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ANALYSIS AND PERFORMANCE ASSESSMENT OF ENERGY RAW MATERIALS IN MINING RAIL TRANSPORT

Janka Šaderová[1], Tomislav Šubaranović [2]

[1] Technical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnology, Institut of Logistics, Letná 9, 042 00 Košice, Slovakia, tel: +421 55 602 3144, e-mail: janka.saderova@tuke.sk

[2] University of Belgrade, Faculty of mining and geology, Djusina 7, 11000 Belegrad, Serbia, tel: +381 11 3219 188, e-mail: tomislav.subarovic@rgf.bg.ac.rs

Abstract:
The raw materials transport is one of the important segments in their extraction and processing. In mining operations are used multiple transport technologies that depend on a number of factors. The paper is presented to the evaluation of rail transport in the mining operation. The performance evaluation of the mining rail transport is based on the calculation of the selected indicator.
The utilization coefficient of the locomotive in the transport k_p was chosen as evaluation parameter, as the indicator, which takes into account not only the trajectory but also the transported quantity by period of time.
The indicator was determined for two types of locomotives for the selected operation. The locomotives are deployed in operation and they provided raw material transportation on two different sections. Under the procedure set out in the paper and on the basis of input data from the operation is concluded that locomotives have low utilization, less than 31% for locomotive type 1 and less than 17% for locomotive 2. It can be stated based on finding, that the current transport system has sufficient reserves.

Key words:
Mining rail transport, Locomotive, Evaluation, Indicator.

INTRODUCTION

The mining transport is closely linked to mining works. It creates two main flow, the current flowing from the underground to the surface, and the current flowing into the underground.

From the mine to the surface are transported: utility mineral for its further treatment and industrial processing, unnecessary ingredients of the raw material, waste material and others.

From the surface to the mine are transported: empty wagons, mining wood, building materials, machinery and equipment, backfill material, explosives and others.

The utilitarian mineral can pass through several types of mine workings on its road from the mine to the surface. We can see the horizontal, inclined and vertical mining transport, according to the curve of the road. We divide the mining transport on cyclical and continuous, according to the activity [1].

Mining rail transport is one of the main transport systems of mining enterprises. The mining rail transport is the most common way of minerals, persons and materials transporting, by rail wagon along the tracking the mine and the surface. Transport capacity is influenced by several factors [2].The basic elements of mining rail transport are mining railroad, mining wagons and mining locomotives [3]. Mining locomotives are currently undergoing various renovations in order to reduce the environmental load (condition) in mining conditions [4].

This paper is devoted to the assessment of rail transport in mining operations. Transport evaluation can be performed on the basis of various indicators: controlling indicators [5], time and power use [6], multi-criteria evaluation [7], FMEA [8] and using of various software tools [9, 10]. The parameter *the utilization coefficient of the locomotive in the transport* k_p, was chosen as an indicator, for this paper. This parameter takes into account the transport route and the transported quantity over a given time period.

1 THE ASSESSMENT METHODOLOGY

The performance evaluation of the mining rail transport is based on the calculation of the selected indicator. Selected indicator *the utilization coefficient of the locomotive in the transport* k_p, is the ratio of two parameters - the required and possible performance of the locomotive, in the selected operation for the selected time period. It should be at least 70% for a good work organization. The coefficient is given by formula [9,11]:

$$k_p = \frac{Q_{RP}}{Q_{PP}} \cdot 100 \qquad [\%] \qquad (1)$$

Parameter Q_{RP} is the required performance of the locomotive in the monitored period (in hours or minutes) and we calculated it according to this formula

$$Q_{RP} = \frac{M_d \cdot L}{n_l} \qquad [\text{t.km}] \qquad (2)$$

where M_d is the mass of daily mining (quantity to be transported) in tons,
L - the average transport distance in km,
n_L - the number of locomotives needed for transport in pieces, we calculate it according to the formula

$$n_L = \frac{M_d \cdot t_0 \cdot k_n}{t_f \cdot Q \cdot n} \qquad [\text{pc}] \qquad (3)$$

where Q is the mass of the raw material in the wagon in tons,

n - the number of wagons in the wagons set,
t_f - the daily transport time fund in minutes,
k_n - the coefficient of transport inequality (1.1-1.5),
t_0 - the cycle time, turn of the locomotive in minutes, given by formula

$$t_0 = \frac{2L}{v} + t_1 + t_2 + t_3 \qquad \text{[min]} \qquad (4)$$

where v is the average transport speed in km.h^{-1},
t_1 - the time of loading of wagons in the wagon set at the loading station in minutes,
t_2 - the time needed to unload of the material from the wagons at the unloading station in minutes,
t_3 - the downtime in minutes.
(time data t_1, t_2, t_3 are determined by measuring).

Parameter Q_{PP} is *possible performance of the locomotive* in the monitored period (in hours or minutes) and we calculate it according to formula

$$Q_{PP} = \frac{n \cdot Q \cdot L \cdot p}{k_n} \qquad \text{[t.km]} \qquad (5)$$

where p is the number of possible rides of the locomotive in the monitored period, calculated by formula

$$p = \frac{t_f}{t_0}\ . \qquad \text{[-]} \qquad (6)$$

Based on the coefficient, it is possible to compare the performance of locomotives deployed in the operation, to assess the number of deployed locomotives and also to determine the required number of locomotives in case of increasing raw material transporting.

Relevant data are required for the correct determination of the coefficient. The transport evaluation procedure is implemented in two parts:

1) Data collection:
   a) Data on installed devices are collected from their technical documentation. The parameters for this calculation are - the mining locomotive transport speed, which corresponds to the speed of the wagons set, the load capacity of the mining wagons.
   b) The collection of operation data, parameters - the number of loading and unloading places, the length of the transport route, mass of daily mining, transported mass over the reference time, the number of wagons in the wagons set, daily traffic time fund.
   c) Data collection by in-service measurement, parameters - downtime at the loading station (the loading time of wagons set), downtime at the unloading station (the unloading time of wagons set), downtime on the line.
2) Calculation of the utilization coefficient of the locomotive in the transport k_p on the basis formula (1).

2 PERFORMANCE ASSESSMENT OF MINING RAIL TRANSPORT

Assessment of transport performance is implemented for selected operation. The rail transport system in operation is divided into two separate sections. Each section has its own type of mining locomotive. Their interconnection is at the workplace, which is referred to as wagons order. Formalized scheme of transport cycle activity and material flow in separate sections is shown in Fig. 1.

The transport cycle provided by the locomotive type 1 (diesel-hydraulic locomotive) is marked by the green colour. Locomotive 1 performs transport of mineral raw materials from loading station (Buffer 1) to wagons order (Buffer 2). Locomotive works 5 days in a week. The transport cycle begins by loading the raw materials from the buffer into a wagon set, followed by a move them to a wagon order, where wagon set is disconnected and parked on a free track. Subsequently, the locomotive will take the ride back to the place of loading (return movement).

The traffic cycle provided by the locomotive type 2 (electric locomotive powered by the overhead contact line) is marked by the blue colour. Locomotive 2 performs transport of mineral raw materials from wagon order (Buffer 2) to unloading station, where are wagons unloaded to buffer (Buffer 3). This transport cycle takes place only one working day in a week, usually on the last day of the week. It means, that the wagons transported by locomotive 1 on the wagon order are transported to the unloading station until the last working day. The wagon order in this case is a temporary buffer.

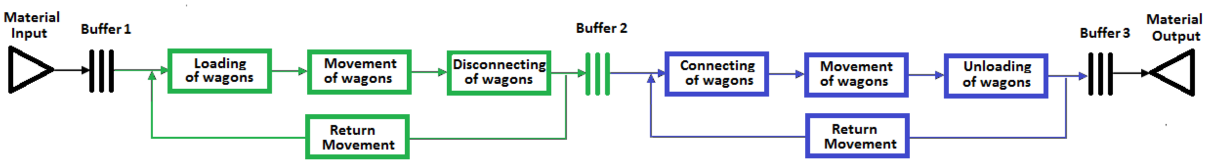

***Fig. 1** Formalized scheme of transport cycle activity*

Daily transport time fund is $t_f = 7$ hours in the selected operation. An evaluation was made based on the selected parameter for both types of locomotives and for this time period. The coefficient was calculated for the number of locomotives determined according to the formula (3), which will later be justified in the discussion. The obtained data, from the operation, required for the calculation are shown in Table 1.

***Tab. 1** Input data*

Parameter	Locomotive 1	Locomotive 2
Transport speed v [km.h^{-1}]	6	12
Average transport distance L [km]	0.536	5.300
Mass of transported raw material M_d [t]	120	600
The weight of the raw material in the wagon Q [t]	4.8	4.8
Number of wagons in wagons set n	16	16
Daily transport time fund t_f [min]	420	420
Loading time of wagons t_1 [min]	48	-
Time of connecting wagons to the locomotive in the wagon order t_1 [min]	-	5
Time to placing and disconnecting of wagons from locomotives to wagon order t_2 [min]	5	-
Downtime on the unloading station t_2 [min]	-	64
The coefficient inequality of transport	1.3	1.1

Table 2 summarizes the results obtained by the calculation according to the formulas (1) to (6) for both types of locomotives.

Tab. 2 Calculation results

Parameter	Locomotive 1	Locomotive 2
Time of cycle t_0 [min]	63,72	122
Required number of locomotives n_L [pc]	1	3
The required performance of the locomotive Q_{RP} [t.km]	64,32	1060
The possible performance of the locomotive Q_{PP} [t.km]	208,72	1273,89
Utilization coefficient of the locomotive in the transport k_p [%]	30,82	83,2

3 RESULTS AND DISCUSSION

Based on the results, it can be stated:

1) For transportation of 120 tons of raw material is required one piece of locomotive type 1 with 16 wagons. The turn-around time is less than 64 minutes. Locomotive type 1 is used during work to less than 31%, which is not half the use that locomotive have to achieve in a good organization of work, as mentioned above. The 70% indicator would be reached in the transport at 275 tonnes of raw material per time period.
2) Tree pieces of locomotive type 2 are required for the transport of 600 tonnes of raw material along the 5.3 km long route. Turnover time of locomotive is 122 minutes. One locomotive of this type is used up to 83.2% during monitoring period. However, that each locomotive is deployed only one day a week. Calculating coefficient for one day of the working week is only 16.64%, which is even lower than for locomotive 1. Coefficient would increase to 50% by modifying the deployment of one locomotive per each working day.

What is the cause of such a low coefficient of locomotive use in transport? The main cause is the low amount of raw materials to transportation, low mining capacity that is affected by demand for the raw material.

4 CONCLUSIONS

The paper assesses the performance of rail transport based on the selected parameter. It was concluded, that the locomotives in operation had a low utilization of 31% and 17%, based on its calculation. The indicator should be at least 70% for a good organization of work. The main cause of low utilization is the insufficient amount of raw material to be transported. This quantity cannot be affected at present, as it depends on the mining capacity, which is currently sufficient to cover the orders from customers. Furthermore, it should be noted, that the operation has available other locomotives types 1 and 2, which could be put into operation in the future. Finally, it is possible to conclude, that the transport system has sufficient reserves for increased mining currently.

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