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Silesian University of Technology
Faculty of Transport and Aviation Engineering

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Keywords: mine haul roads, tires life, mining dump truck, natural rubber

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INFLUENCE OF TEMPERATURE REGIMES ON THE WEAR OF TIRES OF MINING DUMP TRUCKS

Summary. Worldwide growing demand for metals is driving the mining industry. However high-grade metal deposits are nearly all mined out or under operation in countries with favorable investment climates. More and more deposits with low grades in Kazakhstan will be put into operation in the future. Mining in low-grade deposits means that more earth must be moved to have this operation profitable. Transportation costs in low-grade mines may reach 70% costs of mining due to more mining trucks and longer-haul roads that must be put into operation. Off-road tires (OTR) for mining and earthmoving applications which are specially developed for the extreme mine site conditions can take 10-20% of transportation costs. Up to 15% of OTR content is natural rubber.

Southeast Asia covers about 90% of the world's natural rubber production. Tire manufacturers purchase about 70% of the total production. Overall demand for natural rubber since 2000 increased by around 30% worldwide. Rubber production has expanded to Africa in the past 20 years. The total global area utilized for rubber production has increased by more than 35% (about 13 million hectares) [1]. The territory of Spain is 13,7 million hectares for reference. Growing natural rubber production contributes for the deforestation process, unfortunately. Deforestation fronts will account for over 80% of the forest loss projected globally by 2030, i.e. up to 170 million ha [2].

At the same time each year, more than 20 million tons of tires are scrapped worldwide. Unfortunately, more than 30% of OTR from mining dump trucks are scrapped before the target life. In this study, the authors worked out the digital methodology to monitor OTR conditions in mining applications.

1. INTRODUCTION

Tire life in the mine site was studied in 2016 by G.C. Lindeque [3]. The data shows that the achievable tire life for a mining dump truck is notably higher than the recorded tire life. This is due to abnormal wear of tires or tires that fail prematurely. In 2014 it was determined that 41% of all tires failed prematurely [3]. As per Tannont D.D, Regensburg B. [4] the factors affecting tire life include:

1. road conditions (curves, grades, super elevation, haul length, road surface and maintenance),
2. operating conditions (average speed, speed in curves),
3. truck conditions (weight distribution, struts, air pressure in tires, tire matching, tread depth, and tire type),
4. and weather (temperature and precipitation).

Table 1 shows typical values for tire life reduction caused by inflation pressure and various road conditions. Tire inflation pressure should be monitored regularly because it can significantly affect tire life. Traveling at a speed that is compatible with the curve radius and superelevation can minimize tire damage occurring on curves [4].

Tab. 1

Factors affecting average tire life (TLR = tire life reduction)

Inflation Pressure	TLR	Road Conditions	TLR
Recommended pressure	0%	Average soil, no rock	0%
10% under	-10%	Ave. soil, scattered rock	-10%
20% under	-25%	Well maintained with smooth gravel	-10%
30% under	-70%	Poorly maintained with ungraded gravel	-30% or more
20% over	-10%	Scattered blast rock	-40% or more

Curves	TLR	Grades	TLR
None	0%	None	0%
Smooth	-10%	<6%	-10%
Sharp	-20% or more	<15%	-30%

2. SITE RESEARCH METHODOLOGY

It is important to carry out site research to identify the impact of current mine operations from a tire consumption point of view. The study made in 2021 at Bogatyr Komir coal mine in Kazakhstan is represented in this paper. Mine is located in northeast Kazakhstan near Ekibastuz town in Pavlodar oblast and operates BelAZ 75131 dump trucks for transportation. Dump trucks are equipped with 33.00R51 OTR and have 130 tons nominal payload.

In order to make site assessment for tire life, we use “Racelodgic V-box Micro” equipment.

The applied equipment is a measuring and fixing device based on the use of GPS navigation. Normal measurement accuracy is -10 Hz (10 times per second). The device allows to determine the following parameters with high accuracy:
- vehicle speed;
- time;
- distance traveled;
- altitude relative to sea level;
- trajectory of movement;
- acceleration/deceleration longitudinal and transverse;
- radius of turns and speed of their passage;
- calculation of the TKPH indicator for each trip;

The received data is recorded on a memory card, for further decryption, the original Racelodgic V-box Tools software is used.

The TKPH formula (1) calculates the average speed the tire can run within a safe temperature range and within an appropriate truck payload.

$$TKPH = \frac{(Ql+Qe)}{2} * \frac{(N*L)}{H} \tag{1}$$

where: Ql = load per tyre on the loaded vehicle; Qe = load per tyre on the empty vehicle; N = number of cycles per working day; L = length per cycle in kilometers; H = number of operating hours per day.

In mining applications, we must consider weather conditions and load distribution.

Here are results of the measures taken on site:

The route of the movement of dump trucks at the Bogatyr coal mine is shown in Fig. 1. The V-box complex is installed on the BelAZ-75131 with fleet number 159. The route of movement in the mine: from the EKG Excavator to the internal waste dump. The date of the measurement is 05/17/2021, the start time is 13:10, and the end time is 12:10, for this period the BelAZ-75131 dump truck made 3 trips, of which 2 were complete programs suitable for recognition in the calculation of the TKPH indicator. The total distance covered is 24,156 meters.

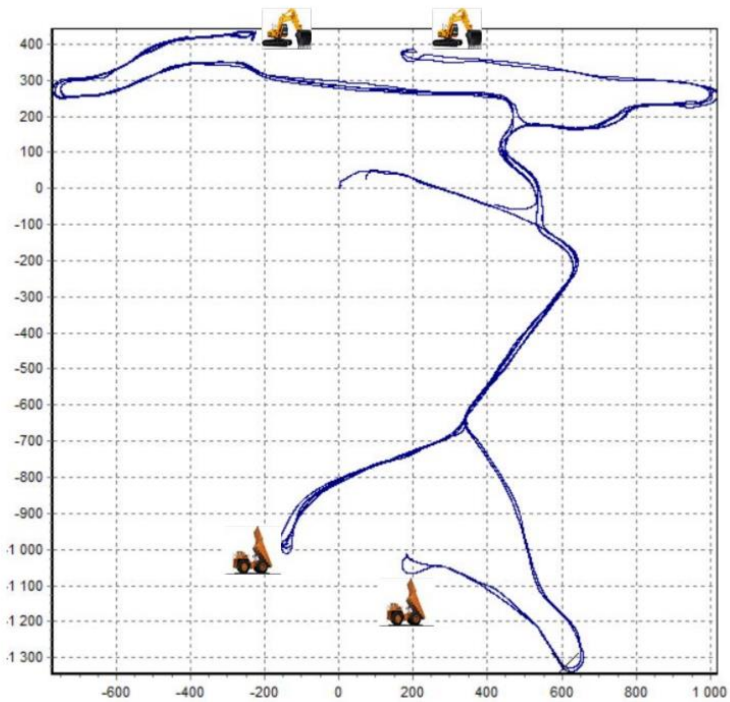

Fig. 1. The route of the movement of dump trucks at the Bogatyr coal mine

Tab. 2

For each trip, the distance traveled, the time elapsed, the TKPH indicator for dump truck BelAZ-75131 #159

Run	Time	Loaded	Empty	Dist (m)	Loaded (m)	Empty (m)	Avg Speed (km/h)	Loaded (km/h)	Empty (km/h)	Cycle TKPH Front	Cycle TKPH Rear
1	22m 52s	09m 53s	12m 59s	7197.71	3625.22	3572.49	22.54	23.79	21.43	748	576
2	21m 44s	10m 03s	11m 41s	6715.18	3594.58	3120.61	22.35	22.67	22.00	747	580
Avg	22m 18s	09m 58s	12m 20s	6956.45	3609.90	3346.55	22.45	23.23	21.71	747	578
Max	22m 52s	10m 03s	12m 59s	7197.71	3625.22	3572.49	22.54	23.79	22.00	748	580
Min	21m 44s	09m 53s	11m 41s	6715.18	3594.58	3120.61	22.35	22.67	21.43	747	576

Based on the data obtained, the V-box Test Suite program calculated the TKPH index for tires of the front and rear axles, which was carried out taking into account a load of 136 tons and with a temperature in the summer t =+35°C in the daytime. According to the data of the Hydrometeorological Center of the Republic of Kazakhstan in the area of Ekibastuz, in June-July 2020, the maximum temperature during the day was t =+34°C, and the maximum temperature at night was t =+27°C.

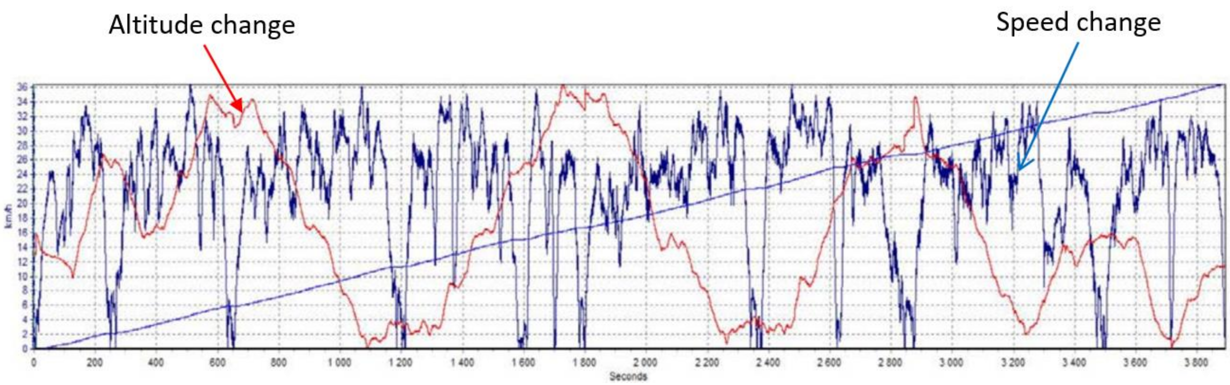

Fig. 2. Speed records of dump trucks for each trip. Speed chart

According to the data obtained for all 3 trips, the value of the average operating speed was up to 22.54 km/h; loaded up to 23.79 km/h; empty at 22.0 km/h. The peak speed of the empty truck reached 36 km/h and the loaded truck up to 35 km/h.

3. ANALYSES OF DATA COLLECTED

Analysis of the obtained data on the longitudinal slopes of technological roads showed that 90% of the route with a loaded dump truck from the point of loading to unloading is carried out uphill does not exceed 8%. Table 3 shows the dependence of tire mileage as a percentage of road slopes. For example: when driving a dump truck loaded uphill with slopes up to 8%, the tire mileage will be 100%, then when driving downhill and with a load, the tire mileage will be up to 61%.

Tab. 3

Dependence of tire life as a percentage of road slopes

Decline slope, %	Loaded cycle uphill, %	Loaded cycle downhill, %
8	100	61
10	81	44
12	64	32

The TKPH calculation showed for the tire 33.00R51 AG01A TKPH=620 with a reserve of values for the rear axle, and for the front axle, it exceeds the allowable value. Therefore, in the pressure recommendation for the front axle, it is necessary to provide tire pressure 1 bar higher than the standard value, thereby reducing the likelihood of a critical tire temperature.

4. CONCLUSION AND RECOMMENDATIONS

Temperature peaks over 38°C during summer can result in heat peeling of the tread due to exceeding the TKPH of the tire. Max speed in the loaded state recorded up to 36 km/h and for an empty dump truck more than 35 km/h. We recommend limiting the movement of loaded dump trucks to 30 km during this period. Given the limitation will not allow the tire temperature to reach a critical value, which will eliminate exceeding the TKPH of the tires and will reduce the wear rate in the hot season. So, monitor the recommended pressure in the tires of the front axle.

The speed of passing on turns with a minimum radius of curvature, in order to exclude the impact of critical lateral forces on the tires, is necessary to arrange a counter slope, which is presented in the table. Without a counter-slope, the passing speed should be lower.

Tab. 4

Relationship between radius, speed and banking for zero lateral force

Radius		Speed										
		km/h	15	20	25	30	35	40	45	50	55	65
		mph	9	12	15	20	22	25	28	31	35	40
(m)	(ft)	Banking %										
50	165		3,5	6	10							
60	195		3	5	8	12						
70	230		2,5	4,5	7	10						
80	260		2	4	6	9	12					
90	295		2	3,5	5,5	8	10,5					
100	330		1,5	3	5	7	9,5					
125	410			2,5	3,5	5,5	7,5	10				
150	490			2	3	5	6,5	8,5	10,5			
175	575				2,5	4	5,5	7	9	11		
200	655					3,5	5	6	8	10	12	
250	820						4	5	7	8	10	
300	985						3	4	5	6	8	10

Slopes up to 8% are the most optimal compromise between speed, production, and tire life.

While route loaded up-hill due to redistribution of load on axles more incentive tire wear takes place:
8-10% slope reduces tire life by 19%;
10-12% slope reduces tire life by 36%;
12%+ slopes are not recommended from a tire life extension point of view.

The average weight of 33.00R51 tire is 2,2 tons and consists of around 10% of natural rubber.

Proper haul road design and condition monitoring can reduce the consumption of tires in mining operations thus contributing to reducing the cost of mining and the environment.

Acknowledgement

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