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TECHNICAL CONDITION OF MOVABLE RAILROADS AND EFFECT ON TECHNOLOGICAL PARAMETERS OF COMBINED OPERATION OF RAILROAD HAULAGE AND BUCKET WHEEL EXCAVATORS

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ABSTRACT
Disadvantages of recently applied dependencies for assessment of the effect of movable rrailroads on the main technological parameters are analyszed. A probablistic approach for that study is suggested and the bases of formulas, allowing the quantitative assessment are developed.

INTRODUCTION

The following disadvantages may not be disregarded when the formulas, known from technology, are applied to a study of the effect of movable railroads on the main parameters of haulage transport and opencast mines in the combined work of railroad transport and bucket wheel excavators:

- Impossibility to read the indeteremined character of processes described by those formulas;
- Not considering the probabilistic character of speed of movement of trains and movable railroads, in particular;
- Impossibility for connecting the system excavator – train + railroad in a single technological structure etc.

On the other hand, the technological condition of movable railroads depends on the actual deviation of railroads from the position, determined by the project. Factors, which effect on the value of that deviation, are many. The most important factors may be grouped as follows:

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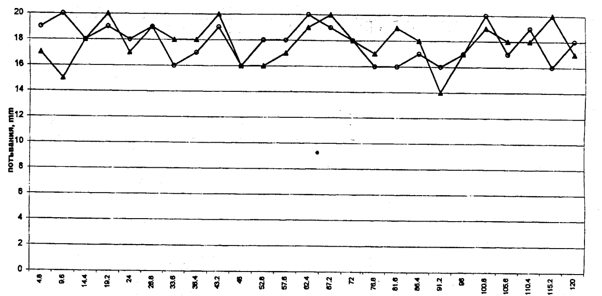

Figure 1. Response of hidden settlements of railroads in the area of bucket wheel excavator RS-2

- Visible and open settlements in the vertical plane. That brings to mudding of the ballast gravel bed immediately in or near the zone of hidden settlements, breaking of road in the zones of joint connections, loosening and breaking of joining connections between rails and sleeves etc. Figure 1 shows the results of measured hidden settlements in a vertical plane for an excavator RS-200 at tthe "Troyanovo" mine and shows the results from an investigation managed by Prof. D. Stoyanov at the same mine in October 1997.
- Visible and hidden deformations in a horizontal plane. That brings to disturbing of distance between rails. (more than 1435 mm), loosening and breaking of connectng joints between rails and sleeves, intensification of lateral wearing out of rails, deviation from the axis of road (destruction) etc. Those deviations from the designed position reduce the reliability of road and require reduction of speeds of trains;

Fig. 2 illustrates the visible deformations in a horizontal plane. They were measured in Ovtober 1997 by a team managed by Prof. Stoyanov in the area of spreader AS 1600 (inventory No 3) in a curved section of the out dumping site at the "Troyanovo-sever" [2].

- Torsion of road round its axis. This is achied due to irregular settlement (visible and hidden) in both rails simulataneously in one and the same cross-section of road, i.e. one and the same sleeve or one and the same area between sleeves.

Figure 3 shows hidden settlements in the area of the same spreader AS-1600, measured and descrbed in the project of D. Stoyanov [2]. Hidden settlements are measured within distances, corresponding to distances between wheel axis of dump-cars. Torsion of road in the middle of the response is evident. It comprises four intervals (five measurements)

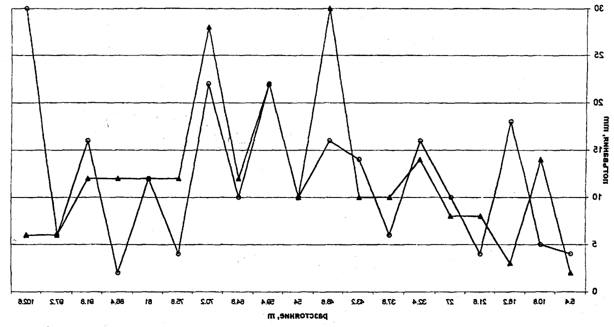

Figure 2. Response of visible settlements of rails in the area of spreader AS-1600, No 3

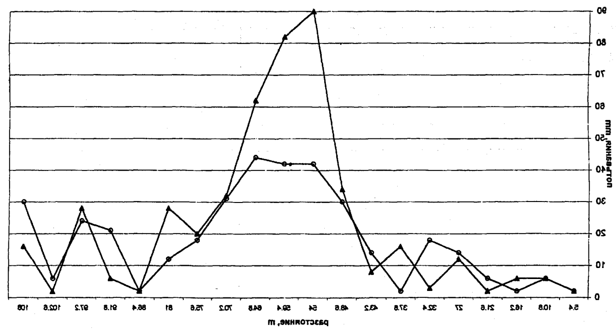

Figure 3. Response of hidden settlements of rails in the area of spreader AS-1600, No 3

Joining of first two to torsion is most often in the basis of derailing of railroad vehicles, i.e. failures of movable railroads.

On the third hand, the real technical condition of movable railroads limits the speed of movement of trains along them. In other words, speed is a synthethic factor, which is a result of all deviations (faults) of the deisgn position of the road. Characteristics of those lines in the layout and profile allow speed up to 45 km/h (according to project of Atanas Smilianov "In-company regulations for moving, maintenance and repair of movable railroads" [3]), but in practice they are limited as follows:

- at the "Maritsa-East Mines" EAD – not more than 25 km/h;
- in the other three mines– not more than 8 km/h in the direction "full" and not more than 12 km/h in the direction "empty".

Considerations are developed below, which establish the functional connection of technical condition of movable railroads (shown by speed of movement) to he main technological parameters in case of joint work of railroad haulage with bucket wheel excavators on the basis of probabilistic approach, aiming to overcome the disadvantages, discussed in the beginning of the introduction.

MAIN PRECONDITIONS

The discussion below presented refers to the common work of a bucket wheel excavator and railway haulage with spreader. The following preconditions are supposed to act:

First:

The performance of production assignment is a priority for the shift, month, year etc. for the system excavator – train – railroad, because it brings to the realization of production assignment.

Second:

Both the system excavator and the system train – railroad refer to the man-machine class of systems, characterized with a high rate of indetermination.

For the system excavator – the productivity is limited by a multitude of factors (constructive, mining, climatic, organization etc.), and the connection between them is different. For example, connection between productivity and constructive factors is functional and connection to other factors is stochastic.

The operator of excavator as a unit of the man-machine system works according to a fuzzy algorithm. The sense of fuzziness consists in the fact that he selects the strategy of his actions alone, which usually does not coincide with preliminary instructions.

Productivity of the system train + railroad is limited by many factors – constructive, mining, organizational etc. and connection is also different. Functional is connection only between volume of bucket of cars and their number in the train. Connection of other factors is also stochastic.

Operator of the excavator as a unit of the man-machine system also works according to a fuzzy algorithm. For example, led by feeling of technical condition of road, cars and locomotives, he changes he speed within wide ranges.

Third:

Treating of the technological structure excavator – train + railroad as a system of continuous transporting line is advisable for assessing its functioning. That is admissible, if the time for realization of train route, calculated in technological accounts as (1)

$$t_{к} = t_{т} + t_{мп} + t_{пп} + t_{р} + t_{техн.п} + t_{др.з} \qquad (1)$$

and it is treated as a failure of the system. From a formal point of view, the above outlet is admissible, because if the excavator is served by only one train compostion, then the excavator does not work during the complete route of train, i.e. the subsystem excavator does not work, it is failed.

$t_{т}$ – time for loading of train, h;

$t_{мп}$ – time for train movement (full and empty) along movable railroads in the mine and the dumping are for each specific route is

$$t_{мп} = l^{з}_{мп}\left(\frac{1}{V^{з}_{мп.п}} + \frac{1}{V^{з}_{мп.пр}}\right) + l^{н}_{мп}\left(\frac{1}{V^{н}_{мп.п}} + \frac{1}{V^{н}_{мп.пр}}\right) \qquad (2)$$

where: $l^{з}_{мп}$ и $l^{н}_{мп}$ are the lengths of movable railroads in the faces of the dumping area;

$V^{з}_{мп.п}$, $V^{з}_{мп.пр}$, $V^{н}_{мп.п}$ и $V^{н}_{мп.пр}$ are speeds for moving of train along those sections for the full and the empty train and the are coordinated with [3];

$t_{пп}$ is time for moving of train on constant railroads on the same route from the face to the dumping site. It is shown by the expression (3),

$$t_{пп} = \sum_{j=1}^{m}\left(\frac{l_j}{V_п} + \frac{l_j}{V_{пр}} + 0,025\right) \tag{3}$$

where $\sum l_j$ is the total length of constant railroads along the route;

$V_п$ and $V_{пр}$ are speeds of movement in direction "full" and direction "empty",

0,025 – factor, reading the time needed for connection to the Central Base;

$t_р$ is the time for unloading at the receiving point at hopper (power plant, dressing factory, briquetting factory) or receiving pit. It depends on the faultless work of compressors, air-conducive systems and pneumatic unloading systems. It is relatively constant for a train with constant number of cars and locomotives and follows the expression:

$$t_p = n_в.t_p, h \tag{4}$$

where $t_р$ is the time for unloading of one car, h (for the summer this is 1,5-2 min, for winter - 3 min).

$t_{техн.\ п}$ is the time for inevitable technological idle time and depends on the route, rail interdistance, installations and fault-free operation of the opening/closing of arrows, type of railroad transportation schemes, $t_{др.з}$ comprises the time for other idle time of any kind. The highest is the share of idle time for removing of faults on the road, cars etc.

PROJECT FOR CONSTUCTION OF PROBABILISTIC APPROACH FOR ESTIMATION

Those precondition allow the use of a set of formulas, developed in the theory of reliability and adapted to large engineering systems, like those in opencast mines ([4], [5], [6], [7] etc.), consisting of mutually interrelated individual engineering subsystems. The system of excavator – train – railroad may be treated like one of those.

The below formulas are referred to a long period of time, for example an year. Having in mind that the technical productivity of the excavator is a variable value (see part II) than the annual productivity may be expressed by (5).

$$Q_{год} = \sum_{i=1}^{n} Q_{техн.(i)}.t_{p(i)}, m^3/a \tag{5}$$

where:

$Q_{год}$ - annual productivity of the excavator, given by the planned schedule ;

$Q_{техн.(i)}$ - technical productivity of the excavator, corresponding to its $i^{-то}$ working condition. It is a function of many factors, described in part II.

n – number of possible conditions, where the excavator is during the year, characterized with the relevant productivity;

$t_р(i)$ – total duration of working time for the $i^{-то}$ condition of the object during the calendar year.

In fact, the times $t_р(i)$ represent a portion or a percentage of the total annual fund of working time of the excavator, i.e.. $t_р(i)$ = $t_р$.n% or

$$t_{p(i)} = t_p.P\left[t_{p(i)}\right] \tag{6}$$

In (6) $P\left[t_{p(i)}\right]$ is the probability that the excavator is in the $i^{-то}$ condition of probability.

Then the equation (5) may be represented as follows:

$$Q_{год} = t_p.\sum_{i=1}^{n} Q_{техн.(i)}.P\left[t_{p(i)}\right], m^3/a \tag{7}$$

According to [4], [5], [6], [7] etc. the distribution of the calendar time during the year, when the bucket wheel excavator works as a technologically combined subsystem excavator – train – railroad is structured into three parts::

$t_p, h -$ total time for continuous work of the system during the calendar year (pure working time);

$t_{об}, h -$ time for technological servicing of the system.

$$t_{об} = t_{ппр} + t_{пр.пр.см.} + t_{пр}, h \tag{8}$$

Those times respectively are:

$t_{ппр.см.}, h -$ time for planned preventive repairs;

$t_{пр.пр.см.}, h -$ time for changing the shifts. Within one day this time is regulated to be 1h.;

$t_{пр.}, h -$ time for compulsory reviews of specific units and aggregates;

$t_{в.}, h -$ time for recreation of the system from non-working into working condition. It consist of:

$$t_{в.} = t_{техн.пр.} + t_{орг.пр.} + t_{ав.пр.} + t_{др.з} \tag{9}$$

Those time respectively are:

$t_{техн.пр.}, h -$ the excavator works but does not realize volumes, change of new positions, waiting of trains, auxiliary operations etc.

$t_{орг.пр.}, h -$ idle time for various organizational reasons;

$t_{ав.пр.}, h -$ idle time for removing the accidents in the subsystem excavator – train – railroad;

$t_{дг.з.}, h$ – time, for which the excavator does not produce for various reasons different from the above: strikes, misfortune etc.

In the case the following expression is valid for the following annual calendar period of time.

$$t_{к.} = t_p + t_{об.} + t_в, h \qquad (10)$$

where: $t_{к.}, t_p, t_{об.}$ и $t_в$ are respectively the annual calendar period of time, pure working time of the sub-system, time for technological service and time for recreation.

According to the above quoted sources each large system for continuous period of time characterizes with the coefficient of readiness $K_г$.

$$K_г = \frac{t}{t_к - t_{об}} \qquad (11)$$

where:
t_p – pure working time of the subsystem excavator – train – railroad;;
$t_{об}$ – time for servicing of the subsystem.

Time for servicing of the subsystem ($t_{об}$) may be represented through the coefficient of servicing:

$$K_{об} = \frac{t_к - t_{об}}{t_к} \qquad (12)$$

the meaning of this is the time, for which the system is not served.

The coefficients $K_г$ and $K_{об}$ allow the annual calendar fund of time to be expressed as:

$$\frac{t_p}{K_г} = t_p + t_в \qquad (13)$$

When reading that from (12), $t_{об}$ may be expressed as :

$$t_{об} = t_к\left(1 - K_{об}\right) \qquad (14)$$

It may be easily proved that between the times for (10) and coefficients $K_г$ and $K_{об}$ tyhere is a connection:

$$t_p = t_к.K_г.K_{об} \qquad (15)$$

In that case, for the annual productivity the following is valid:

$$Q_{год.} = \sum_{i=1}^{n} Q_{техн.(i)}.t_{p(i)}.t_к.K_г.K_{об}, m^3/a \qquad (16)$$

Expressions from (5) to (16) are in the basis of mathematical methods, studying the technological peculiarities of line systems.

In the case above described, when movement of train along the route is considered as a specific failure of the system, it is in fact transferred from cyclic into continuous. Considering the opportunities for the excavator to work in "n" massifs with "m" different characteristics (hardness, bulk weight, humidity, cohesion, angle of inner friction etc.), the equation (16) may be written as follows::

$$Q_{год} = t_к.K_г.K_{об}\left(Q_{техн.(1)}.m_1\% + Q_{техн.(2i)}.m_2\% + ... + Q_{техн.(n)}.m_n\%\right), m^3/a \qquad (17)$$

On the other hand, the readiness for work of the technological structure, consisting of consecutively related systems (like the discussed sub-system excavator – train – railroad) for significantly continuous period of time (year, for example) is expressed by the coefficient of readiness of the whole system. Its structure according to [4], [5] etc. is represented by (18).

$$K_г = \left[\sum_{i=1}^{n} \frac{1}{K_{г(i)}} - (n-1)\right]^{-1} \qquad (18)$$

The type of formula (18) is easily transformed into (19)

$$K_г = \frac{1}{1 + \sum_{i=1}^{n} \frac{1 - K_{г(i)}}{K_{г(i)}}} \qquad (19)$$

which is much more convenient to work with. That is because in (19) each of the consecutively related elements in one technological structure like the structure of excavator – train – railroad acquires an individual presence by its individual coefficients of readiness. The prove is in the development of the nominator in the expressions (20):

$$1 + \sum_{i=1}^{n} \frac{1 - K_{г(i)}}{K_{г(i)}} = 1 + \sum_{i=1}^{n}\left[\frac{1}{K_{г(i)}} - 1\right] = 1 + \sum_{i=1}^{n} \frac{1}{K_{г(i)}} - \sum_{i=1}^{n} 1 =$$
$$= 1 + \sum_{i=1}^{n} \frac{1}{K_{г(i)}} - n = \sum_{i=1}^{n} \frac{1}{K_{г(i)}} + 1 - n = \sum_{i=1}^{n} \frac{1}{K_{г(i)}} - (n-1) \qquad (20)$$

The last expression in (20) is completely adequate to the denominator in (18).

In that case the pure working time for the years of the technological structure excavator – train – railroad is:

$$t_p = t_к.\frac{t_к.K_{об}1}{1 + \left(\frac{1 - K_г^б}{K_г^б} + \frac{1 - K_г^{вл}}{K_г^{вл}} + \frac{1 - K_г^{пп}}{K_г^{пп}} + \frac{1 - K_г^{мп}}{K_г^{мп}}\right)} \qquad (21)$$

Therefore, the main task of that paper – to reason the opportunity through the apparatus of probabilistic approach to show the effect of movable railroads on technological parameters (the example shows the annual productivity) has been fulfilled.

ASPECTS OF THE ASSESSMENT OF EFFECT OF TECHNICAL CONDITION OF MOVABLE RAILROADS

The authors have been working on that idea for long. In spite of that there are no enough data to prove the unimeaning decisions. For that reason, below is presented the essence of the idea for assessment of technological condition and coefficient of readiness of railroads in the conventional railroads of Russia. The reason is in the high values of loading of railroads in Russia in comparison to high values of loading at the "Maritsa-East" mines Co for the movable railroads. The treated Russian approaches are adopted in Poland, the Czech Republic, Hungary, Romania and recent members of CIS.

The idea consists in the fact that technical condition of railroads is controlled and predicted through the norms of consumption of materials (rails, sleeves, joints etc.) The presumption is that expenses for those resources for current maintenance increases with the aging of the road after its previous innovation (capital repair). The approach is based on the theory of reliability and binds the number of failures of all the elements of the upper structure and general technical condition of road. The idea is laid down in [8], developed in [9], [10], [11], [12] etc. Its meaning is illustrated in fig. 4and is used a basis for different principles of accumulation of deformations in both media – upper and lower structure, and therefore, different intensity and different intensity of their norms of failure.

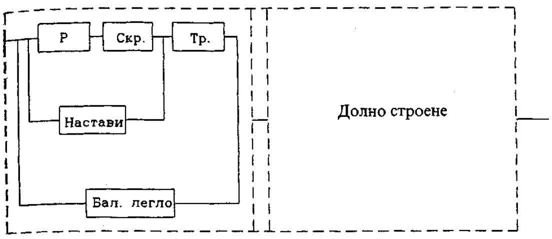

Figure 4. Illustration of binding of failures of elements of the upper structure of the railroad

It is proved in ([10], [11] etc.), precisely enough for the practice, that failures in the all the structural elements of the upper structure may be described by functions of the type

$$A = B + C.T^t \qquad (22)$$

where:
T – loading;
t – exponent, showing the norms of amortization for term of service of specific elements;
B, C – empirical coefficients, obtained by the root-mean-square methods after processing the statistical data for failures.

An exception is the ballast gravel bed, where A of (22) characterizes the norm of contamination for bulk weight.

It should be mentioned that (22), referred to rails and joints has a coefficient B = 0, which means that the function starts from the beginning of the coordinate system. This is related to the highest requirements for them in comparison to the other elements.

In [9], [10] and [11] the norm of failure is referred to the real one and the coefficient of reliability of elements of the upper structure is obtained. In fact this represents the probability for the system not to give a failure because of the failures of it specific elements:

$$P_{жсп}(t) = P_p(t).P_{скр}(t).P_н(t).P_{тр}(t).P_б(t) \qquad (23)$$

where: $P_{жп}(t)$ – probability for failure of construction of upper structure and the railroad;
$P_р(t)$, $P_{скр}(t)$, $P_Н(t)$, $P_{тр}(t)$, $P_б(t)$ - probabilities for failures of rails, joints, sleeves and ballast gravel, respectively.

It is worth mentioning that this part of the issue has not been developed. The reason consists in the extremely high responsibilty, related to mathematical formalization of the probabilistic failure in the railroad. However, all the authors support the opinion that recent construction of upper structure has a high rate of reliability and each subsequent change has to increase the reliability without making the structure more expensive – [10], [11] etc., approximating to he reliability to one, and the risk of failure – to zero.

Furthermore, up to now there are no decisions, bringing to quantitative characteristics for determining the reliability of lower structure of railroad.

In the sense of the above mentioned, and the developed opportunity for assessment of technical condition of the system – excavator – train – railroad of (19) and in particular movable railroads in their common work with railroad haulage with bucket wheel excavators – following (21) the authors using formulas (11) and (12) derived a representative number of data from the dispatching inventory lists of mines "Troyanovo" and "Troyanovo – sever".

Data are processed according to methods of statistical modeling and the idea is to acquire preliminary information for parameters of both coefficients for each elemet of the subsystem excavator – train – railroad and to acquire the real value for the pure working time, according to (21).

Results will show the importance of the idea.

CONCLUSIONS

1. Representing the effect of technical condition of movable railroads on main technological parameters of opencast mines is shown by an approach based on probabilistic methods. That will give an opportunity for more realistic planning of a technically achievable calendar fund of working time for the mining equipment – bucket wheel excavators and enhance the rate of complete utilization.
2. The ideas will be easily adopted into technological practice, if the authors make the ideas closer to classical differentiation of working time of mine equipment. That means "specifying" from a point of view of technology the expreessions (8) and (9) and appearance of another member in (10), and therefore – e coefficient of the structure like (11 and (12).

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