UDC 622.625.5:004.67

DOI: 10.29202/nvngu/2018-4/12

O. V. Denyshchenko, Cand. Sc. (Tech.). Assoc. Prof.,
orcid.org/0000-0002-4011-5422,
A. L. Shyrin, Cand. Sc. (Tech.),
orcid.org/0000-0003-0026-2767,
V. O. Rastsvietaiev, Cand. Sc. (Tech.). Assoc. Prof.,
orcid.org/0000-0003-3120-4623,
O. V. Cherniaiev,
orcid.org/0000-0001-8288-4011

National Mining University, Dnipro, Ukraine, e-mail: alexxden097@gmail.com

FORMING THE STRUCTURE OF AUTOMATED SYSTEM TO CONTROL GROUND HEAVY-TYPE ROPEWAYS

Purpose. To substantiate efficient structure of automated system to control ground heavy-type ropeways relying upon the analysis of calculation scheme.

Methodology. Theoretical studies on mathematical model of a mine ropeway to determine the regularities concerning the formation of dynamic forces within ground ropeway (GRW) chains in transient conditions as well as experiments concerning the facilities use in the context of the mine conditions involving original equipment.

Findings. A structure of automated system to control ground heavy-type ropeways has been substantiated making it possible to improve both their efficiency and operational safety; moreover, it has been proposed to introduce additional functions.

Originality. For the first time, the dependence of GRW dynamic coefficient on acceleration period has been determined with the consideration of the self-oscillation period of the system. A method aimed at the minimization of dynamic forces within the rope has been proposed.

Practical value. Introduction of controlling functions of starting time into a structure of automated control system depending upon transportation distance, weight of a train, and limitation of maximum forces within a rope with the use of current element base makes it possible to prolong operational life substantially and, thus, reduce costs for its replacement and transportation costs on the whole while improving the efficiency of the facilities and their underground operation.

Keywords: *ropeway, control system, automation, dynamics, oscillations, durability*

Introduction. Ground ropeways (further GRWs) and overhead monorails (further OMRs) operating according to the principle of load haulage on guidance rails with the help of closed traction rope, started up in Germany in the middle of the last century. They rapidly become important for the segment of means of support service mine vehicles of the leading coal-mining countries developing seams with varying hypsometry.

Despite the fact that compared to standard ground transportation means for materials and people, monorail rope systems are more advantageous (i. e. adaptation for relief conditions of mine workings; possibilities of efficient operations in the mines with floor heaving; increase in the capacity of mine workings owing to transportation performed within their upper part; and reduced expenses connected with their service and operation) they have a grave disadvantage being a force impact on a mine working support and roof rocks on the whole [1]. That is why, the problem concerning the selection of either an overhead system or a ground one should be solved for each specific case with the consideration of mining and geological conditions.

Initially, basic purpose of GRW and OMR was transportation of equipment and materials with comparatively insignificant unit mass (up to 10 tons). However, scientists and researchers of the National Mining University have developed and successfully implemented a technology to use ground ropeways as the single transportation means in the process of construction of mine workings [2]. That has resulted in the development of heavy-type facilities for the transportation of modern mining equipment whose unit mass is up to 30 tons. Thus, railroad of ДКНП-1.6 type whose length is 3360 meters has been mounted and operates successfully at *Pavlohradska* mine. The railroad supports the behind-fault part of a mine field with the simultaneous possibility to transport up to 100 people to their working places as well as great volumes of materials and rock mass from the areas of construction of mine workings.

Analysis of the recent research and publications. The carried out analysis of the papers dealing with the research [3], introduction, and implementation of automated control system [4] helps conclude that its formation on the structure of ground heavy-type ropeways is a topical and timely problem in the context of the tendency.

Unsolved aspects of the problem. Expanding the range of GRW application involved the improvement of their control towards the development of automated system providing both efficient and safe operation of the facilities.

In this context, the whole range of mining and geological factors (i. e. bedding angle, dimensions of a mine field, physical and mechanical properties of rocks, water abundance, and others) as well as production and technical factors (i. e. the extent of a mine working and its section, duration of processing procedures and so forth) should be taken into consideration since such a control system must correspond to them, which places strict demands on its adaptational capabilities.

The objective of the paper is to substantiate an efficient structure of automated system to control ground heavy-

---

type ropeways on the basis of calculation scheme analysis.

Materials and methods. Determination of control parameters, a range and nature of their changes in such a complicated electrohydromechanical system as the modern ground heavy-type ropeway are impossible without the detailed analysis of processes taking place in each part of it during operation under complicated mining and geological conditions.

The two fundamentally different problems were emphasized while studying the system dynamics:

- analysis of a transient process while starting;
- analysis of a transient process in the context of safety machine braking and service braking.

The studies were carried out within a ground ropeway with hydrostatic drive widely used in the world practices of underground coal mining. Fig. 1 demonstrates its functional chart.

To analyze processes taking place within the device, it is convenient to represent it in the form of aggregate of crucial components joined by means of connections.

While compiling the calculation scheme of mechanical portion of GRW, the following was assumed: availability of a chain with the increased flexibility (of a rope) within the ground ropeway makes it possible to consider friction wheel and mechanical transmission of a drive as an absolutely rigid component of the system; flexibility of the car couplings is not considered making it possible to consider the train as an absolutely solid body (concentrated mass) [5, 6]; aerodynamic forces of resistance to the train motion are not involved due to relatively minor velocity of the train and airflow; forces resisting to the train motion and a rope are assumed as those being proportional to standard pressure and are involved by coefficients of motion resistance which cannot distort physics of the process; weights of support rolls and actuating rolls have been referred to as the traction rope weight; weights of pull side of the rope and down-leg side of the rope have been considered according to the method of linear and piecewise approximation [7] which makes it possible to consider wave processes within the rope; the rope rigidity remains constant during unstable motion since the processes under study experience insignificant variations; the rope moving along the rolls is taken as flexible viscoelastic uniform-section thread [8]; lateral oscillations do not effect longitudinal ones since the rope has been stretched and placed on the rolls [9, 10].

Taking into account the assumptions, the calculation scheme of the mechanism can be represented in the form of a multi-weight system with elastic couplings. According to the method of linear and piecewise approximation of the rope, its weight is replaced by several (*n*) concentrated weights located within congruent segments of weightless rope; thus, total sum of the weights as well as total rigidity of the segments is equal to total weight and total rigidity. In this form of the machine representation, we obtain a system consisting of nodes in which weights are concentrated; the weights interact as material points, i.e. motions and forces are equal within a contact of two neighbouring nodes. Further, nodes with their contact points are considered, and weight of the train joins the nodes depending upon its location within a mine working.

Fig. 1. Functional chart of GRW:

EE is electric engine; HSG is hydraulic speed gear (hydraulic pump, hydraulic motor, connecting pipelines); M is mechanical (reducing gear, friction wheel, tension station, end block, traction rope and train)

In the context of the research, a velocity of a driving pulley was taken as an input parameter of the system. The velocity depends upon a pump control. The dynamic factor, being equal to the ratio between maximum rope tension (F_{Dmax}) and its steady-state value (F_C), was taken as an output parameter.

Let us consider forces acting on the nodes. Viscoelastic forces within the rope are

$$F_{з} = \begin{cases} 2C_y\left[(x_{PL}-x_1)+\mu(V_{PL}-V_1)-\Delta_B\right], & i{=}1 \\ C_y\left[(x_{i-1}-x_i)+\mu(V_{i-1}-V_i)\right], & 2{\le}i{\le}n{-}1 \\ C_n\left[(x_{n-1}-x_n)+\mu(V_{n-1}-V_n)\right], & i{=}1 \\ C_B\left[(x_n-x_{PL})+\mu(V_B-V_n)-\Delta_H\right], & i{=}n{+}1 \end{cases}, \qquad (1)$$

where x_i is motion of ith node; V_i is velocity of the ith; x_{PL} is motion of a pulley; V_{PL} is the pulley velocity; μ is a coefficient of the rope viscosity; Δ_B, and Δ_H are lengths of the rope within upper and lower tension devices, respectively; C_B, C_n, and C_y stand for rigidity of the last, next to the last, and other sections respectively.

Rigidity of any section of the rope with the exception of the last section and next to the last one is

$$C_y = \frac{E_K F_K}{\left(2L-L_B\right)\left(n-1\right)},$$

where E_K is the elasticity module of the rope; F_K is the sectional area of the rope wires; L is the machine length; L_B is the last section length; and n is the number of nodes.

Rigidity of the next to the last section and the last one is

$$C_n = \frac{2}{1/C_y + 2/C_B}; \quad C_B = \frac{E_K F_K}{2L_B},$$

where L_B is length of the last section.

Weights of the system nodes are

$$m_i = \begin{cases} \dfrac{I_{PL}}{R_{\mathrm{PL}}^2} + \rho^* L_y, & i = 0 \\ \dfrac{\rho^*\left(2L-L_B\right)}{n-1}, & 1 \le i \le n-1 \\ \dfrac{\rho^*\left(2L-L_B\right)}{n-1} + m_b, & i = n_b \\ \dfrac{\rho^*\left(2L-L_B\right)}{n-1} + m_B, & i = n_B \\ \rho^* L_B, & i = n \end{cases}, \qquad (2)$$

where I_{PL} is the inertia moment of rotating components of the pulley, reducing gear, and hydraulic motors; R_{PL} is the pulley radius; m_b is weight of the end block; m_B is weight of the train; n_B and n_b is the number of a node where the train and end block are placed.

"Reduced bulk weight of "rope-rolls" concept" was introduced to take into consideration weight of supporting rolls

$$\rho^* = \frac{\rho b_p + m_p}{b_p},$$

where ρ is bulk weight of the rope; m_p weight of the roll; b_p is a pitch of the rolls arrangement.

Gravity forces of the nodes

$$F_{Bi} = \begin{cases} m_i g \sin\alpha, & 1 \le i \le n_{b-1} \\ 0, & i = n_b \\ -m_i g \sin\alpha, & n_{b+1} \le i \le n \\ -\left(m_1 + m_{TR}\right) g \sin\alpha, & i = n_B \end{cases}, \tag{3}$$

where α is a slope angle of a mine working.

Friction forces

$$F_{TPi} = \begin{cases} w_{?} m_{\text{з}} g \cos\alpha, & 1 \le i \le n \\ 0, & i = n_b \\ \left(m_1 + m_{TR}\right) w_{TR} \cos\alpha, & i = n_B \end{cases}, \tag{4}$$

where $w_к$ is the coefficient of resistance to the rope motion on rolls.

Using d'Alembert method, we obtain the following for i^{th} node

$$m_i \ddot{x}_i = F_i - F_{i+1} + F_{Bi} - F_{TPi}\,\mathrm{sign}\left(V_i\right),$$

where F_i and F_{i+1} are viscoelasticity forces of the i^{th} and $(i+1)^{\text{th}}$ sections; F_{Bi} are gravity forces of the i^{th} section; and F_{TPi} are friction forces of i^{th} section.

To solve equations (1–3), and (4) it is required to introduce initial conditions.

The number of a node where the train is located: $i = n$ (the train is at the bottom); and $i = [(n/2) + 2]$ (the train is at the top).

If $\alpha > 0$ (the train is suspended to the upper branch of the rope)

$$F_{n+1} = F_{HG},$$

where F_{HG} is strength of a tension device.

$$F_i = F_{i+1} - F_{Bi}, \quad 1 \le i \le n;$$

$$x_1 = -\frac{F_1}{2C_y}, \quad n = 1;$$

$$x_i = x_{i-1} - \frac{F_i}{C_y}, \quad 2 \le i \le n-1;$$

$$x_n = x_{n-1} - \frac{F_n}{C_{ï}};$$

$$\Delta_{Í} = -x_n; \quad \Delta_B = 0.$$

If $\alpha < 0$ (the train is suspended to the lower branch)

$$F_1 = F_{HG};$$

$$F_{i+1} = F_i + F_{Bi}, \quad 1 \le i \le n;$$

$$x_B = \frac{F_{n+1}}{C_B};$$

$$x_{n-1} = x_B + \frac{F_n}{C_n};$$

$$x_i = x_{i+1} + \frac{F_{i+1}}{C_y}, \quad 1 \le i \le n-2;$$

$$\Delta_B = x_i; \quad \Delta_H = 0.$$

The developed calculation scheme makes it possible to analyze the processes taking place within the mechanical part of the complicated system of ground ropeway in terms of different modes of its operation, i.e. starting, braking, varying profile overcoming and others.

In accordance with current standards, informational functions, controlling functions, and protective ones are the basic functions of operational and production control of complicated dynamic systems. To coordinate transportation and technological processes of load transfer within curvilinear mine workings with alternating track profile, it is recommended to introduce new information and controlling modules equipped with programmable microprocessor-based controllers into APCS structure being formed.

Specifications involving the availability of control modules with functions of forecasting, control, and consideration of random factors have been formed. It means that they take into account effect of negative factors (i.e. unsatisfactory condition of rail, changes in profile, and others) on the parameters of rock transportation under the conditions of indeterminacy. According to the analysis of production processes connected with GRW rock transportation on zonal underground mine workings from its car loading points to their unloading points, a system of technological operations, being potential automation objects, has been determined.

Fig. 2 represents a scheme of functional structure of automated GRW control adapted to technological processes of rock transportation under actual conditions of a mine environment.

The results of previously carried out research helped determine that to implement the control functions, the information received by GRW operator, should provide:

- centralized control over the operation;
- diagnosis of transportation and technological equipment;
- registration of the process development (option);
- computing and logic functions of informational nature.

It was proved experimentally that under actual conditions of a mine environment, a system of corresponding demands are placed on the listed information functions of GRW ACS. Table contains both functions and a structure of GRW APCS determined according to the carried out research.

The functions of control of rock transportation processes were considered as the basic ones while classifying

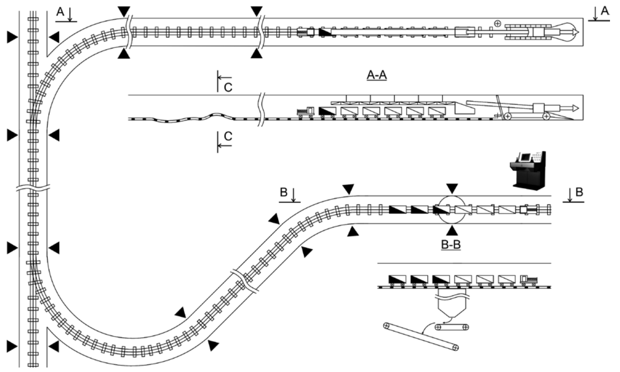

Fig. 2. Functional structure of automated control of technological processes connected with GRW rock transportation:

A – A is car loading of rock; B – B is car unloading points; C – C is a zone of active bedrock heaving; ► ◄ are zones of GRW nodes diagnosis

automation objects in the context of mine district transport application with the use of the ground ropeways.

Formalization of productive structure of automated control of GRW operation modes was implemented in accordance with the listed requirements. Fig. 3 demonstrates the structural and functional scheme of APCS adapted to technological processes of rock transportation under actual mine environment.

APCS of rock transportation involves the following:

- asynchronous three-phase motor (*AM*) to which the shaft drive friction pulley (*FP*) is connected through a gear-box;
- measuring transducer (MT_v) of rotational velocity of a drive friction pulley to transduce it into the normalized output signal of 4–20 mA;
- measuring transducers (MT_F) of tension forces of a rope to transduce them into the normalized output signal of 4–20 mA; they are mounted in the entering drive pulley branch of the rope (F_H) and in the leaving one (F_C);
- variable-frequency drive of the asynchronous motor providing smooth control of its velocity;
- line filter to prevent high-frequency disturbance from its entering the network;
- reversing starter connected to ≈ 660/380 V network through disconnecting device *P*;
- cabinet for manual control of the drive;
- measuring transducers for current, voltage, active power and reactive power, consumed by *AM*, transducing the abovementioned parameters into the normalized signals of 4–20 mA;
- auxiliary controller to provide automatic protection, blocking, and control of the ropeway;
- available manual controller for the drive end;
- computer-based operator control station.

APCS functions are as follows.

Normalized current signals of 4–20 mA enter analogue inputs of the controller; then, they are directed towards an emergency protection unit and a regulatory control unit.

According to the drive pulley velocity, the regulatory control unit compares the incoming signal with the preset one according to a proportional control mode; in terms of a value of the rope tension force, the comparison takes place according to the preset one.

To accelerate the operation and prevent over-loads in the context of power efficiency, the controller is added by a derivative component, acting upon the first derivative of the incoming signal, and integral component, providing the required accuracy of the friction pulley control.

To determine location of the train within the ropeway, regulatory control block involves a controller with the preset travel of the train being determined by means of integration of friction pulley rotational velocity in the context of the whole travel.

Introduction of the regulatory control block makes it possible to adjust the train velocity while starting, in terms of curvature movement and complicated rail sections with the help of programmable velocity controller in the function of current path value. Since the latter ex-

Table

The demands placed on GRW APCS functions and structure

The demands placed on APCS functions with the use of GRW		
Information functions	Control functions	Protective functions
Support of: - centralized control of the operation; - diagnosis of transportation and technological equipment condition; - registration of the process development (option); - computing and logic functions of informational nature	*Regulation of*: - the train velocity; - conditions of interaction between traction rope and pulley as well as with linear components of GRW; - traction force of a drive unit; - supply of cars for their unloading; - a degree of hopper filling with rock; - coefficient of a mine car volume use; - program and logic control of GRW staring and braking according to the set algorithm	*Support of*: - remote control of the rolling stock; - automated control of stops and faults; - protection of GRW traction member and a drive against over-loads; - GRW maintenance under emergency conditions
Requirements for the structure		
A system of upper level	A system of middle level	A system of lower level
Automated operator working area on the basis of industrial computer with the applied software [11]	Main controller for technological process of rock transportation, equipment of loading-unloading points and emergency protection (EP)	Means of instrumentation and control equipment (ICE)

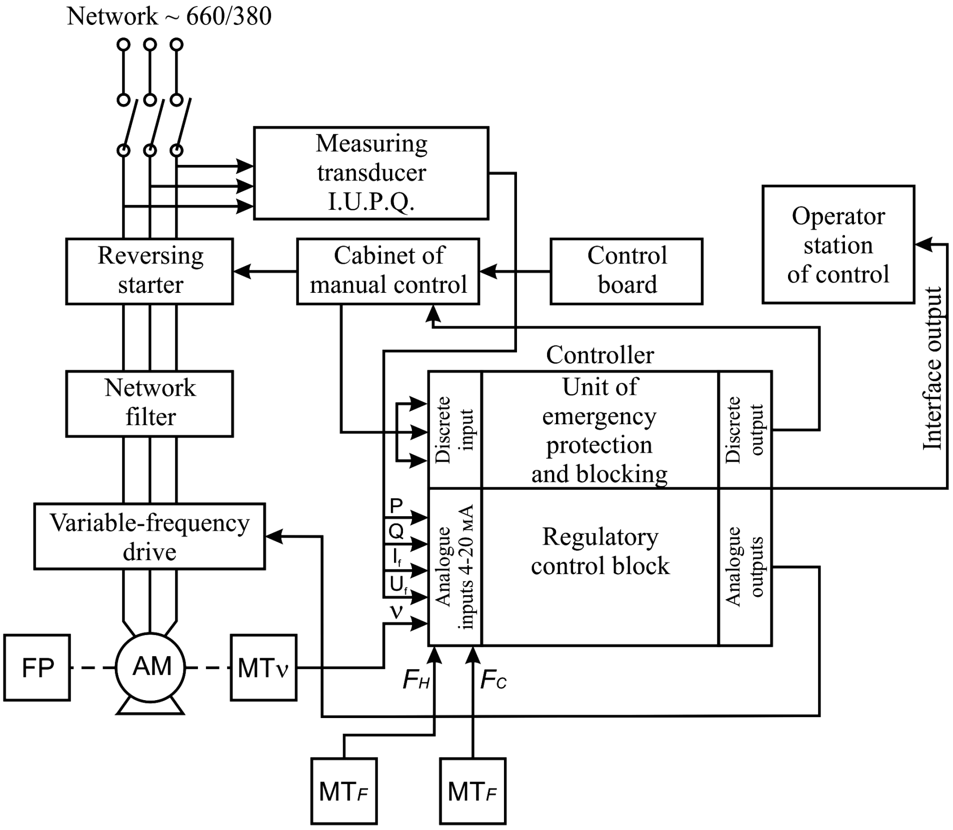

Fig. 3. Structural and functional scheme of APCS

periences its alternations with the working area advance, then operator will have the possibility of its manual introduction into the control system as well as the correction of location of areas with negative process events.

The design of the regulatory control block should provide free increasing of the capabilities in the process of the system upgrading. For instance, according to the results of the studies, it was recommended to introduce auxiliary module of automated control concerning changes in the motor parameters into the active scheme to control a drive ДКНП-1.6. The module is based upon current transducer ДТА-1; it provides sustainable operation of the system under actual mine environment. At the same time, formation of energy-saving approaches involved the necessity to carry out a number of specific studies to substantiate the expediency of introducing extra functions of automated control of processes of rock unloading from mine cars to a hopper.

According to the carried-out studies, traction GRW ropes have high coefficient of relative faults (0.2) and their service length is from several months to a year resulting in significant cost and decreased transportation safety. In this context, basic reasons of short duration are:

- substantial bending stresses whose decrease is possible within the restricted area owing to the increase in the diameters of pulleys, blocks, and rolls as well as to the decrease in the diameters of the rope wires;
- fatigue failure due to the oscillatory process with high dynamic factor arising in transient modes when each oscillation acts as a cycle of wire loading.

Results. To estimate unbalance movement of GRW train, such a notion as "a train unbalance movement coefficient" (K_V) is applied. The coefficient is being determined as a ratio between the current train velocity within transient operation mode and its steady-state value. The paper has analyzed the effect of a law of a driving pulley velocity variation while starting (parabolic, expotential, and linear) on the value of the coefficient (Fig. 4, *a*). As a result, an optimum one (i. e. linear) has been determined when the unbalance is minimal. Dependences for its different starting periods have been obtained (Fig. 4, *b*).

Analysis of the developed mathematical model of working processes of GRW has made it possible to determine the following dependence: in the context of starting period, being equal to a semi-period of natural oscillations of the system ($t_P = T_C$), the oscillation process within the rope almost damps after the first amplitude which is impossible in the context of any other ratio of theirs ($t_P < T_C$ or $t_P > T_C$). The effect has been supported by mine experiments with the sufficient degree of the results repeatability. Moreover, it is illustrated by means of dependence graphs of the system dynamic coefficient being the ratios between the maximum force value within transient mode and its steady-state value from the starting period (Fig. 5).

It is known, that a period of harmonic oscillation of load on elastic chain is [10]

$$T = 2\pi\sqrt{\frac{ml}{EF}} \quad \text{then} \quad T_C = \pi\sqrt{\frac{ml}{EF}},$$

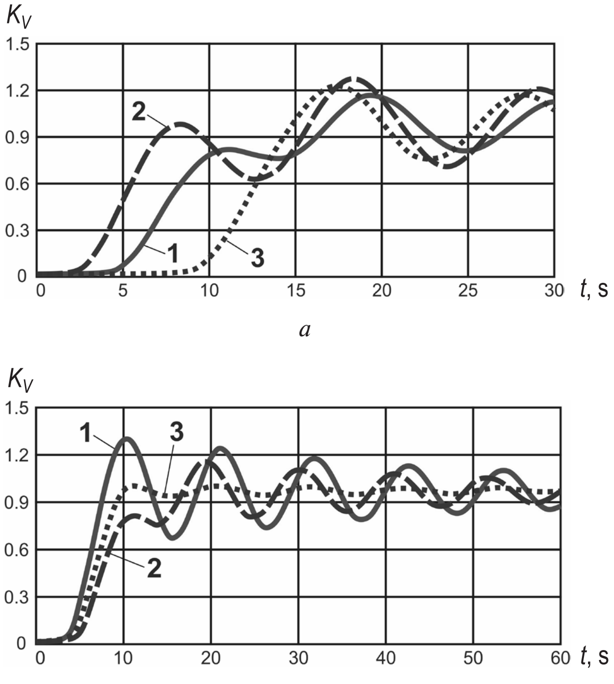

Fig. 4. Coefficient of a train unbalance movement:

a is a pulley velocity change in terms of laws: 1 – linear; 2 – parabolic; 3 – exponential; b is for long-term acceleration: 1 – $t_P < T_C$*; 2 –* $t_P > T_C$*; 3 –* $t_P = T_C$

where *m* is a load weight; *l* is a length of a rope to the load; *E* is elasticity module of the rope; and *F* is an area of the rope cross section.

Since in the context of specific rope values of module of the rope elasticity *E* and areas of its cross section *F* are constant [9], and the proposed system determines length of the rope to a load automatically, the train weight is the only unknown value. It can be identified rather accurately on the force of the rope tension within the corresponding area of diagnosis of the GRW nodes. However, the authors believe that it would be more suitable if the information concerning the number of cars within the train and their state (i.e. they are empty or loaded) is introduced by an operator manually. Relying upon the obtained information, the regulatory control block sets required acceleration when the starting period is equal to the semi-period of natural oscillations of the system ($t_P = T_C$) which will minimize oscillation amplitude. Moreover, to prevent the traction rope from over-loads in the process of its operation and to preserve its aggregate strength, it is required to introduce preliminary maximum value of tension force (i.e. 90 % of its breaking tension) into the regulatory control block. The value is compared with current values of forces F_H and F_C. If they are equal, the drive is disconnected and operator obtains related information.

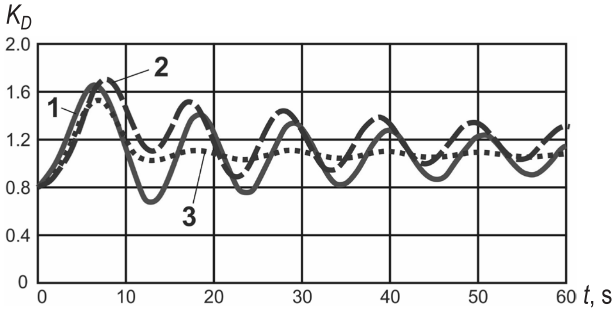

Fig. 5. The effect of the acceleration pulley period on the oscillatory process within the system (force within traction branch of the rope):

1 – $t_P < T_C$*; 2 –* $t_P > T_C$*; 3 –* $t_P = T_C$

Conclusions. Basing upon the carried-out studies, it may be concluded that:

- ground ropeways are both efficient and reliable transportation means for rock mass, auxiliary materials, equipment and personnel in mines;
- current designs of heavy-type GRWs for rock mass transportation, characterized by changes in route and weights of trains in the process of construction of mine workings, should be equipped with automated control system;
- it has been proposed to introduce the functions control of starting period into the system depending upon transportation distance, weight of train and restriction of maximum forces within a rope with the use of modern element base making it possible to extend a life cycle of a traction rope substantially while reducing expenses connected with its replacement as well as transportation prime cost on the whole;
- the developed structure of automated control system may be adapted successfully to any transportation plant with closed traction rope (i.e. rope monorails, rope underground railway).

Acknowledgements. “Scientific foundations to form unified system of energy saving and generating in the context of the objects of fuel and energy complex of Ukraine”, ГП-489 (# ДР 0117U001127) and “The development of background technology for environmentally friendly mineral extraction in the context of technogenically loaded mining regions of Ukraine”, ГП-496 (# ДР 0117U001134).

References.

1. Rastsvetaiev, V.O., 2014. Additional load on arch support of mine workings by overhead monorail roads in the context of mines in Western Donbas In: M.S. Poliakov Institute of Geotechnical Mechanics of the NAS of Ukraine, 2014. *Geotechnical mechanics: Inter-institutional collection of papers*. Publication 117, pp. 53–59.

2. Denyshchenko, O.V., Posunko, L.N., Shyrin, A.L. and Kechin, M.A., 2015. Improving the efficiency of ground ropeways while constructing mine site development mine workings. *Collection of scientific papers of the NMU*, 46, pp. 159–168.

3. Babina, O.I., 2015. Review of simulation models while planning in the context of enterprise. *Fundamental studies*, 12–6, pp. 1173–1178.

4. Meshcheriakov, L.I. and Shyrin, A.L., 2013. Technological substantiation of a structure of automated system to control the processes of rock transportation by means of Ground ropeways. *Collection of scientific papers of the National Mining University*, 43, pp. 71–78.

5. Koptovets, O.M., Koroviaka, Ye.A., Diachkov, P.A., Yavorska, V.V. and Samusia, C.V., 2013. Modeling controllable mine train operation. In: *Mining electromechanics and automation: Scientific and technical collection of papers. National Mining University*. Publication 91, pp. 105–110.

6. Bartashevsky, S. Ye., 2013. Improving the design of braking system of a mine electric locomotive. *Collection of scientific papers of the National Mining University*, 43, pp. 66–70.

7. Kazachenko, G. V., Balasai, G. A., Rusak, A. O. and Eliasov, M. A., 2013. Features of face conveyors calculation. *Collection of scientific papers BNTU*, 1, pp. 473–478.

8. Osipova, T. N. and Nesterov, A. P., 2014. On the dynamics and optimization of mine hoists. *Mashynobuduvannia*, 13, pp. 74–79.

9. Shvagunov, A. S., Dorokhov, N. Yu., Perig, A. V. and Stadnik, A. N., 2014. The simulation of load handling in case of rope breakage on bridge cranes. *Messenger of Kharkiv National Vehicular-Road University*, 65–66, pp. 185–188.

10. Podlesny, S. V., Stadnik, A. N. and Larichkin, A. V., 2015. Modeling of dynamics of electromechanical systems. *Messenger of Donbas State Machine-Building Academy*, 3, pp. 171–176.

11. Pivnyak, G., Dychkovskyi, R., Smirnov, A. and Cherednichenko, Y., 2013. Some aspects on the software simulation implementation in thin coal seams mining. *Energy Efficiency Improvement of Geotechnical Systems*, pp. 1–10. DOI: 10.1201/b16355-2.

Формування структури автоматизованої системи керування канатними надґрунтовими дорогами важкого типу

О. В. Денищенко, А. Л. Ширін, В. О. Расцвєтаєв,
О. В. Черняєв

Державний вищий навчальний заклад „Національний гірничий університет“, м. Дніпро, Україна, e-mail: alexxden097@gmail.com

Мета. Обґрунтування ефективної структури автоматизованої системи керування канатними надґрунтовими дорогами важкого типу на основі аналізу розрахункової схеми.

Методика. Теоретичні дослідження математичної моделі канатної шахтної дороги для встановлення закономірностей формування динамічних зусиль у ланках доріг канатних надґрунтових (ДКН) у перехідних режимах роботи та експериментальні дослідження установки в шахтних умовах з використанням оригінальної апаратури.

Результати. Обґрунтована структура автоматизованої системи управління канатними надґрунтовими дорогами важкого типу, що дозволяє істотно підвищити їх продуктивність і безпеку експлуатації, запропоноване введення до неї додаткових функцій.

Наукова новизна. Уперше встановлена залежність коефіцієнта динамічності ДКН від часу розгону з урахуванням періоду власних коливань системи й запропоновано спосіб мінімізації динамічних зусиль у канаті.

Практична значимість. Уведення до структури автоматизованої системи управління функцій регулювання тривалості пуску в залежності від відстані транспортування, маси та обмеження максимальних зусиль у канаті з використанням сучасної елементної бази дозволяє істотно збільшити термін служби тягового каната і, тим самим, знизити витрати на його заміну й собівартість транспортування у цілому, а також підвищити продуктивність установки та безпеку її експлуатації в підземних умовах.

Ключові слова: *канатна дорога, система управління, автоматизація, динаміка, коливання, довговічність*

Формирование структуры автоматизированной системы управления канатными напочвенными дорогами тяжелого типа

А. В. Денищенко, А. Л. Ширин, В. А. Расцветаев,
А. В. Черняев

Государственное высшее учебное заведение „Национальный горный университет“, г. Днепр, Украина, e-mail: alexxden097@gmail.com

Цель. Обоснование эффективной структуры автоматизированной системы управления канатными напочвенными дорогами тяжелого типа на основе анализа расчетной схемы.

Методика. Теоретические исследования математической модели канатной шахтной дороги для установления закономерностей формирования динамических усилий в звеньях дорог канатных напочвенных (ДКН) в переходных режимах работы и экспериментальные исследования установки в шахтных условиях с использованием оригинальной аппаратуры.

Результаты. Обоснована структура автоматизированной системы управления канатными напочвенными дорогами тяжелого типа, позволяющая существенно повысить их производительность и безопасность эксплуатации, предложено введение в нее дополнительных функций.

Научная новизна. Впервые установлена зависимость коэффициента динамичности ДКН от времени разгона с учетом периода собственных колебаний системы и предложен способ минимизации динамических усилий в канате.

Практическая значимость. Введение в структуру автоматизированной системы управления функций регулирования продолжительности пуска в зависимости от расстояния транспортирования, массы и ограничения максимальных усилий в канате с использованием современной элементной базы позволяет существенно увеличить срок службы тягового каната и, тем самым, снизить затраты на его замену и себестоимость транспортирования в целом, а также повысить производительность установки и безопасность ее эксплуатации в подземных условиях.

Ключевые слова: *канатная дорога, система управления, автоматизация, динамика, колебания, долговечность*

Рекомендовано до публікації докт. техн. наук В. І. Бузилом. Дата надходження рукопису 30.05.17.