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Rationing of Tire Mileage in the Operating Conditions of the Kalmakyr Quarry

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ABSTRACT: The article presents the results of the road studies of the wear resistance of the tire size 33.00.51 in the Kalmakyr quarry. It is established that the predicted norm of the operational mileage of the tire was 30500 km (Belshina). On Kalmakyr, BelAZ-75131 dump trucks deliver cargo at the Overburden Quarry and the Central One, carrying out lifting, which averages about 60% of the length of the entire route. Based on the analysis of the characteristic causes of premature decommissioning of 23% of controlled oversized tires (OT), it is shown that all of them failed due to cuts and punctures of the tread or side walls. It was revealed that radial tires 33.00R51 VRLS, "BRIDGESTONE" are much more resistant to cuts: on average, their cuts occur after a run of 40000km.

KEYWORDS: tread wear, dump truck, rationing, correction factors, oversized tires.

1. INTRODUCTION

Operating costs for tires represent 25-30% of the cost of transporting rock mass by dump trucks, so increasing tire mileage is essential to reduce costs. The decisive factor determining the efficiency of using tires is the performance of tires, performance, technical level of their operation. The performance and durability of tires are affected by the average density and strength of the transported rocks, the correct loading of the dump truck and the uniformity of the location of the rock mass, the road profile, the condition and type of road surface. In this regard, in order to obtain the maximum efficiency of tires, it is necessary to properly operate and maintain them [1].

Tire wear is generally affected by about 30 different factors, which can be grouped into the following four groups: tire quality; technical condition of the motor vehicle; violation of the conditions and modes of operation of the vehicle; road and climatic conditions [2, 9].

In the course of the study of the state of roads of the Kalmakyr Mine Administration, all routes of technological and auxiliary transport at the Kalmakyr and Sary-Cheku quarries were analyzed in detail. Quarry Kalmakyr deep type. The roads in the quarry naturally crumble or build on the rocks that lie there. The Kalmakyr ore field is composed mainly of intrusive and volcanic rocks. In the north of the quarry, ionite-diorite porphyries occur, on the left side - quartz porphyries, on the right side of the observation deck - diorites with chlorides, related to soft rocks. At the bottom of the quarry, there are granodiartine porphyries and basalts, a very hard rock; in the southeast of the quarry, there are sheet-like quartz porphyries [3, 4].

The rock in the Kalmakyr quarry is not homogeneous. Formed with stacked and discontinuous disturbances. Therefore, on different horizons, one can find various rocks, up to soft ones, based on sandstone and limestone [5].

2. METHOD OF CALCULATION

According to the methodology “Individual norms for the operating mileage of automobile large tires”, developed at the Scientific Research Institute of Large Tires (SRILT), taking into account the listed factors, careers are divided into three categories according to the severity of tire operating conditions [6]:

I-category (L) - careers with light operating conditions;

II-category (C) – quarries with medium-heavy operating conditions;

III-category (T) - careers with difficult operating conditions.

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The quarry category is determined by three generalized parameters - X_1, X_2, X_3, which characterize the operating conditions of tires in this particular quarry. The X_1 parameter, which takes into account the influence of the type of road surface and its share in the transportation shoulder on tire mileage, is determined by the expression

$$X_1 = \sum_{i=1}^{3} K_i \cdot N_i, \quad (1)$$

where N_i is the share of the *i*-th coating (asphalt, crushed stone, soil on a rocky base) in the transportation leg; K_i is a coefficient that takes into account the influence of the i-th coating on the tire mileage. The values of the coefficient *K* are given in table.1.

Table 1. Coefficient values *K*

Type of road surface	*i*	*K*
Advanced asphalt pavement and soft ground	1	1
Crushed stone and gravel	2	0,8
Natural covering on a rocky base (rocky soil)	3	0,7

The parameter X_2 takes into account the influence of the magnitude of the longitudinal slope and its share in the shoulder of transportation on the mileage of tires and is determined by the formula

$$X_2 = N_y \cdot \theta, \quad (2)$$

where N_y is the share (percent) of slopes in the shoulder of transportation; ϑ is the average value of slopes, %.

The parameter X_3 takes into account the hardness of the transported rocks and is determined by the formula

$$X_3 = \sum_{j=1}^{n} M_j \cdot f_j, \quad (3)$$

where M_j is the share of the *j*–th rock in the total volume of rock mass transportation; fj is the hardness coefficient of the *j*-th rock on the Protodyakonov M.M. scale; *n* is the number of types of transported rocks with different hardness.

Each category of quarries is characterized by the average values of generalized parameters $\overline{X}_{1к}$, $\overline{X}_{2к}$, $\overline{X}_{3к}$.

To determine the category of operating conditions of a particular quarry, it is necessary to calculate the D_k parameter, which characterizes the measure of "proximity", "approximation" of the generalized parameters of this enterprise X_1, X_2, X_3 to the average values of the generalized parameters $\overline{X}_{1к}$,$\overline{X}_{2к}$,$\overline{X}_{3к}$ characterizing each category. The maximum value of the parameters D_1, D_2, D_3 determines whether the quarry belongs to the corresponding category.

The D_k parameter is determined by the formula

$$D_k = \left\{1 + 0{,}01\left[\frac{1{,}33(X_1-\overline{X}_{1к})^2}{\sigma_1^2} + \frac{0{,}67(X_2-\overline{X}_{2к})^2}{\sigma_2^2} + \frac{1{,}33(X_3-\overline{X}_{3к})^2}{\sigma_3^2}\right]\right\}^{-1}, \quad (4)$$

where X_1, X_2, X_3 are generalized parameters characterizing the operating conditions of this quarry; $\overline{X}_{1к}$, $\overline{X}_{2к}$, $\overline{X}_{3к}$ are the average values of parameters characterizing the severity categories of operating conditions (Table.2); σ_1, σ_2, σ_3 are the standard deviations of the parameters X_1, X_2, X_3 obtained as a result of statistical data processing.

The tire mileage rate for a particular quarry is determined by the formula

$$S = \overline{S_k} \cdot C_{1k} \cdot C_{2k} \cdot C_{3k}, \quad (5)$$

where $\overline{S_k}$ is the basic tire mileage rate for each category of operating conditions; $C_{1к}$, $C_{2к}$, $C_{3к}$ are correction coefficients that take into account the change in the basic tire mileage rate for each category depending on the values of the parameters X_1, X_2, X_3 of a particular quarry; K= 1, 2, 3 is the index of the category of operating conditions.

The basic rate of tire mileage for each category of operating conditions is set by the manufacturer. For the 27.00-49 and 33.00-51 FT-116 AM2 models, the basic mileage standards are presented in table 2.

Table 2. **Basic standards of tire mileage**

Category of operating conditions	Basic tire mileage rate $\overline{S_k}$, thousand km		
	model (tire brand)		
	27.00-49(Bel)	33.00-51(Bel)	33.00R51 (Bridg)
I (easy)	40	40	90
II (average)	34	35	75
III (heavy)	25	30	60

Correction coefficients that take into account the change in the basic mileage rate of tires for each category are given in table 3.

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Table 3. Correction factors that take into account the change in the base rate of tire mileage

X_{11}	C_{11}	X_{21}	C_{21}	X_{31}	C_{31}
0,85	0,93	0,5	1,25	1	1,10
0,85 - 0,90	0,95	0,5 - 1,0	1,10	1 – 2	1,05
0,90 - 0,93	0,98	1,0 - 1,5	1,00	2 – 3	1,00
0,93 - 0,95	1,00	1,5 – 2,5	0,97	3 – 4	0,97
0,95 - 0,97	1,10	2,5	0,95	4	0,95
0,97 - 1,00	1,20				
X_{12}	C_{12}	X_{22}	C_{22}	X_{32}	C_2
0,75	0,95	2,0	1,10	3	1,10
0,75 – 0,80	1,00	2,0 – 2,5	1,05	3 – 4	1,08
0,80 – 0,85	1,03	2,5 – 3,0	1,00	4 – 5	1,04
0,95 – 0,90	1,05	3,0 – 4,0	0,98	5 – 6	1,02
0,90 – 0,95	1,07	4,0	0,95	6 – 7	1,00
0,95 – 1,00	1,10			7	0,95
X_{13}	C_{13}	X_{23}	C_{23}	X_{33}	C_{33}
0,70	0,85	2	1,10	12,0	1,10
0,70 – 0,75	0,95	2 – 3	1,05	12,0 – 13,0	1,08
0,75 – 0,80	1,00	3 – 4	1,00	13,0 – 14,0	1,05
0,80 – 0,90	1,05	4 – 5	0,95	14,0 – 14,5	1,00
0,90 – 1,00	1,10	5 – 6	0,90	14,5 – 15,0	0,90
		6	0,85	15,0	0,80

3. EXPERIMENTAL RESEARCH

According to the standards of Building codes and regulations 2.05.07–91 "Industrial transport", the quarry roads of the Kalmakyr facility belong to the III category of mountain roads. 90% of technological roads are temporary with a service life of up to one year.

Considering that the rock contains a lot of quartzite of the Kalmakyr quarry up to 67%, which is considered the hardest rock, it is natural that all wheeled vehicles operating there will experience intense tire wear. Even bulldozers that perform a huge amount of work in the quarries of the Almalyk Mining and Metallurgical Combine (AMMC), the tracks wear out before the planned service life in hours. Judging by the location of various rocks in layers of a certain height, the road from the descent to the bottom of the quarry is heterogeneous in the hardness of its base.

According to the classification of rocks, their strength and hardness are evaluated on the scale of M.M.Protodyakonov. The strength of the rocks on which the road in the Kalmakyr quarry is based is estimated on average at 15 units out of 20 on the scale. Data on the strength of rocks were obtained from geologists of specific quarries and refined in the department of the Chief Geologist of the AMMC [7, 10, 11] (table 4).

Table 4. Characteristics of the magnitude of slopes and their length on the main routes of transportation of rock mass in the Central and Overburden quarries of Kalmakyr

Slope, %	Length of horizontal sections, km					The length of the ascent, km					Length of descent, km					Total, km
	№ transportation route					№ transportation route					№ transportation route					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
0	0,7	0,13	0,05	0,56	1,32											2,76
0-1						0,24					0,15					0,39
1-2						0,1					0,09					0,19
2-3						0,16				0,1						0,26

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3-4						0,31	0,31	0,31	0,96		0,05				0,28	2,22
4-5						0,23			1,22							1,45
5-6						0,29							0,09	0,26		0,64
6-7						0,36	0,31	0,31								0,98
7-8						0,72				0,22	0,09					1,03
8-9						0,24										0,24
9-10						0,18	0,04	0,04								0,26
Total																**10,42**

The mileage of the diagonal 33.00-51 FT-116AM2 model of the BelAZ-75131 dump truck at the Kalmakyr quarry in the winter season of 2019 in November – April was 32624 km, and in the summer-autumn 27821 km, in 2020 respectively –32733 km and 29995 km [8] (table 5).

Table 5. Initial data on the routes of transportation of rock mass by cars BelAZ-75131. Name of the quarry: Kalmakyr (Central + Overburden)

№	Name of indicator	Designation	Unit of measure-ment.	Value
1	2	3	4	5
1.	Route length	L	km	10,42
2.	Type of coverage and its length on the leg of transportation: -asphalt - concrete, soft ground;	l_a	km	-
	-crushed stone and gravel;	$l_щ$	km	1,88
	-natural coating on a rocky base, rocky soil	$l_{ск}$	km	8,54
3.	For each coating in the general shoulder of transportation: -asphalt concrete, soft ground;	N_1	%	-
	-crushed stone and gravel;	N_2	%	18
	-natural coating on a rocky base, rocky soil	N_3	%	82
4.	The number of slopes and their length on the shoulder of transportation: 1st – slope	l_1	km	0,39
	2nd – slope	l_2	km	0,19
	3rd – slope	l_3	km	0,26
	4th – slope	l_4	km	2,22
	5th – slope	l_5	km	1,45
	6th – slope	l_6	km	0,64
	7th – slope	l_7	km	0,98
	8th – slope	l_8	km	1,03
	9th – slope	l_9	km	0,24
	10th – slope	l_{10}	km	0,26
5.	The total length of slopes in the shoulder of transportation	l_y	km	7,66
6.	The share of slopes in the shoulder of transportation	N_y	%	74

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7.	The magnitude of each slope on the shoulder of transportation: 1st – slope	Θ_1	%	1
	2nd – slope	Θ_2	%	2
	3rd – slope	Θ_3	%	3
	4th – slope	Θ_4	%	4
	5th – slope	Θ_5	%	5
	6th – slope	Θ_6	%	6
	7th – slope	Θ_7	%	7
	8th – slope	Θ_8	%	8
	9th – slope	Θ_9	%	9
	10th – slope	Θ_{10}	%	10
8.	The average value of the values of all slopes on the shoulder of transportation	Θ	%	5,5
9.	For each rock in the total volume of rock mass transportation: 1st (breed)	M_1	%	100
10.	The coefficient of rock strength on the Protodyakonov scale: 1st (breed)	f_1	-	14

4. CALCULATION

The following generalized parameters characterizing the operating conditions of tires in the Kalmakyr quarry are calculated: a parameter that takes into account the influence of the type of pavement and its share in the transportation arm on the tire resource:

$$X_1 = \sum_{i=1}^{3} K_i \cdot N_i = 0{,}8 \cdot 0{,}18 + 0{,}7 \cdot 0{,}82 = 0{,}718.$$

a parameter that takes into account the effect of the magnitude of the longitudinal slope and its share in the shoulder of transportation on the mileage of tires:

$$X_2 = N_y \cdot \theta = 0{,}74 \cdot 5{,}5 = 4{,}07.$$

a parameter that takes into account the influence of rock strength on tire mileage:

$$X_3 = \sum_{j=1}^{n} M_j \cdot f_j = 1 \cdot 14 = 14.$$

According to the calculations of the measure of proximity D_k of the generalized parameters X_1, X_2, X_3 of the operating conditions of the Kalmakyr quarry to the average values of the typical parameters characterizing the category of severity of the operating conditions, it was found that:

$$D_1 = \left\{1 + 0{,}01\left[\frac{1{,}33(0{,}718 - 0{,}95)^2}{0{,}09^2} + \frac{0{,}67(4{,}07 - 1{,}43)^2}{2{,}43^2} + \frac{1{,}33(14 - 2{,}04)^2}{4{,}5^2}\right]\right\}^{-1} = 0{,}84,$$

$$D_2 = \left\{1 + 0{,}01\left[\frac{1{,}33(0{,}78 - 0{,}78)^2}{0{,}09^2} + \frac{0{,}67(4{,}07 - 3{,}03)^2}{2{,}43^2} + \frac{1{,}33(14 - 6{,}89)^2}{4{,}5^2}\right]\right\}^{-1} = 0{,}96,$$

$$D_3 = \left\{1 + 0{,}01\left[\frac{1{,}33(0{,}718 - 0{,}79)^2}{0{,}09^2} + \frac{0{,}67(4{,}07 - 3{,}89)^2}{2{,}43^2} + \frac{1{,}33(14 - 14{,}41)^2}{4{,}5^2}\right]\right\}^{-1} = 0{,}991.$$

A comparison of the calculated values of the parameters D_1, D_2, D_3 indicates that the largest value is D_3=0,991, therefore, the Kalmakyr quarry belongs to the III category with severe tire operating conditions. According to TURB 700016217.126-2001, for the III category of operating conditions, the base mileage rate of tires 33.00-51 of the FT-116AM2 model is $\overline{S_k}$ =30000km [8, 10, 11].

The values of the correction coefficients C_{13}, C_{23}, C_{33} for a quarry with severe operating conditions are from table.3 according to the values of the generalized parameters X_1, X_2, X_3. The adjusted rate of tire service life for specific operating conditions of the Kalmakyr quarry is determined by the formula

$$S = \overline{S_k} \cdot C_{1k} \cdot C_{2k} \cdot C_{3k} = 30000 \cdot 0{,}95 \cdot 0{,}95 \cdot 1{,}05 = 28428\text{км}.$$

According to the Operating Manual of the oversized tires company "BRIDGESTONE" for 2018, for the III – category of operating conditions, the basic warranty rate of radial tires 33.00R51 is $\overline{S_k}$ = 60000km.

The adjusted norm of the operational mileage of tires for specific operating conditions of the Kalmakyr quarry is determined by the following formula, making up 33.00R51 "BRIDGESTONE" for tires:

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$S_к = \overline{S_к} \cdot C_{1к} \cdot C_{2к} \cdot C_{3к} = 60000 \cdot 0{,}95 \cdot 0{,}95 \cdot 1{,}05 = 56875$км.

5. CONCLUSIONS

1. After carrying out activities in the quarry under study to improve the quality of quarry roads and bring them into compliance with at least the minimum requirements of the interstate Building codes and regulations 2.05.07-91 "Building codes and regulations. Industrial transport" the mileage of these radial tires should increase by at least 15-20%.

2. Radial tires 33.00R51 VRLS, "BRIDGESTONE" are much more resistant to cuts: on average, cuts occur after a run of 40000km. The cost of these tires is more than diagonal tires of the same size produced by JSC "Belshina", and the walking capacity is 2 times higher. Calculations show that in the case of switching to the purchase of radial tires 33.00R51 VRLS "BRIDGESTONE" instead of diagonal tires 33.00-51 "Belshina" for 34 BelAZ-75131 dump trucks operating today, the annual economic effect on truck depots No. 1 and No. 4 will amount to more than 3 million US dollars.

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