4.0	78.5	10	24
VUR-80	Two-mass balanced	4.0	97.4	10	38
VKVS	Two-mass balanced	0.65	294	1.6	55
PEV-1-0,5×3,6	Two-mass	0.60	314	0.5	60
PEV-2-0,5×5	Two-mass	0.70	314	0.5	70
PEV-3-9×2,5	Two-mass	0.80	314	2.0	80
79-TS	Two-mass	0.80	314	2.0	80
PVG-2	Two-mass balanced	4.0	78.5	30	24
GRL62	Two-mass balanced	10	52.3	13	27
PEV-2-4×12	Two-mass	0.90	314	4.0	90
EV	Two-mass	5…15	52.3…105	5…8	39…51
EF	Two-mass	5…15	105…209	6	39…51
RJ	Two-mass	5…14	105…209	6	36…51
S	Two-mass	5…14	105…209	6	36…51
RMS-2,25	Two-mass	5…14	105…209	3.5…5	36…51
RMN-4,5	Two-mass	5…14	105…209	5…9	36…51
RS	Three-mass	5…14	105…209	6	36…51
DV	Four-mass	5…15	105…209	5…8	39…51
GC	Four-mass	10…12	105…209	6…8	51…72

Table 1.5 Technical characteristics of Johnson-Ross gravity concrete mixers

Standard size and loading volume			Drum rotation drive power, kW		Number of mixing blades	Mass, t
yd^3	m^3	l	engine power	total		
4.5	3.44	3 440.7	1×29.8	29.8	3	6.804
6	4.59	4 587.6	2×22.4	44.8	3	12.701
8	6.12	6 116.8	2×29.8	59.6	4	14.515
10	7.65	7 646.0	2×37.3	74.6	4	16.33
12	9.18	9 175.2	2×44.8	89.6	4	17.917
15	11.47	11 469.0	2×56.0	112	4	19.958

Table 1.6 Specifications of BMH Systems of The Roll Master Gravity Reversible Mixers

Loading volume, m^3	Drum diameter, m	Drive power, kW	Productivity, m^3/hour	Mass, kg
3	2.5	2×22	85	12 000
4.5	2.8	4×18	112	15 000
6	3.15	4×22	165	18 000
9	3.35	4×37	245	21 000

The variety of currently used concrete mixers can also be explained by an unreliable comparative assessment of their technical, technological and operational parameters. Based on a review of the designs of prototypes of concrete mixing machines (**Tables 1.5, 1.6**), the key parameters were identified that affect the mixing process. According to the analysis of technical and economic indicators and parameters, the tasks of researching vibration concrete mixers are determined.

Thus, studies using the above technique have established that for the processes of grinding [6, 7], sorting [8], mixing [9], compaction [10, 11], cavitation treatment [12–14], research of parameters, modes and reliability machines [15–20] there is a significant difference in the numerical values of the criteria of the studied class of technical systems. The main reason lies in the use of simplified models, the absence of modeling and consideration of the joint movement of the working bodies of the technical system and the processed medium or material.

1.3 DISCUSSION OF RESULTS AND IDENTIFICATION OF MAIN DIRECTIONS OF RESEARCH

For the development of general principles for the creation of technological technical systems, for the further development of the theory of the working process, classification signs are determined. The monograph considers only the classification features that determine their purpose and the nature of the work they perform. This has some limitations of the existing classification signs.

An important point in the analysis of existing works is the assessment of the design and technological parameters of the existing technical systems of industrial engineering. New and improved evaluation criteria have been used. Reliable assessment and analysis made it possible to formulate more reasonably methods for solving the problem. Continuously improving, the technology leaves a reflection on the directions of development of technical system designs. On the basis of this, working hypotheses and research methods were formulated, the results of which are presented in the corresponding sections of the monograph.

Working hypotheses for researching technical systems for technological purposes:

– consideration (modeling) of the medium and the technical system as a single system with its own dynamic personality. The embodiment of this principle guarantees the movement of the studied systems in a given or established mode of operation;

– «technical system – medium» system is a complex hybrid (mixed) dynamic system, in which the technical system is a system with discrete parameters, and the medium is with distributed parameters, and this system is reduced to the calculated one in the form of a system with discrete parameters, in which wave phenomena of the medium and are represented by contact force;

– an increase in the efficiency of technical systems for various technological purposes is achieved through the efficient use of energy supplied to the medium both on the main and on the superharmonic resonance mode of oscillations of the system under study, as well as with a variable, time-controlled mode of operation;

– reliability of the machine is ensured by a rational combination of the effect of shock and vibration at low frequencies, as well as the use of reliable vibration exciters.

Research methodology for technical systems for technological purposes:

– analytical research and rational use of the regularities of changes in the internal (elastic-inertial and dissipative) properties of the «machine – medium» system;

– conducting experimental studies based on the determination of rational operating modes of technical systems for various technological purposes;

– reliability assessment based on a small number or absence of failures;

– study of the stress-strain state of metal structures of machines of static and dynamic action;

– establishment of regularities in the distribution of normal and contacting stresses for different shapes of the cross-section of elements of metal structures.

The proposed method of compiling a mathematical model [1, 2] is based on the idea of considering at the first stage a separate medium, the stress-strain state of which is under the load of the force of any law of its change.

The next stage of the analytical solution of the motion of the medium is based on the premise that the structure of the dependence reflecting its state at any moment of motion consists of two components – one is capable of accumulating energy that passes from one form to another (reactance), and the other is energy dissipation (active resistance). The resulting formula has a discrete form in structure, however, its constituent parameters and characteristics take into account wave processes in the medium.

The final stage is the drawing up of the equation of the joint motion of the vibration system «machine – medium» by the appropriate combination of reactive and active components of the resistance of the machine and the medium, for which the method of vector diagrams is used.

CONCLUSIONS TO SECTION 1

1. For the development of general principles for the creation of technical systems for technological purposes, the further development of the theory of their working process, classification features and proposed criteria have been determined, according to which the assessment of the design and technological parameters of the existing technical systems of industrial engineering is carried out.

2. Working hypotheses of research of technological technical systems are formulated, the implementation of which is a guarantee of the reliability of the obtained results of the movement of the systems under study in a given or established operating mode.

3. A method for researching technological technical systems has been developed, which provides for the implementation of analytical research and the rational use of the regularities of changes in the internal properties of the machine-medium system based on the joint use of models with discrete and distributed parameters.

REFERENCES

1. Nazarenko, I., Gaidaichuk, V., Dedov, O., Diachenko, O. (2017). Investigation of vibration machine movement with a multimode oscillation spectrum. Eastern-European Journal of Enterprise Technologies, 6 (1 (90)), 28–36. doi: http://doi.org/10.15587/1729-4061.2017.118731
2. Nazarenko, I., Gaidaichuk, V., Dedov, O., Diachenko, O. (2018). Determination of stresses and strains in the shaping structure under spatial load. Eastern-European Journal of Enterprise Technologies, 6 (7 (96)), 13–18. doi: http://doi.org/10.15587/1729-4061.2018.147195
3. Nazarenko, I. I., Harnets, V. M., Sviderskyi, A. T., Pentiuk, B. M. (2009). Systemnyi analiz tekhnichnykh obiektiv. Kyiv: KNUBA, 164.
4. Mishchuk, Y., Nazarenko, I., Mishchuk, D. (2021). Definition of rational operating modes of a vibratory jaw crusher. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 4, 56–62. doi: http://doi.org/10.33271/nvngu/2021-4/056
5. Nazarenko, I., Mishchuk, Y., Mishchuk, D., Ruchynskyi, M., Rogovskii, I., Mikhailova, L. et. al. (2021). Determiantion of energy characteristics of material destruction in the crushing chamber of the vibration crusher. Eastern-European Journal of Enterprise Technologies, 4 (7 (112)), 41–49. doi: http://doi.org/10.15587/1729-4061.2021.239292
6. Nazarenko, I. I., Oryshchenko, S. V. (2009). Modeliuvannia protsesu rukhu materialu po hrokhotu. Tekhnika budivnytstva. Naukovo-tekhnichnyi zhurnal, 22, 81–84.
7. Ruchynskyi, M. M., Svyrydiuk, D. Ya. (2013). Doslidzhennia kolyvan vibratsiinoho betonozmishuvacha z urakhuvanniam vplyvu peremishchuvanoho materialu. Tekhnika budivnytstva. Naukovo-tekhnichnyi zhurnal, 31, 35–42.
8. Nazarenko, I., Ruchynskyi, M., Delembovskyi, M. (2018). The Basic Parameters of Vibration Settings for Sealing Horizontal Surfaces. International Journal of Engineering & Technology, 7 (3.2), 255–259. doi: http://doi.org/10.14419/ijet.v7i3.2.14415
9. Bernyk, I., Luhovskyi, O., Nazarenko, I. (2018). Effect of rheological properties of materials on their treatment with ultrasonic cavitation. Materiali in Tehnologije, 52 (4), 465–468. doi: http://doi.org/10.17222/mit.2017.021
10. 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: http://doi.org/10.14419/ijet.v7i3.2.14417

11. Nazarenko, I. I., Ruchynskyi, M. M., Sviderskyi, A. T., Kobylanska, I. M., Harasim, D., Kalizhanova, A., Kozbakova, A. (2019). Development of energy-efficient vibration machines for the buiding-and-contruction industry. Przeglad Elektrotechniczny, 95 (4), 53–59. doi: http://doi.org/10.15199/48.2019.04.10
12. Bernyk, I., Luhovskyi, O., Wojcik, W., Shedreyeva, I., Karnakova, G. (2019). Theoretical Investigations of the Interaction of Acoustic Apparatus with Technological Environment Working Process. Przeglad Elektrotechniczny, 1 (4), 32–37. doi: http://doi.org/10.15199/48.2019.04.06
13. Luhovskyi, O., Bernyk, I., Gryshko, I., Abdulina, D., Zilinskyi, A.; Stryczek, J., Warzyńska, U. (Eds.) (2021). Mobile Equipment for Ultrasonic Cavitation Inactivation of Microorganisms in the Liquid Environment. NSHP 2020. Lecture Notes in Mechanical Engineering. Cham: Springer, 272–281. doi: http://doi.org/10.1007/978-3-030-59509-8_24
14. Babič, M., Calì, M., Nazarenko, I., Fragassa, C., Ekinovic, S., Mihaliková, M. et. al. (2018). Surface roughness evaluation in hardened materials by pattern recognition using network theory. International Journal on Interactive Design and Manufacturing, 13 (1), 211–219. doi: http://doi.org/10.1007/s12008-018-0507-3
15. 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: http://doi.org/10.29202/nvngu/2019-5/8
16. Nesterenko, M., Nesterenko, T., Skliarenko, T. (2018). Theoretical Studies of Stresses in a Layer of a Light-Concrete Mixture, Which is Compacted on the Shock-Vibration Machine. International Journal of Engineering & Technology, 7 (3.2), 419–424. doi: http://doi.org/10.14419/ijet.v7i3.2.14564
17. Dmitrenko, A., Lebedyk, G., Nesterenko, M. (2018). Product Cost Calculation Methods in Construction. International Journal of Engineering & Technology, 7 (3.2), 6–11. doi: http://doi.org/10.14419/ijet.v7i3.2.14367
18. Nazarenko, I., Dedov, O., Bernyk, I., Rogovskii, I., Bondarenko, A., Zapryvoda, A. et. al. (2020). Determining the regions of stability in the motion regimes and parameters of vibratory machines for different technological purposes. Eastern-European Journal of Enterprise Technologies, 6 (7 (108)), 71–79. doi: http://doi.org/10.15587/1729-4061.2020.217747
19. Nazarenko, I., Svidersky, A., Kostenyuk, A., Dedov, O., Kyzminec, N., Slipetskyi, V. (2020). Determination of the workflow of energy-saving vibration unit with polyphase spectrum of vibrations. Eastern-European Journal of Enterprise Technologies, 1 (7 (103)), 43–49. doi: http://doi.org/10.15587/1729-4061.0.184632
20. Nazarenko, I., Gavryukov, O., Klyon, A., Ruchynsky, N. (2018). Determination of the optimal parameters of a tubular belt conveyor depending on such an economical. Eastern-European Journal of Enterprise Technologies, 3 (1 (93)), 34–42. doi: http://doi.org/10.15587/1729-4061.2018.131552