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

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ABSTARCT
The effect of technological condition of movable railroads on some of the technological parameters of combined mining operation of railroad transport and single-bucket excavators is studied by means applied to the processes and technology of opencast mining.

INTRODUCTION

Technical condition of movable railroads is determined by the real deviation of rails from their design postioned. The most important factors to determine deviation are as follows:
- visible and hidden settlements of the vertical plane;
- visible and hidden deformations in a horizontal plane;
- torsion of road round its axis.

The above factors bring to mudding of the gravel ballast bed, breaking of railroad in the zone of joint connections, loosening and breaking of joints between rails and sleepers, breaking of rails bringing to visible or invisible settlements.

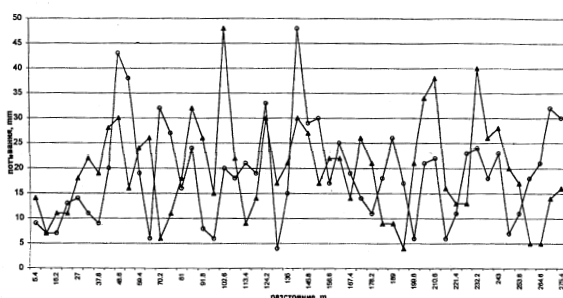The first type of deformations are shown in fig. 1, and the third type – in fig. 2.

Figure 1. Response of invisible settlements of spreader railroad of inner dumping areas at the AS-1600, No 3, "Troyanovo – 1′ mine
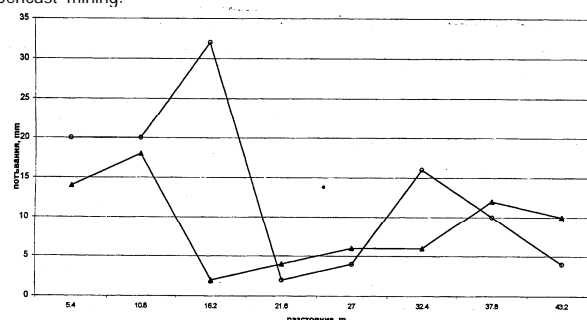

Figure 2. Response of invisible settlements of railroads at the area of spreader AS-1600, No 6, "Troyanovo north"

The first figure is shared by a project, managed by Prof. D. Stoyanov "Preventive control and repair and maintenance of movable railroads at the "Troyanovo" opencast mine of the "Maritza-East" EAD mines [1], and the second – by a project of the same author and identical title [2], but studying the same issues at the "Troyanovo-sever" mine. Measurements were carried out in October 1998.

On the other hand, the real technical condition of movable rialrods results in the admissible speed of train cars on them. For example, similar issue is treated at the "Kremikovtsi" mine by Atanas Smilianov in the project entitled "Expert assessment of road and railroad network at the "Kremikovtsi" mine [3], which is the reason for limiting the speeds of motion within their safe speeds. However, geometrical characteristics in the plane and section and haulage characteristics of locomotives allow a speed up to 45km/h, however the project of Atanas Smilianov "Problems of the moving, maintenance and repair of movable railroads at the "Kremikovtsi" mine [4], recommends speeds of moving along them limited as follows:
- in the mine – not more than 5 km/h along the southern line;
- in the dumping area and the special dumping site:
  o not more than 12 km/h in direction "empty;
  o not more than 8 km/h in direction "full"

Considering the above mentioned, technical condition of movable railroads effects significantly on major operating parameters of the mines, shown below.

EFFECT OF TECHNICAL CONDITION ON MAJOR TECHNOLOGICCAL PARAMETERS

The concept consists in presenting the effect by formulas, applied in technology of opencast mining. This is implemented by showing the consecution and interrelation of commonly applied formulas, describing the movable railroads in a more or less evident type.

Below presented cconsiderations are shown in the example of the scheme of railroad transport of the "Kremikovtsi" mine, and even more, to simplify the model, only mine – dumping area routes are treated – fig. 3.
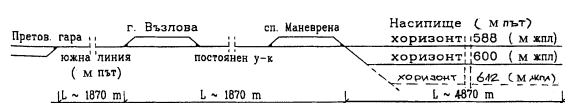
Figure 3. General haulage scheme for transportation away of overburden from the "Kremikovtsi" mine

It is worth mentioning that considerations and conclusions refer to other routes as well, including movable railroads in the specialized depot with different ways for barite ore and iron ore.

The scheme in fig. 3 is subordinated to the idea of minimum idle time of excavator at the re-loading station, i.e. the mine is supposed to work with its maximum design capacity. That suggests 100 % use of the capacities of the illustrated haulage scheme.

That requires a minimum idle time of the excavator to guarantee the performance of production capacities. In that case, if admitted that excavator works only for overburden, the number of trains, serving the excavator for a unit time is a function of time for moving of train in both directions and time for loading and unloading and expecting the next composition. It is shown by (1).

$$N_{вл} = \frac{t_{к}}{t_{тов} + t_{o}} \qquad (1)$$

where:

$N_{в}$ –number of trains, operating in one and the same route, and served by one excavator during a shift;

$t_{тов}$ – time for loading of train. It depends on number and volume of cars and actual technical productivity of excavator. The expression (2) is accepted as precise enough to simplify below the presented calculations

$$t_{тов} = \frac{n_{в}.V_{в}}{Q_{тех}} \qquad (2)$$

where:

$n_{в}$ – number of cars in a train. It depends on geometrical characteristics in layout and profile (R_{min} [m], i_{max} [‰]) of movable railroads in the mine and haulage characteristics of electric locomotives.

$V_{в}$ –volume of mass (in that case overburden) in one car;

$Q_{техн}$ – technical productivity of excavator.

The product $n_{в}.V_{в}$ represents the useful load, transported by the train. It depends on the maximum slope of longitudinal sections of movable and constant railroads, radiuses of curve and additional effect on the maximum value of slope within the specific portion of the railroad.

The locomotives used at the mine are E type "Bo – Bo". The haulage calculations, carried out (by method of Lipetsk MPS, shown in [5] according to a reduced longitudinal section (reading the additional effect of resistance of curves) in [3] show values of time for moving on the southern line of the mine as follows – table 1.

Table 1. Results of haulage calculations, carried out by [3].

One locomotive				Two locomotives				Three locomotives			
7 в.	8в	9 в.	1 0 в.	7 в.	8в	9 в.	1 0 в.	7 в.	8в	9 в.	1 0 в.
2 4 , 3	-	-	-	1 9, 6	2 7, 2	-	-	1 9, 6	2 3, 2	2 6, 1	2 9, 0

When values of slopes are reduced, the effect of radiuses of the curve within that portion of the railroad is read by the formula (3) according to [5].

$$W_r = \left(\frac{200}{R} + 1,5.\tau \right).\frac{l_k}{l_{вл}} \qquad (3)$$

where:

W_r – resistance from the curve in ‰;

R – radius of the curve in m;

τ – absolute value of non-compensated centrifugal acceleration in m/s^2, determined by formula (4).

$$\tau = \left(\frac{V^2}{13.R} - \frac{h}{S} \right).g \qquad (4)$$

where:

V – speed of train m/s;

h – exceed of railroad transport in the curve mm;

$S = 1500$ mm – axial distance between rails;

$G = 9,81$ m/s^2 – earth acceleraion;

l_k, m – length of curve

$l_{вл}$, m – length of train.

The cars used at the mine are of dumpcar type, both Bulgarian and Russian manufacture, with a volume of 40 m^3, four axes.

Bulk weight of overburden, volume of car and own weight of car are used for calculating the total weight of cars of the train. The principal resistance of train is read as follows:

        for cars – by formula (5) – according to [5].

$$W_o'' = \frac{V+65}{12+0,55q} \qquad (5)$$

where:
W_o'' – principal resistance of mition of the four cars;
V – speed of train km/h;
q – gross weight of car in t;

- for locomotives in ghaulage and non-haulage mode of operation, respectively by formulas (6) and (7), according to [5].

$$W_o' = 1,9 + 0,01.V + 0,0003.V^2 \qquad (6)$$

$$W_{o6}' = 2,4 + 0,11.V + 0,00035.V^2 \qquad (7)$$

where:
V – speed of moving in km/h.

In the other two portions of the railroad, according to the scheme in fig. 3, the maximum slopes are within the zones of roads towars benches of dumping area and combined to the effect of curved portions they do not exceed 9 ‰. For that reason speed is limited only by the geometry and is considered by the formula (8)

$$V = c\sqrt{R}, \; km/h \qquad (8)$$

where:
R, m – radius of curves;
c – constant. It depends on width between rails and value of overheight of the outer rail.

A value of c=3,4 is recommended for values from 150 to 200 meters, according to S. Trendaphilov in "Construction of opencast mines" [6].

The maximum achievable speed in those portions of the railroad, not reading their technical condition, is about 45 km/h (according to geometrical characteristics of the layout and section and haulage characteristics of locomotives applied). The admissible maximum sped of trains in he mineis limited by in-company orders, reasoned by [4].

t_0 – (according to formula (1))is time for expecting the train by excavator. The thransportation scheme for re-oading station allows reducing that time to the minimum, i. e. time for maneuvres for in-coming of the empty train after out-going of the full one.
t_k – (according to formula (1)) is the time for a complete route and it is determined by (9)

$$t_k = t_m + t_{мп} + t_{пост.п} + t_p + t_{техн.п} + t_{др.з} \qquad (9)$$

where:
t_T – time for loading, according to (2)
$t_{мп}$ – time for movement of train along movable railroads of specific route and it is determined according to formula (10)

$$t_{мп} = \frac{2.\sum_{i=1}^{n} l_{i\,мп}}{V_{i\,мп}} \qquad (10)$$

where:

the numerator shows the total length of all portions of the railroad, where the trains moves along movable railroads in both directions of specific route;
$V_{i(м\,п)}$ – speed of train along the movable roads in km/h and according to [4]'
$t_{пост.\,п}$ – time for motion of train along the constant railroads of the same route and determined according to (11)

$$t_{пост.п} = \sum_{j=1}^{m}\left(\frac{l_j}{V_n} + \frac{l_j}{V_{nn}} + 0,0025\right), \; h \qquad (11)$$

where:
$\sum l_j$ - total length of portions of constant railroad for a specific route;
V_n, km/h – speed of full train;
V_{np}, km/h– speed of empty train.
t_p – time for unloading the train. It depends on power and faultless work of compressors in locomotives, faultless work and power of air-conductive system and pneumatic unloading systems of cars. In the case of a train of constant number of cars and locomotives that time is a rather constant value;
$t_{техн.п}$ – depends on the route, railroad track development, installations for opening and closing of railroad switching arrows, type of track transportation schemes. For the specific case it also is a rather constant value.
$t_{др.з}$ – time for other retains of any kind. The highest is the weight of time for repairing faults of some of he sub-systems of railroad transport: railroad itself, vehicle etc. Options for reducing that time to the minimum are consist in well-dimensioned activities of scheduled repair of vehicles and maintenance of movable and constant roads in a good working condition.

It is evident that for the specific route from the example in fig. 3 the movable railroads have the most significant relative share in the algebraic total for t_k. It is evident that time for movement itself reverse proportional to speed, limited by the order, according to [4] .

It is evident that if recommendable engineering activities are suggested that may effectively and reliably counteract to to intensity of accumulation of residual deformations the technical condition will be significantly improved. That will allow speed acting according to [4] to be changed with higher ones in the denominator of (10). When an increase of the above speeds of 5/8/12 km/h to only 15 km/h, due to the high relative share of time for moving along the moveable portions of the railroad, number of routes by one and the same train for serving one and the excavator, is significantly increased.

Thus a consecutive effect on a number of important technological parameters occures. For example:
Number of routes, done by one train;

$$r = \frac{T_{см} - t_{регл}}{t_к}, \; бр \qquad (12)$$

where:
$T_{см}$ – duration of shift in hours h;
$t_{регл}$ – regulated time for review and revision of cars and locomotives before and after the shift;
t_k – time for total route of train.

Productivity of train:

$$Q_{вл.(см)} = r.n_в.V_в \qquad (13)$$

- Productivity of car:

$$Q_{в.(см)} = \frac{Q_{вл.(см)}}{n_в} \qquad (14)$$

The effect of movable railroads on the following technological parameters may be shown in the same way:

- Total number of routes for shift:

$$R = \frac{f.W}{n_в.V_в} \qquad (15)$$

where:
W – shift loading of volume of transported overburden according to the example;
f = 1,2 – 1,25 – recommended coefficient of reserve aiming to guarantee the shift loading.

- Total number of trains in the mine:

$$N_{вл} = \frac{R}{r}, \, бр \qquad (16)$$

- Total number of cars in the mine:

$$N_в = N_{вл}.n_в, \, бр \qquad (17)$$

Determination of inventory number of cars and locomotives is realized by formulas, applied in opencast mining and according to approved organization of work in the opencast mine, approved system for planned repairs, qualification of machine-operators, reviewers and other repairing staff, condition of equipment etc.

At the second place, movable railroads effect on the time-schedule of train movement and therefor on permission and haulage capabilities of the mine railroad network. Different versions of time-schedules are applied in opencast mines. The main types of time-schedules are the parallel ones and the package one.

For example, in the case of parallel time-schedule, time necessary for permitting of a couple of trains through a certain portion of the railroad (in the example of fig. 3 oror certain distance between two stations) along a single line is:

$$T = t_1 + t_2 + 2.\tau, \, min \qquad (18)$$

where:
T – period of the time-schedule of train movement;
t_1 and t_2 – time for moving of the train in direction "full" or direction "empty", respectively;
τ – time for maneuvers for permitting the train in both directions.

In the case of a single line the permissible ability is:

$$N = \frac{T - t_{регл}}{t_1 + t_2 + 2.\tau} \qquad (19)$$

where:
N – ability of the portion to permit trains;;

T – duration of shift;
$t_{регл}$ – regulated idle time. For a 24 hour day the idle time is from 180 min to 300 min.

The importance of time for moving of trains is evident related to portions of movable railroads from (19). It depends on the speed, and speed depends on technical condition.

Thus an effect is exerted on haulae ability "M" of different portions and combinations between them, crossing the capital trench.

$$M = \frac{N}{f}.n_в.q_м \qquad (20)$$

where:
f – coefficient of reserve
$q_м$ – useful loading of the train;

The following approaches are applied to increase the haulage ability of any route:

- increase the speed of train movement. In the portion , depending on movable railroads that may be achieved only by realization of engineering activities, which will significantly incrase their stability;
- increase of weight of train. It may be achieved (in the portion, depending on movable railroads) by the realization of activities, icreasing the stability of lines, i.e. the upper case or increasing the number of locomotives (coupled haulage capability) and aplication of motor-car integrated sections;
- improvement of the means of moving, opening and closing of railroad switching arrows for formation of specific routes. That is applicable to our conditions, however, each further improvement of those systems is expensive and senseless in case all other activities for improvement of stability of movable railroads have not been performed before.

The entire above presentation shows that technical condition of movable railroads effects synthetically through the admissible speed. For the example in fig. 3 It may easily be shown that if speed is increased to 15 km/h (compared to admissible speeds – see the initial page), then the time for one route will be reduced with 40 % and numbr of routes done by one train will be increased with nearly 50 % etc.

This may be digitally shown for all the technological parameters of haulage system, shown by the dependencies (12), (13), (14), (19), (16), (17), (19) and (20). In a reverse aspect the effect on important technological parameters of mine equipment – technical, shift, week productivity of single bucket excavators may be revealed.

CONCLUSION

The dependencies are presented, where speed of motion of trains on movable railroads, directly or indirectly, effects on the technological parameters of haulage.

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