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ON THE PROBABILISTIC CHARACTER OF HAULAGE FOR ROUTES WITH MOVABLE RAILROADS

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ABSTRACT:
Movable railroads are in both ends of routes of the technologic haulage: beginning– at overburdening or mining areas and ending – at dumping areas or receiving stations. It is shown how routes may be found at different levels of intensity depending on probability of working condition, which predetermines the probabilistic character of provoked deformations in movable roads.

The movable railroads are unique facilities, typical and applicable only to opencast mines equipped with technological railroad haulage. Their effect on continuity of haulage is crucial and depends on their technical condition. This is so, because it determines the speed of movement on them.

On the other hand, it is subjected to the probability of haulage on one and the same routes, where the movable railroads are at the both ends: beginning – in overburdening or faces and ends – dumping areas, depots in intermediate storage, receiving devices.

The overall efficiency of the performance of the large engineering system "opencast mine" is limited by the probability of failure-free performance of its subsystems, including the subsystem "railroad haulage". The probability of failure-free performance, according St. Irinkov in "Automation of technological processes in opencast mines" [1], may be presented as follows:

$$P_{жп}(t) = P_{пс}(t).P_{прп}(t).P_{мрп}(t).P_{мо}(t).P_{рп}(t) \qquad (1)$$

or

$$P_{жп}(t) = k_1.e^{-\lambda_1 t}.k_2.e^{-\lambda_2 t}.k_3.e^{-\lambda_3 t}.k_4.e^{-\lambda_4 t}.k_5.e^{-\lambda_5 t} \qquad (2)$$

where:
$P_{жп}(t)$ – probability of failure-free performance of the subsystem railroad haulage, treated as an independent system;
$P_{пс}(t)$ – probability of failure-free performance of movable railroad haulage components – locomotives and cars;
$P_{прп}(t)$ – probability of failure-free performance of the railroad haulage caused by the constant railroads;
$P_{мрп}(t)$ – probability of failure-free performance of the railroad haulage caused by the movable railroads;
$P_{мо}(t)$ – probability of failure-free performance of the railroad haulage caused by maneuver operations;
$P_{трм}(t)$ – probability of failure-free performance of the railroad haulage caused by the loading and unloading stations;
K_i – coefficient of readiness for operation for each separate detail of the transport system.

$$k_i = \frac{T_{ср.р}}{T_{ср.р} + T_{ср.пр}} = \frac{1}{1 + \dfrac{T_{ср.пр}}{T_{ср.р}}} = \frac{1}{1 + k_п} \qquad (3)$$

where:
$T_{ср.р.}$ – average time of efficiency of the independent subsystem railroad haulage (in a shift, in a month etc.);
$T_{ср.пр.}$ – average idle time of trains caused by different reasons.

Equation (3) reveals the physical essence of the coefficient for readiness of the system. When

$$T_{ср.пр} > T_{ср.р}$$

the coefficient of readiness for K_i decreases, i.e. according the value K_i it may evaluate the level of maintenance and repair of all subsystems in the system railroad haulage.

Below, there is an illustration of an example of the railroads of "Kremikovtsi" mine for a more complete differentiation of the probability of railroad haulage – fig. 1.

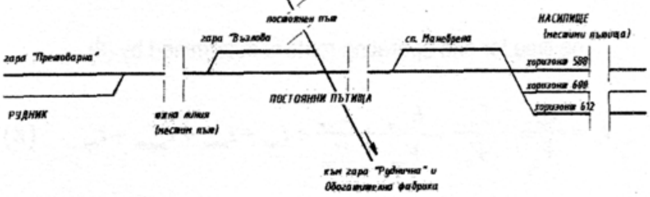

figure1. Principle scheme of railroad network for "Kremikovtsi" mine

The scheme in fig. 1 corresponds to the real production program for the year 2002 and shows the active operating layers (two) of the dumping area and the special depot (called "spetsotval"), also shows two operating tracks – for barite and for ferrous ore.

If we set aside the transport of ore from the mine directly to the ore-dressing plant, there are available four actively operating routes from the mine: two for the layers 588 and 600 into the dumping area and two for the special depot "spetsotval".

The production capabilities of each of routes may be presented as follows:

$$V_{\tau} = \sum_{i=1}^{n} V_i . t_{pi} \tag{4}$$

where:
V_t – volume of transported ore aggregate for a respective period of time of duration t;
V_i – volume of ore aggregate in i-st train-composition (also a probabilistic quantity);
n – number of train-compositions;
t_{pi} – continuousness of time of traffic, i.e accomplishment of a real transport operation i-st train-composition.

If the probability of train-composition **i** being in an operating status is denoted by $P(t_{pi})$, then the probability to find the same in a non-operating status is $1 - P(t_{pi})$.

In such a case for the transport system, including "m" independent haulage flows, the probability to find it at "к" status is expressed by:

$$P.(t_{pc})_k = \prod_{i=1}^{s} P(t_{pi}) . \prod_{1+s}^{m} \left[1 - P(t_{pi})\right] \tag{5}$$

The permission ability of this haulage system in status "к" is:

$$V_{ok} = \sum_{i=1}^{s} V_i \tag{6}$$

In such case the volume of the operation done for a definite calendar period of time "$T_к$" will be:

$$V_{kk} = V_{ok} . T_k . P(t_{pc})_k \tag{7}$$

The result obtained by equation (7) is actually a prognosis for the ability of the haulage system, working with the dumping area and the specific depot "spetsotval".

The time for one operating route is determined by (8)

$$t_p = \frac{L_{м.п}}{V_п} + \frac{L_{п.п}}{V_п} + \frac{L_{м.п.}}{V_{пр}} + \frac{L_{п.п}}{V_{пр}} + t_{мо} + t_{тов} + t_{разт} + t_{др.з.} \tag{8}$$

where:
$L_{м.п.}$ & $L_{п.п.}$ – total lengths of the sections with movable railroads and permanent railroads;
$V_п$ и $V_{пр.}$ – speed of movement of the train at direction "loaded" and direction "unloaded";
$t_{м.о.}$ –time for maneuver operation;
$t_{тов}$ – time for loading;
$t_{разт}$– time for unloading;
$t_{др.з.}$ –time for other unforeseen delays.

In Bulgarian practice special observations on the different motion routes of trains in all the five opencast mines with technological railroad transport have not been performed. However, such observations are made into underground mines and S. Irinkov [1] assumes, that time for movement for train compositions there, sufficiently for the practice, may be subordinated to the Gausses distribution. In such case the dispersion of time, in which the train occurs during operating status is [1]:

$$Д(t_p) = L^2\left[\frac{Д(V_п^{м.п})}{V_п^4} + \frac{Д(V_п^{п.п})}{V_п^4} + \frac{Д(V_{пр}^{м.п})}{V_{мр}^4} + \frac{Д(V_{пр}^{м.п})}{V_{мр}^4}\right] + \tag{9}$$
$$+ Д(t_{мо}) + Д(t_{тов}) + Д(t_{разт}) + Д(t_{др.з.})$$

The required number of courses of the trains to provide the shift productiveness $Q_{см}$ is:

$$n_p = \frac{Q_{см}}{Q_{вл}} \tag{10}$$

where:
$Q_{вп.} = V_в . n_в . \gamma$ – effective weight of train, as
$n_в$ – number of cars in the train;
$V_в$.- volume of a car;
γ – bulk weight of carried rocks.

The root-mean-square deviation of time needed for movement of trains is:

$$\sigma_t = \sqrt{Д(t_p) . n_p} \tag{11}$$

In case of limited (caused by different reasons) number N of train compositions in the mine, the necessary time for transportation of rock mass is:

$$T_p = \frac{t_p . Q_{см}}{Q_{вл}} \tag{12}$$

The average root-mean-square deviation of flow stream of average value is;

$$\sigma_Q = \frac{m_Q . \sigma_t}{T_p} \tag{13}$$

The probability for transportation of a planned for a shift volume of load can be expressed by (14)

$$P(Q) = \Phi\left(\frac{T_{см} . m_Q}{T_p}\right) . \frac{1}{\sigma_Q} \tag{14}$$

Upon the obtained result (14), the value of the function can be found into conventional scales, i.e. to determine the numerical value of probability for realization of the transport production program at assigned parameters for railroad transport.

According to S. Irinkov, in such a case the entire transport operation at scheme in fig. 1. may be presented by the matrix of Wetich. For the purpose probability of failure-free operation of each of four routes is marked by P(t), and the idle time is marked by 1- P(t).

Weitch matrix can be applied when the routes are not more than six. On the illustrated example in fig. 1 they are four and the \Weitch matrix looks like in fig. 4.

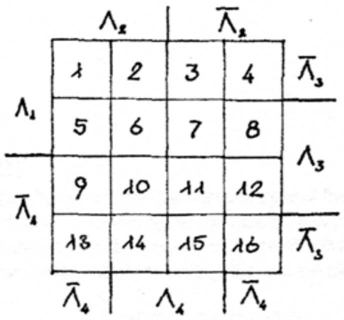

Figure 2 Weitch matrix for four routes.

With availability of four routes the combination of conditions in which the haulage system may be found during a particular period of time is $2^4=16$.

The mathematical model of possible conditions of the four routes for same period of time are represented by the following system of equations:

$$
\begin{cases}
P_{k1}(t)=P_{11}(t).P_{12}(t).[1-P_{13}(t)].[1-P_{14}(t)] \\
P_{k2}(t)=P_{11}(t).P_{12}(t).[1-P_{13}(t)].P_{14}(t) \\
P_{k3}(t)=P_{11}(t).[1-P_{12}(t)].[1-P_{13}(t)].P_{14}(t) \\
P_{k4}(t)=P_{11}(t)..[1-P_{12}(t)].[1-P_{13}(t)].[1-P_{14}(t)] \\
P_{k5}(t)=P_{11}(t).P_{12}(t).P_{13}(t).[1-P_{14}(t)] \\
P_{k6}(t)=P_{11}(t).P_{12}(t).P_{13}(t).P_{14}(t) \\
P_{k7}(t)=P_{11}(t).[1-P_{12}(t)].P_{13}(t).P_{14}(t) \\
P_{k8}(t)=P_{11}(t)..[1-P_{12}(t)].P_{13}(t).[1-P_{14}(t)] \\
P_{k9}(t)=[1-P_{11}(t)].P_{12}(t).P_{13}(t).[1-P_{14}(t)] \\
P_{k10}(t)=[1-P_{11}(t)].P_{12}(t).P_{13}(t).P_{14}(t) \\
P_{k11}(t)=[1-P_{11}(t)].[1-P_{12}(t)].P_{13}(t).P_{14}(t) \\
P_{k12}(t)=[1-P_{11}(t)].[1-P_{12}(t)].P_{13}(t).[1-P_{14}(t)] \\
P_{k13}(t)=[1-P_{11}(t)].P_{12}(t).[1-P_{13}(t)].[1-P_{14}(t)] \\
P_{k14}(t)=[1-P_{11}(t)].P_{12}(t).[1-P_{13}(t)].P_{14}(t) \\
P_{k15}(t)=[1-P_{11}(t)].[1-P_{12}(t)].[1-P_{13}(t)].P_{14}(t) \\
P_{k16}(t)=[1-P_{11}(t)].[1-P_{12}(t)].[1-P_{13}(t)].[1-P_{14}(t)]
\end{cases}
\tag{15}
$$

It is obvious from (15), that the illustrated example for "Kremikovtsi" mine in fig. 1, the haulage system with four routes holds five levels of intensity:

Level I - consists of combination $P_{к16}(t)$;

Level II - consists of combination $P_{к6}(t)$;

Level III - consists of combinations $P_{к1}(t)$, $P_{к2}(t)$, $P_{к3}(t)$, $P_{к7}(t)$, $P_{к8}(t)$, $P_{к9}(t)$, $P_{к11}(t)$ и $P_{к14}(t)$;

Level IV - consists of combinations $P_{к4}(t)$, $P_{к12}(t)$ and $P_{к13}(t)$,

Level V: consists of combinations $P_{к5}(t)$ and $P_{к10}(t)$,

Therefore and hereby, the probability of failure-free operation of the transport system dependently on level of intensity, can be recorded in the following way:

$$
\begin{cases}
P_{IH}=P_{k16}(t); \\
P_{IIH}=P_{k6}(t); \\
P_{IIIH}=P_{k1}(t)\vee P_{k2}(t)\vee P_{k3}(t)\vee P_{k7}(t)\vee P_{k8}(t)\vee P_{k9}(t)\vee P_{k11}(t)\vee P_{k14}(t) \\
P_{IVH}=P_{k4}(t)\vee P_{k12}(t)\vee P_{k13}(t) \\
P_{VH}=P_{k5}(t)\vee P_{k10}(t)
\end{cases}
\tag{16}
$$

CONCLUSIONS

First:

If the characteristics of (16) are known, it is not a problem to find the prognostic time for operating of each route and therefore with a sufficient precision to prognosticate the level of probability for fulfilling the haulage operation, rate of probability of haulage work, the continuity of which depends on technical condition of the movable railroads.

Second:

The obtained different levels of intensity predetermine also the probable character for appearance of deformations at the movable railroads, which may be an object of future studies.

REFERENCES

Irinkov S., 1986. Automation of the technological processes in the opencast mines. - Sofia, Techniques.

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