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DYNAMIC OPTIMIZATION OF A MINE WINDER ACCELERATION MODE

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ДИНАМІЧНА ОПТИМІЗАЦІЯ РЕЖИМУ РОЗГОНУ ШАХТНОЇ ПІДЙОМНОЇ МАШИНИ

Purpose. Improving the mine winder operation efficiency by the acceleration mode optimization and study of an optimezed mode using energetic and dynamic criteria.

Methodology. The methods of numerical integration of mathematical modelling and non-linear differential equations were used to study the dynamic and energetic indicators of the mine winder operation. The approximate solution of the issue of optimal motion control of mine winders concerning the acceleration mode was found using the collocation method. Assessment of impact of the optimal machine motion law parameters on the dynamic and energetic indicators of its operation was carried out through the implementation of a series of computer aided analysis.

Findings. It was found that peak loads and significant values of power consumption occur in machines components during the rheostat launch of mine winder asynchronous drive when switching the rotor resistances. Regularities of influence of machine acceleration optimal duration and ratio, which determines the importance of the respective components in the structure optimization criterion, on estimated energetic and dynamic indicators of machine acceleration mode were revealed.

Originality. An optimal acceleration mode of a mine winder was synthesized by the complex integral criterion using the direct variational method. The obtained optimal motion mode is described by continuously differentiated function that reduces the dynamic loads in machine components and improves the energetic characteristics of its drive.

Practical value. The mode duration rational values and the ratio, which determines the role of the components in the optimization criterion structure, were found on the basis of dynamic and energetic analysis of mine winder optimized acceleration mode. This allows approaching reasonably to the implementation of the found mine winder acceleration mode that relies on frequency control of asynchronous electric drive of a machine.

Keywords: *mine winder, dynamic load, optimal motion control*

Introduction. The issue of efficient operation of mine winders is particularly relevant in modern conditions of mining. This is due to the fact that you can increase the technical and economic indicators of the whole production process carrying out certain activities (machine design modernization, flexible and damping and/or inertial elements introduction to the machine design, relay control system replacement to the modern computer integrated one etc.). The mentioned activities should be carried out primarily for technically outdated mine winders. It is possible to extend their service life, and in some cases to improve the energy efficiency performance of hoisting by reducing the dynamic loads in the machine components.

Analysis of the recent research. The issue of mine winder operation dynamics was considered in scientific papers [1, 2] as multimass mechanical system with visco-flexible links. This has enabled to take into account wave processes in the ropes and assess their loading [1]. The calculations of rope complex spatial fluctuations have been carried out in scientific papers [3, 4], which showed their dynamic loading taking into account skip rate change diagram. Such an approach [5] has made it possible to offer recommendations on preventing severe wear of ropes. The issue of ropes dynamic calculation using approximate methods of non-linear model surveys is presented in the scientific paper [6]. These results can be used for approximate evaluation of dynamic processes in mine winders.

Experimental research results of loads arising in machine components in different operation modes are presented in scientific paper [7], the main factors affecting the machine dynamics are specified there as well. The following factors can be conditionally distinguished among them: parametric and operating parameters [8]. The inertial, stiffness and some other parameters of individual machine components, as well as machine structure (components placement order in its design) belong to the first group. The operating parameters include acceleration and braking time, nature of external force impact and its magnitude [9].

Hoisting machine motion modes optimization allows getting significant improvement of their technical

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and economic indicators [10]. However, the optimization issue for mine winders has been studied in few scientific papers [2, 11]. It means that the mine winder efficiency improving reserves are used not in full.

Unsolved issues. The issue of mine winder motion optimal modes synthesis is of pressing importance. Nowadays, its final solution has not been found, that is why the scientific research in this field is continued. Moreover, considering the progress in the field of controlled electric drive, the realization of mine winder optimal motion laws is not the subject of the principal difficulties. Thus, the development of algorithmic part of modern mine winder motion control system should be carried out taking into account the nature of dynamic and energetic processes optimal conditions.

Unsolved aspects of the problem. Since a mine winder is a complex mechatronic system, several factors should be considered during the synthesis of optimal motion control. Therefore, the most appropriate in terms of machine efficiency improvement will be control found when solving the complex optimization problems (tasks with complex optimization criteria). In addition, the very important issue is optimal control modelling which allows setting optimal motion impact on dynamic and energetic indicators of mine winder operation. This will enable us to substantiate recommendations for implementation of optimal control on practice.

Objectives of the article. The objective is a synthesis of the mine winder optimal acceleration mode whereby its energetic and dynamic technical and performance indicators are increasing.

Presentation of the main research. For studying, we take a mine winder dynamic model, which is shown in Fig. 1.

The diagram in Fig. 1 shows: J_1 – equivalent load inertia of the motor rotor and connecting halfcoupling; J_2 – reduced load inertia of connecting halfcoupling, reduction unit and rope drum; m – reduced to the vertical motion weight of final load; R – rope drum radius; c_φ – reduced ratio of couplings stiffness; c_x – reduced ratio of rope stiffness; M – reduced torque of mine winder drive; F – reduced resistance force during skip motion. Reduced weight of final load m includes the skip and the rope weight: according to the Rayleigh method it is sufficient to add a third part of the rope weight to the final load for calculating the rope weight when vibrating. All mine winder dynamic parameters are reduced to rope drum.

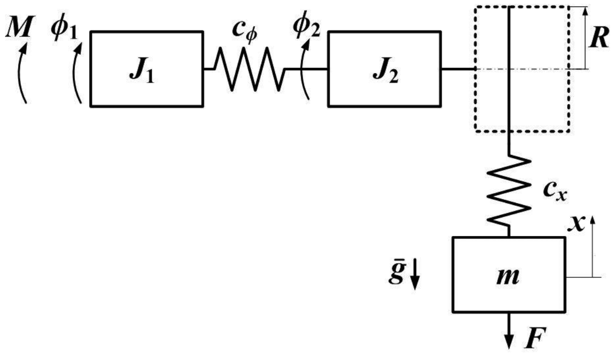


Fig. 1. The dynamic model of mine winder

The following assumptions were used to build the model (Fig. 1): 1) all components, except the flexible rope and flexible coupling, are absolutely rigid bodies with the same weights (moments of inertia); 2) when hoisting the load the reduced stiffness ratio *cx* changes slightly, so we take that it as constant; 3) all the resistance forces and skip weight are reduced to the force *F*; 4) elastic properties of the coupling and rope are subject to the Hooke's law.

The mathematical model which meets the mine winder dynamic model (Fig. 1) can be represented as follows

$$\begin{cases} M = J_1\ddot{\varphi}_1 + c_\varphi(\varphi_1 - \varphi_2) \\ c_\varphi(\varphi_1 - \varphi_2) = J_2\ddot{\varphi}_2 + c_x(\varphi_2 R - x)R. \\ c_x(\varphi_2 R - x) = m\ddot{x} + F \end{cases} \qquad (1)$$

The point above the symbol means differentiation by time. The model shown in Fig. 1 allows studying the dynamic load of flexible coupling and rope.

In order to carry out the machine acceleration mode optimization we use the complex integrated criterion which is presented in the following form

$$I = \frac{1}{T}\int_0^T \left(\delta_1 M^2 + \delta_2 \dot{M}^2\right) dt = \\ = \frac{1}{T}\int_0^T \left(\delta_1 \left(A_0 + \sum_{i=1}^{3} A_i x^{(2i)} \right)^2 + \delta_2 \left(\sum_{i=1}^{3} A_i x^{(2i+1)} \right)^2 \right) dt, \qquad (2)$$

where T is time of system acceleration to the steady rate v; δ_1 and δ_2 are ratios which drive the respective components (driving torque and its change rate) to dimensionless form and determine the importance of each of the components in the criteria structure; $A_0 \ldots A_3$ are constants ratios which are determined with the following ratios

$$\begin{cases} A_0 = FR \\ A_1 = \dfrac{J_1 + J_2}{R} + mR \\ A_2 = \dfrac{1}{c_\varphi}\left(mRJ_1 + \dfrac{J_1 J_2}{R} \right) + \dfrac{m}{c_x R}\left(J_1 + J_2\right) \cdot \\ A_3 = \dfrac{J_1 J_2 m}{c_x c_\varphi R} \end{cases} \qquad (3)$$

Criterion (2) is a complex one: expression at δ_1 shows mean square value of driving torque for the machine acceleration time. Choosing this component in the criterion structure is caused by the need to reduce the variable electrical losses in the mine winder electric drive. In addition, it will help decrease the level of unwanted dynamic loads in the machine components. Expression at δ_2 shows the change rate of the driving torque of the drive motor. Quick change of the machine drive electromagnetic torque requires applying considerable voltages to its windings which can damage the windings insulation. Therefore, the rate of drive motor torque increasing and decreasing should be minimized; that determines the second term in the expression under integral sign structure of optimization criterion (2).

The system components motion boundary conditions should be noted for the final formulation of variational problem.

$$\begin{cases} x(0)=x_0;\ \varphi_1(0)=\varphi_2(0)=0 \\ \dot{x}(0)=\dot{\varphi}_1(0)=\dot{\varphi}_2(0)=0 \\ x(T)=x_0+\dfrac{vT}{2};\ \varphi_1(T)=\varphi_2(T)=\dfrac{vT}{2R}, \\ \dot{x}(T)=v;\ \dot{\varphi}_1(T)=\dot{\varphi}_2(T)=\dfrac{v}{R} \end{cases} \quad (4)$$

where x_0 is the final load position at the motion start; v is the constant final load motion rate; T is the final load acceleration time to the constant rate v.

We express all boundary conditions through higher derived functions $x(t)$ by time, whereby we obtain

$$\begin{cases} x(0)=x_0;\quad \dot{x}(0)=\ddot{x}(0)=\dddot{x}(0)=\overset{IV}{x}(0)=\overset{V}{x}(0)=0 \\ x(T)=x_0+\dfrac{vT}{2};\quad \dot{x}(T)=v; \\ \ddot{x}(T)=\dddot{x}(T)=\overset{IV}{x}(T)=\overset{V}{x}(T)=0 \end{cases}. \quad (5)$$

We use variations calculus to minimize the expression (2). For this purpose we write the Euler-Poisson formula [12], which looks as follows for the integral functional (2)

$$\sum_{i=2}^{7}(-1)^i B_i x^{(2i)}=0, \quad (6)$$

where B_i are constant ratios expressed in terms of ratios $A_0 \ldots A_3$ (3) and ratios δ_1 and δ_2. In order to find the solution of the homogeneous differential equation (6) you should note corresponding characteristic equation by the introduction of substitution $x^2 = z$ presented in the following form

$$z^2 \cdot \left(B_2+\sum_{i=1}^{5}(-1)^i B_{i+2} z^i\right)=0. \quad (7)$$

In order to find the roots of the equation (7) it is necessary to solve the fifth degree algebraic equation, which cannot be done analytically (in radicals) [13].

Therefore, we will only find approximate solution of variational problem (1–5). For this purpose we use direct variational method [14]. The essence of the method consists in necessity to find a solution to the boundary value problem

$$\begin{cases} \overset{XV}{x}=0 \\ \begin{cases} x(0)=x_0;\quad \dot{x}(0)=\ddot{x}(0)=\dddot{x}(0)=\overset{IV}{x}(0)=\overset{V}{x}(0)=0 \\ x\left(\dfrac{jT}{4}\right)=q_j,\quad j=1,2,3 \\ x(T)=x_0+\dfrac{vT}{2};\quad \dot{x}(T)=v; \\ \ddot{x}(T)=\dddot{x}(T)=\overset{IV}{x}(T)=\overset{V}{x}(T)=0 \end{cases} \end{cases}, \quad (8)$$

where q_j are unknown ratios which in the future will be used to minimize the importance of functional (2).

The expression, i.e. the solution of the boundary value problem (8), features a significant amount and therefore is not presented here. In order to minimize the functional (2) we will find its expression under integral sign, which is represented through higher derivatives by time solving the boundary value problem (8). Thereafter, we take definite integral (2), which will be a function of unknown ratios q_j. In order to minimize the functional $I(q_j)$ it is necessary to solve a system of linear equations

$$\frac{\partial I}{\partial q_j}=0. \quad (9)$$

Having found ratios q_j from system of equations (9) and having substituted them in the solution of the boundary problem (8), we obtain an approximate solution of the variational problem (1–5). Choosing only three ratios q_j, under which the functional (2) minimization is performed, has been substantiated by the fact that further complications of calculations due to the increase in their value j) only slightly affects the problem solution accuracy. On the other hand, the use of two or only one ratio q_j does not allow finding adequate approximation to the exact solution of variational problem (1–5).

Let us compare the found optimal motion mode with the one which was implemented using the rheostat resistance change of the machine asynchronous drive. Actuation of the mine winder is carried out by АКН-2-16-39-12УХЛ4 500 kW high voltage asynchronous motor with phase rotor. Engine rate change is carried out due to the three stage change of rotor circle resistance, while changing the stress-related characteristics stiffness.

Fig. 2 shows the characteristic curves illustrating mine winder motion properties during its acceleration. All diagrams are built for the following parameters of the mine winder: $T = 5$ s; $\delta_1 = 0.5$; $\delta_2 = 0.5$; $v = 12$ m/s; $m = 4400$ kg; $J_1 = 2400$ kg · m^2; $J_2 = 2000$ kg · m^2; $R = 2$ m; $c_x = 1.06 \cdot 10^5$ N/m; $c_\varphi = 1.2 \cdot 10^9$ Nm/rad.

Fig. 2 shows grey diagrams corresponding to mine winder acceleration during rheostat control of the electric drive, and black diagrams corresponding to one during optimal control.

Analysis of characteristic curves in Fig. 2 shows that in conditions of identical launch time the energetic and dynamic indicators of mine winder during optimal motion control are better than those corresponding to the drive motor rheostat control.

For example, the maximum power consumption during optimal control is 22.5 % less than during rheostat control of the drive. The maximum torques of the engine and coupling are respectively 29.9 and 84.0 % less than those obtained during rheostat control. While switching to the optimal control the maximum force in the rope is decreased by 40.0 %.

In addition, Fig. 2 shows that at the end of acceleration (which lasts 5 seconds) according to the optimal law the machine motion energetic and dynamic indicators

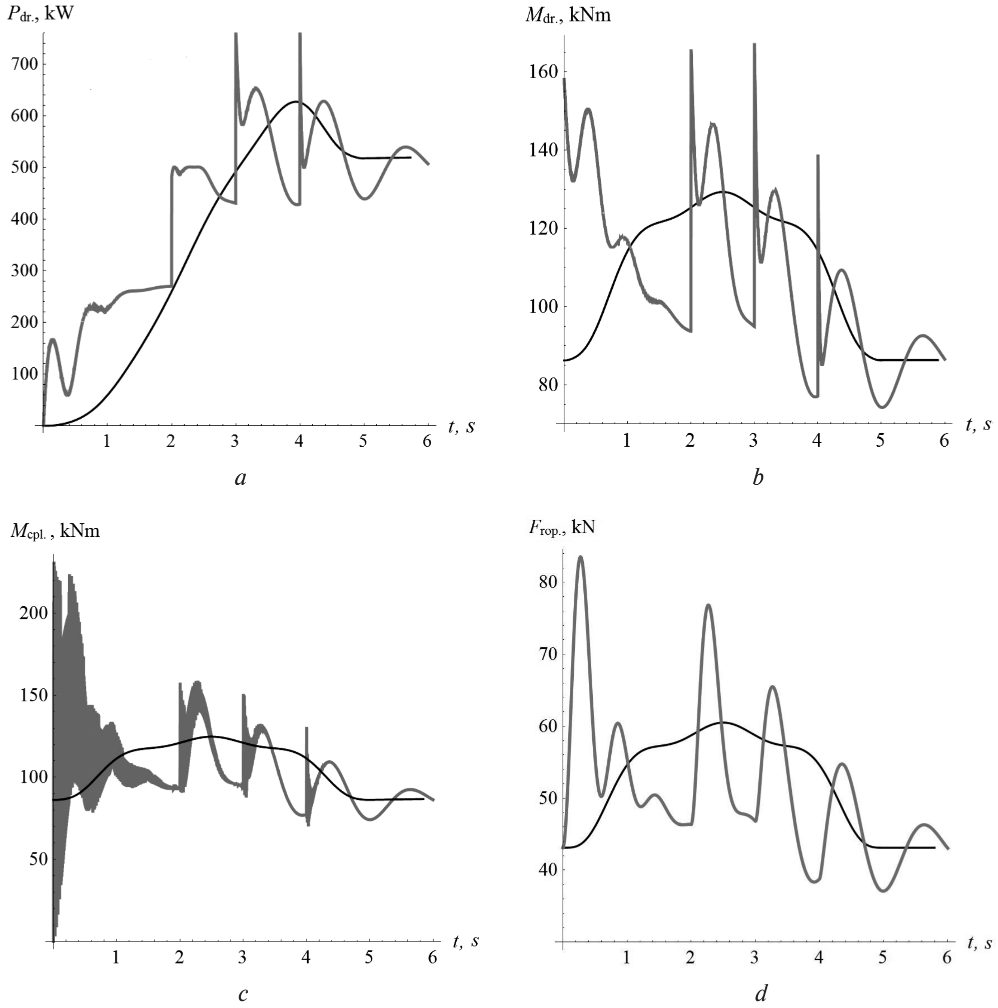


Fig. 2. Diagrams of mine winder motion characteristics during its acceleration:
a – engine capacity; b – machine drive torque; c – torque in the flexible coupling; d – force in the rope

take constant values. With the rheostat launch these characteristics continue to fluctuate.

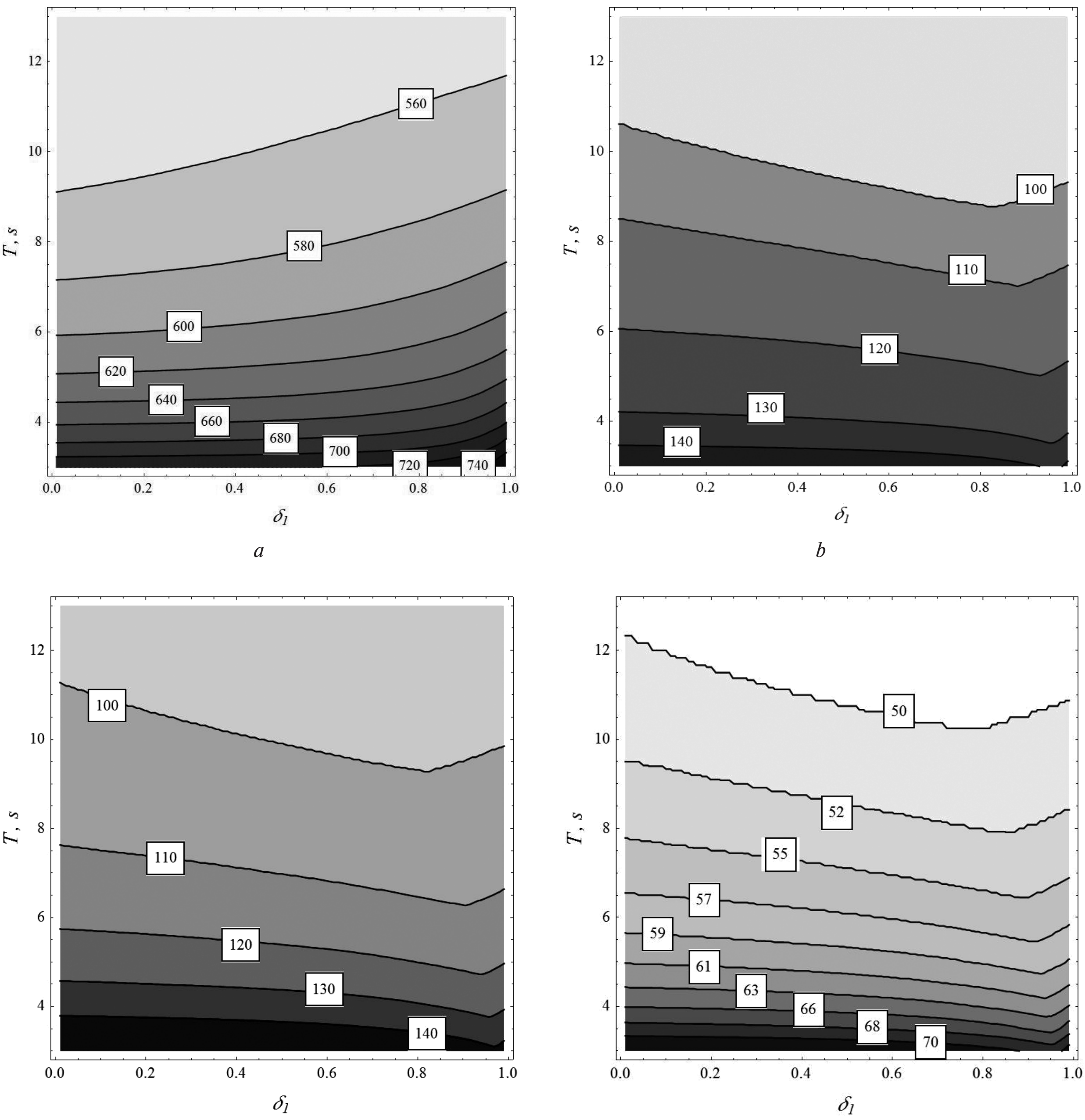
Hence, the effect of switching to optimal control exerts in reducing the unwanted dynamic loads in machine components (in rope and flexible coupling), as well as in minimization of drive motor capacity peak values.

We carry out the study of obtained approximate solution for optimization problem (1–5) to determine its practical value. For this purpose we choose the indicators under which the analysis of the system motion optimal mode during acceleration is carried out. Such indicators include: 1) maximum drive motor capacity $P_{\max}$, kW; 2) maximum torque in coupling $M_{\mathrm{cpl.max}}$, kNm; 3) maximum drive motor torque $\mathrm{M}_{\mathrm{dr.max}}$, kNm; 4) maximum force in the rope, $F_{\mathrm{rop.max}}$, kN.

Independent factors were δ_1 and T. Value T varied in the range of 3–13 s in increments of 0.5 s. Ratio δ_1 varied in the range of 0.01–0.99 in increments of 0.01. Thus, 2079 computer experiments have been carried out to evaluate the approximate solution of optimization issue (1–5). Each experiment determined six estimated indicators. Calculation results are shown in Fig. 3.

In order to determine the rational parameter settings δ_1 and T during mine winder operation we carry out an analysis of the data obtained. First of all, we note that with increasing the acceleration time T all unwanted evaluation indicators had intensively decreased at first, but then hardly changed (Fig. 3). In this way, rationally substantiated minimum acceleration time value T is in the range of 5–6 s. In this case the engine is overloaded by 1.21–1.17 times and dynamic factors of the coupling and the rope are 1.45–1.33 and 1.46–1.37 respectively. It should be noted that the implementation of the optimal mode of machine acceleration is carried out by using the frequency transducer, which can withstand overload current by 1.5 times for 60 s [15]. Thus, overload of the engine and the frequency transducer at $T = 5$ s will be within acceptable limits.

Using Fig. 3, it is possible to determine the impact of the parameter δ_1 on the dynamic and energetic indicators of mine winder operation. While increasing δ_1 the indicator $P_{\max}$ is slightly increasing, for example $T = 5$ s when changing ratio δ_1 from 0.01 to 0.99 the value $P_{\max}$ increases only by 4.8 %. The opposite situation occurs for estimated dynamic indicators: for T = 5 s when changing ratio δ_1 from 0.01 to 0.99 $M_{cpl.\max}$ and $M_{dr.\max}$ decrease by 5.9 % and $F_{\mathrm{rop.max}}$ by 5.1 % respectively. For large values T the impact of the ratio δ_1 is not significant.



a *b*

c *d*

Fig. 3. Contour graphics illustrating dependence of estimated indicators on the values δ_1 *and T:*
a – $P_{\max}$*, kW; b –* $M_{cp\mathrm{l}.\max}$*, kNm; c –* $M_{dr.\max}$*, kNm; d –* $F_{rop.\max}$*, kN*

In order to reduce the criterion value it is desirable to configure insignificant value δ_1, i.e. the advantage should be given to reducing the root mean-square value of the driving torque change rate of the motor drive.

Conclusions and recommendations for further research. For better performance of a mine winder, the drive motor rheostat control should be replaced by the frequency control that implements the optimal machine acceleration (deceleration) characteristics. Under similar conditions the optimal control allows reducing the dynamic loads of machine components to 22.5–84.0 %, as well as minimizing peak values of the drive motor power consumption.

The impact of acceleration T and parameter δ_1 on the dynamic and energetic indicators of mine winder operation, which enables reasonably to approach to the implementation of obtained optimal acceleration mode of the mine winder and to configure the appropriate settings based on the requirements for improving the machine operational efficiency was found.

Prospects for further studies consist in establishing regularities concerning influence of other machine optimal motion laws (for example, found by the fast response criterion, terminal and integral-terminal dynamic and energetic criteria) on its operation efficiency. It will enable to determine the most appropriate in practical terms motion mode under certain operating conditions of a mine winder. In addition, the issue of synthesis and study of optimal motion laws of the mine winder for deceleration mode and analysis of the machine operation under the optimal control needs comprehensive study.

References.

1. Stepanov, A. G., 2013. Theoretical basis of the mine hoist dynamics. *Mining Machinery and Electromechanics*, 7, pp. 31–40.

2. Osipova, T. N., 2014. To a question about the dynamics and optimization of mine hoists. *Mechanical Engineering*, 13, pp. 74–81.

3. Dagang, W., Dekun, Z., Zefeng, Z. and Shirong, G., 2012. Effect of various kinematic parameters of mine hoist on fretting parameters of hoisting rope and a new fretting fatigue test. *Engineering Failure Analysis*, 22, pp. 92–112.

4. Dagang, W., Dekun, Z. and Shirong, G., 2014. Effect of terminal mass on fretting and fatigue parameters of a hoisting rope during a lifting cycle in coal mine. *Engineering Failure Analysis*, 36, pp. 407–422.

5. Jiannan, Y. and Xingming, X., 2016. Effect of hoisting load on transverse vibrations of hoisting catenaries in floor type multirope friction mine hoists. *Shock and Vibration*, 36, pp. 1–15.

6. Pukach, P. Ya. and Kuzo, I. V., 2013. Nonlinear transverse vibrations semibounded rope considering resistance. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 3, pp. 82–86.

7. Ilin, S. R., Trifanov, G. D. and Vorobel, S. V., 2011. Complex experimental studies of the dynamics of ore-lifting trunk. *Mining Machinery and Electromechanics*, 5, pp. 30–35.

8. Kyrychenko, Y., Samusia, V. and Kyrychenko, V., 2012. Software development for the automatic control system of deep-water hydrohoist. In: *Geomechanical Processes during Underground Mining*, pp. 81–86.

9. Popov, Yu. P., Kudriavtsev, S. V. and Stepanov, S. V., 2015. Modernization of the braking system of mine hoisting plant. *Mining informational and analytical bulletin (scientific and technical journal)*, 9, pp. 195–197.

10. Loveikin, V. S. and Romasevych, Yu. O., 2016. *Dynamics and optimization of movement modes of brige cranes*. Kyiv: TsP "KOMPRINT".

11. Loveikin, V. S., Chovniuk, Yu. V. and Liashko, A. P., 2014. The crane vibrating systems controlled by mechatronic devices with magnetogeological fluid: the nonlinear mathematical model of behavior and optimization of work regimes. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 6, pp. 97–102.

12. Eduardo, S. de C., 2015. *Variational methods for engineers with Matlab*. London, UK; Hoboken, USA.

13. Bronshtein, I. N. and Semendyayev, K. A., 2013. *Handbook of mathematics*. Reprint of the third edition. Springer Science & Business Media.

14. Loveikin, V. S., Romasevich, Yu. O. and Loveikin, Yu. V., 2012. Analysis of the direct variational methods for solving optimal control problems. *Proceedings of the National University "Lviv Polytechnic". Optimization of production processes and technical control in machine and instrument*, 729, pp. 70–79.

15. FR-E700: frequency inverter instruction manual, 2011. Art. no.: 213994. Version D. Mitsubishi Electric Industrial Automation.

Мета. Підвищення ефективності роботи шахтної підйомної установки за рахунок оптимізації режиму її розгону та дослідження оптимізованого режиму за енергетичними й динамічними критеріями.

Методика. Для дослідження динамічних та енергетичних показників роботи шахтної підйомної машини використані методи математичного моделювання й чисельного інтегрування нелінійних диференціальних рівнянь. Знаходження наближеного розв'язку задачі оптимального керування рухом шахтної підйомної машини для режиму її розгону виконано з використанням методу коллокацій. Оцінка впливу параметрів оптимального закону руху машини на динамічні та енергетичні показники її роботи проведена шляхом виконання серії машинних експериментів.

Результати. Встановлено, що при реостатному пуску асинхронного приводу шахтної підйомної машини в моменти перемикання опорів ротора в її елементах виникають пікові навантаження й значні величини споживаної потужності. Розкриті закономірності впливу тривалості оптимального розгону машини й коефіцієнту, що визначає важливість відповідних складових у структурі оптимізаційного критерію, на енергетичні та динамічні оціночні показники режиму розгону машини.

Наукова новизна. Запропоновано оптимальний режим розгону шахтної підйомної машини за комплексним інтегральним критерієм із використанням прямого варіаційного методу. Отриманий у роботі оптимальний режим руху описується неперервно-диференційованою функцією, що дозволяє зменшити динамічні навантаження в елементах машини й покращити енергетичні характеристики її приводу.

Практична значимість. На основі динамічного та енергетичного аналізу оптимізованого режиму розгону шахтної підйомної машини встановлені раціональні значення тривалості режиму та коефіцієнт, що визначає вагу складових у структурі оптимізаційного критерію. Це дає змогу обгрунтовано підходити до реалізації знайденого режиму розгону шахтної підйомної машини, що покладається на частотне керування асинхронним електроприводом машини.

Ключові слова: *шахтний підйом, динамічні навантаження, оптимальне керування рухом*

Цель. Повышение эффективности работы шахтной подъемной установки за счет оптимизации режима ее разгона и исследование оптимизированного режима по энергетическим и динамическими критериям.

Методика. Для исследования динамических и энергетических показателей работы шахтной подъемной машины использованы методы математического моделирования и числового интегрирования нелинейных дифференциальных уравнений. Нахождение приближенного решения задачи оптимального управления движением шахтной подъемной машины для режима ее разгона выполнено с использованием метода коллокации. Оценка влияния параметров оптимального закона движения машины на динамические и энергетические показатели ее работы проведена путем выполнения серии машинных експериментов.

Результаты. Установлено, что при реостатном пуске асинхронного привода шахтной подъемной машины в моменты переключения сопротивлений ротора в ее элементах возникают пиковые нагрузки, что сопровождается значительными величинами потребляемой мощности. Раскрыты закономерности влияния продолжительности оптимального разгона машины и коэффициента, который определяет важность соответствующих составляющих в структуре оптимизационного критерия, на энергетические и динамические оценочные показатели режима разгона машины.

Научная новизна. Предложен оптимальный режим разгона шахтной подъемной машины по комплексному интегральному критерию с использованием прямого вариационного метода. Полученный в работе оптимальный режим движения описывается непрерывно-дифференцированной функцией, позволяющей уменьшить динамические нагрузки в элементах машины и улучшить энергетические характеристики ее привода.

Практическая значимость. На основе динамического и энергетического анализа оптимизированного режима разгона шахтной подъемной машины установлена рациональная продолжительность режима и коэффициент, определяющий вес составляющих в структуре оптимизационного критерия. Это позволяет обоснованно подходить к реализации найденного режима разгона шахтной подъемной машины, при использовании частотного управления асинхронным электроприводом машины.

Ключевые слова: *шахтный подъем, динамические нагрузки, оптимальное управление движением*

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DYNAMIC MODEL OF INTERACTION OF MECHANISMS ON THE SECTION BETWEEN THE ROLL MILL STAND AND THE COILER IN THE PROCESS OF WIRE WINDING BY GARRETT REEL

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ДИНАМІЧНА МОДЕЛЬ ВЗАЄМОДІЇ МЕХАНІЗМІВ ДІЛЯНКИ КЛІТЬ-МОТАЛКА ПРИ ЗМОТУВАННІ СОРТОВОГО ПРОКАТУ МОТАЛКОЮ ТИПУ ГАРРЕТА

Purpose. The purpose of the present research is to find ways to manage the coiler-mill drive system, which provides an increase in the tension stability of long products when winding on Garrett-type coiling machines at the output mill-coiler section at a level that does not lead to the extension of the profile in the outlet stand caliber.

Methodology. For the purpose of obtaining static and dynamic models of rolling tension at the output mill-coiler section, experimental studies of the winding of long products were carried out. The experimental activities included measuring electrical parameters such as the current of the exhaust cage engine, the current of the pinch roll motor, the speed of the wire feeding machine motor, the current of the coiler motor, the speed of the coiler motor, the position of the coil-laying pipe. The investigations were carried out during the rolling of profiles with a diameter of 16 and 18 mm using a digital recorder "Vizir".

Findings. Taking into account the quantitative and qualitative analysis of the results of the study, a general structural scheme was obtained for the rolling-up model in the mode of stabilizing only the amperage of the winder. Dependencies describing the complex of interrelationships between the mechanisms of the output mill-coiler section and the tension and length of the rolling in this site were obtained. A dynamic model for the interaction of the mechanisms of the mill-coiler section during rolling of long products was developed.

Originality. For the first time, a dynamic model of the interaction of the mechanisms of the mill-coiler section has been created for rolling coils with a coiler of the Garrett type, which takes into account both the direct and indirect influence of the mechanisms on the coiling process, which makes it possible to search for rational methods for stabilizing the tension of rolled products.
