Evaluation of the influence of the longitudinal slope of carriage roads on the tire life

Umidbek Yusupov*, and *Akmal* Mukhitdinov

Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. This article presents an analysis of the results of an experiment conducted in the Muruntau quarry. All routes are divided into 5 groups depending on the average slope of the road. For the first group, routes with an average road slope from -1 to +1% were chosen; for the second group, with an average road slope from 1 to 3%; for the third, from 3 to 5%; for the fourth, from 5 to 7%; fifth more than 7%. The experiments were carried out on Komatsu HD785-7 dump trucks with a carrying capacity of 91 tons. According to the results of the experiment, it was found that the life of dump truck tires operated on routes with an average road slope of 6% is reduced by 2 times compared to tires operated on a horizontal road.

1 Introduction

Mining is a complex technological process of extracting solid minerals from the bowels of the earth using technical means, which is costly [1–3]. At present, the main types of transportation of minerals at mining enterprises are motor vehicles, rail transport and conveyor transport. Road transport has found wider use than other types of transportation of minerals. The advantage of this type of transportation is high maneuverability, overcoming large slopes and mobility. For mining enterprises in the extraction of minerals, one of the urgent tasks is to reduce the operating costs for the transportation of minerals [4 - 8].

Operating costs for tires are 25 – 30% or more of the cost of transporting rock mass by dump trucks. Therefore, increasing tire mileage is essential to reduce costs [9–10].

At mining and metallurgical enterprises, special requirements are imposed on the tires of heavy dump trucks transporting rock, since their operation is carried out in difficult road conditions [11–14]. The tire life is affected by the following factors: proper loading of the dump truck and uniform distribution of the shipped ore, condition and type of road surface, longitudinal and transverse slope of the road, internal pressure in the tire, driver experience, etc.

2 Analysis of existing studies

According to Michelin, the following decrease in the resource (mileage) of tires has been established depending on the longitudinal slope of the roads: calculation during tire operation - 33% of the service life on the front axle, and 67% - on the rear [15] (Table 1).

*Corresponding author: umidyusupov20161978@gmail.com

 https://doi.org/10.1051/e3sconf/202340103025

Table 1. Reduced tire life depending on the slope of the roads

Slope, %	Lift cycle with load, %	Downhill cycle with load, %
8	100	61
10	81	44
12	64	32

Based on the analysis of statistical data, N. A. Tsytsenko recommends using the values of the tire wear increase coefficients given in table 2.

Table 2. Increase in tire wear coefficient depending on the value of the longitudinal slope[16]

Slope, %	0 – 2	3	4	5	6	7	8	9
Tire wear factor, I_t	1	1,1	1,22	1,35	1,5	1,65	1,8	2,0

The studies of S. B. Nikitin revealed the dependence of the average tire wear on the longitudinal slopes when driving an empty and loaded car on ups and downs (Fig. 1).

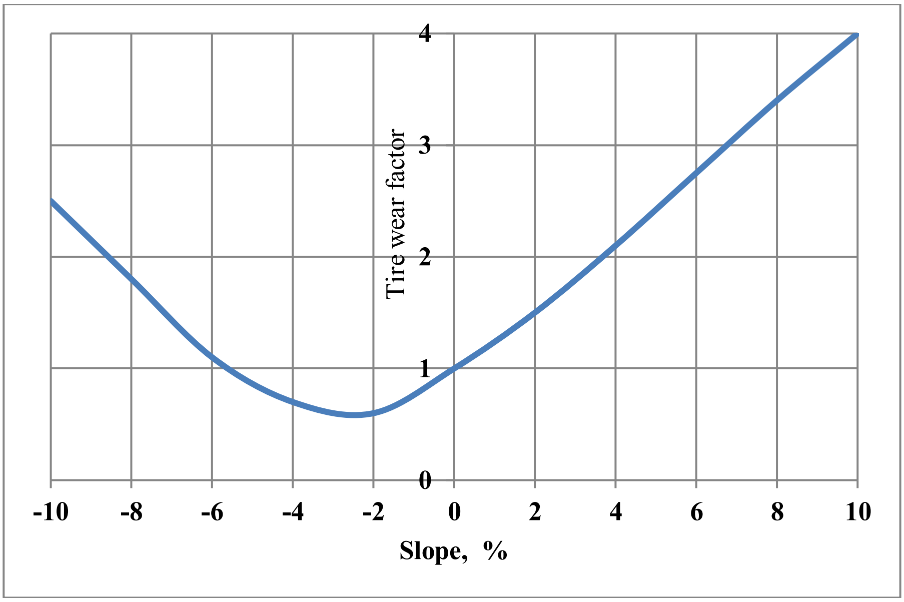

Fig. 1. Dependence of tire wear on the value of the longitudinal slope

Taking tire wear as a unit on a horizontal flat area, we obtained the value of the average (half the sum of wear on the ascent and descent) relative tire wear on the value of the longitudinal slope (Fig. 2) [17].

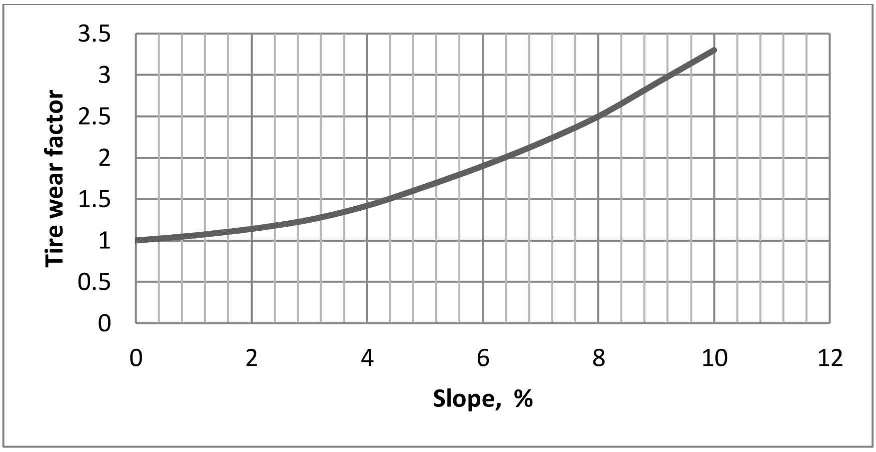

Fig.2. Dependence of the relative wear of tires on the value of the longitudinal slope

All of the previous analyzes have examined the effect of road gradient on tire life in mountainous conditions, i.e. asphalt road at the pass. The influence of the slope of quarry technological roads on the resource of tires has not been studied sufficiently. Based on the analysis of studies, an attempt was made to assess the impact of the slope of the technological road of the Navoi Mining and Metallurgical Combine (NMMC) on the tire resource.

3 Characteristics of objects and subjects of research

Mining heavy dump trucks are designed to transport rock mass along technological roads in open pit mining with different climatic conditions [18–19]. Experimental studies are being carried out at the Muruntau, Amantai and Turbay quarries, which belong to the Navoi Mining and Metallurgical Complex. The object of the study is tires (27.00R49) of mining dump trucks Komatsu HD785-7 (table 3). The subject of research is the resource of tires.

Table 3. Main technical data of dump truck Komatsu HD785-7

Load capacity, kg	91000
Operating weight, kg	72300
Gross weight, kg	163300
Mass distribution, kg:unladen: -front -rear gross weight: -front -rear	 33980 (47%) 38320 (53%) 51440 (31,5) 111860 (68,5)
Tipper body capacity, m^3: -geometric -with a hat (2:1)	 40 60
Maximum travel speed, km/h	65
Ability to overcome the rise,%	35
Minimum turning radius, m	10,1
Dump angle,^{0}	48
Overall dimensions, mm: -length -width -height	 10290 5050 4950

Tires must meet basic performance specifications, including tonne-kilometers per hour, tread type, tire pressure, ply rating, etc. [11].

4 Test equipment

During the experimental studies, the following equipment was used:

1. Electronic thermometer for measuring ambient air temperature with an accuracy of ± 0.1 °C.
2. U901 tire pressure monitoring system, wireless TPMS with 6 external sensors.
3. Average cruising speed as measured data.
4. A special inclinometer sensor installed on the basic set of machines to fix the road slope.
5. Electronic depth gauge with an accuracy of 0.1 mm - a device for determining the measurement points of the tread height in order to increase the reliability of the results.
6. Torque, power and wheel speed received from the dump truck ECU using a computer using a special RealDisp program.
7. Pressure sensors on the suspension cylinders of the machine (all 4 sensors), from the parameters of which the mass of the load was recorded.

5 Road test methodology

Experimental studies begin with determining the degree of strength of the quarry rock.

All career routes are divided into 5 groups, based on the average longitudinal slope of the road. The routes of the first group are roads with an average slope from -1 to +1%. The average slope of the route of the second group should be in the range from +1 to +3%, the third group - in the range from +3 to +5%, the fourth group - in the range from +5 to +7%, the fifth group - over +7%.

Experiments begin with the selection of dump trucks (at least 3, based on the number of the garage) in a group with an average road slope of up to 1%. Qualified drivers with at least 5 years of experience are selected for the experiment.

Then dump trucks are selected for the rest of the routes. A tire model is selected for dump trucks, after which the tires are checked for quality and prepared for testing. Depending on the capabilities of the organization, the dump trucks participating in the experiment will be fitted with new tires.

Experiments are carried out simultaneously on all routes, divided into 5 groups. A separate table is compiled for each group of dump trucks. The table records the distance traveled by the truck, the remaining tread depth of each tire, and the average tire wear rate. The average tire wear rate is calculated using the following formula:

$$\gamma_{\text{cp}} = \frac{h_1 - h_2}{S_2 - S_1} \quad (1)$$

whereh_1 is the initial tread height, mm; h_2 – tread height at the end of the measured run, mm; S_1 – mileage at the beginning of measurements, thousand km; S_2 – the value of the run at the end of the measured run, thousand km.

Experimental studies are carried out within 3 – 9 months, depending on the change in the length of the routes. Once every two weeks, measurements are taken and entered in the table.

Based on the table (see table 5), graphs are built and the dynamics of tire tread wear is analyzed. For dump trucks of each group, the operational (expected) mileage is calculated using the following formula.

$$L_{ex} = \frac{1000(h_{in} - h_{res})}{\gamma_{av}} \quad (2)$$

whereL_{ex} – is the distance traveled by the dump truck to maintain the tread height of 1 mm, km; γ_{av} – is the average intensity of tire wear, mm/1000km; h_{in} – begin – initial tread height, mm;h_{res} =1 мм.

The results of the experiment are due to the analysis of the mileage of dump trucks moving along the routes of the first group. On roads with an average longitudinal slope from -1 to +1%, the impact on tire wear is assumed to be $K_{ук} = 1$. According to formula (2), we calculate L_expect for each of the 5 groups and determine $K_{ук2}$, $K_{ук4}$, $K_{ук6}$, $K_{ук8}$ by comparing them with each other. Estimated coefficients of the average road slope that affect the life of tires $K_{ук2}$, $K_{ук4}$, $K_{ук6}$, $K_{ук8}$ are determined by predicting the coefficients that affect the tire life of each percentage of the road slope.

With the help of these correction factors, it is possible to predict the resource of tires for mining trucks operating on any road slope, and the degree of rock hardness.

Experimental studies were carried out in accordance with the requirements and methods of the international standard "GOST 28169-89. Tires are pneumatic. Methods for determining the wear resistance of tires during road tests.

6 Study to determine the effect of the average longitudinal slope of open-pit roads on tire life

Experimental studies were carried out at the Muruntau quarry, owned by the Navoi MMC. First, the operating conditions of the quarry were studied and the following was established:

1. Quarry depth: 630 m, on average – 450 m.
2. Makes and models of dump trucks BelAZ-75307 (220t.), SAT-785 (136t.), BelAZ-75131 (136t.), SAT-777 (90t.) and Komatsu HD 785-7 (91t.).
3. Road surface and its percentage at the transportation distance: hard rock, 20–30%.
4. Access roads to excavators and to the place of unloading of the total transportation distance: approximately 15 to 25%.
5. Width of technological roads, m: maximum 22 – 26 m, average – 18 m.
6. The number of turns on the entire transportation arm: 2 – 10 and their radii, m:maximum – 60 – 80;minimum – 26 – 30.
7. Evaluation of slopes,%: maximum – 12, average – 5 – 7.
8. Shoulder transportation (one way), m:maximum – 10000 – 14400;minimum – 250 – 1000;medium – 4300 – 5800.
9. Operating time (cycle), h: 0,5 – 0,8.
10. Dump truck speed, km/h: maximum: – 40 – 45, average –14–17.
11. TKPH for tires37.00R57, 42/90R57 – TKPH>700, for tires 40.00R57,46/90R57 – TKPH>750, for tires 33.00R51 –TKPH >600, for tires 27.00R49 – TKPH >415.
12. Type of transported rock, loosening coefficient, weight of rock, kg/m^3: overburden – hard rock with a density of 1.8 to 2.2; ore – hard rocky rock with a density of 2.2 to 2.8.
13. Coefficient of rock strength according to the scale of M. Protodyakonov: 10 – 12.
14. Loading equipment (model, bucket volume): ECC-15, bucket volume - 15m^3, EC-20,

EC-25, bucket volume 20 and 25m³.

15. Load control system: on BelAZ-7513,75307 dump trucks, the load and fuel control system (LFCS) was installed, on CAT-789 dump trucks - the VIMS system and on Komatsu HD 785-7 was recorded from the parameters of pressure sensors on the vehicle suspension cylinders (all 4 sensors).
16. Determined how many days with bad road conditions due to weather conditions. The roads are serviced daily by the road service, periodically 3 – 4 days.
17. Maximum seasonal temperature: in winter - maximum -25^{0}C, average -0 – -10^{0}C, in summer – maximum +45^{0}C, average +30 – +40^{0}C.

All routes of dump trucks in the Muruntau quarry have been studied and analyzed. More than 90 dump trucks and 27 excavators are used as technological transport at the Muruntau quarry. The following table of routes contained the calculated average longitudinal slope of the road received from the quarry operation department (table 4).

Table 4. Dump truck routes in the Muruntau quarry

№	№ ECC	ECC horizon	Warehouses	Warehouse horizon	Distance, km	Average longitudinal slope of the route, %
1	12	30	Steeply inclined conveyor (SIC)	300	4.4	6.19
2			SIC XX	300	3.8	7.11
3			SIC XXI	300	3.7	7.30
4			Dump 9 A-5	550	9.8	5.31
5			Sector III	567	13.0	4.13
6			Sector VIII	545	13.4	3.84
7			Sector XI	552	9.6	5.42
8			Sector XII	552	9.4	5.55
9			Sector XIII	545	9.4	5.48
10			Sector XIV	545	9.5	5.41
11			Sector XX	565	9.8	5.49
...			...	...	...	...
...			...	...	...	...
...			...	...	...	...
215	92	530	Sector I	567	7.7	0.48
216			Sector III	567	7.6	0.49
217			Sector IV	567	7.8	0.47
218			Sector V	567	7.9	0.47
219			Sector VIII	545	8.1	0.19
220			Sector XI	552	3.7	0.59
221			Sector XIII	565	3.4	1.04
222			Sector XVIII (square XX)	565	3.6	0.97
223			Sector XX	565	3.7	0.94
224			Stock 7Б 7/9-1	575	7.7	0.58
225			Stock 7Г 11	530	2.4	0.00

Analyzing table 6, we see that the shortest route is 0.3 km and the longest route is 14.4 km. From these routes, we choose routes up to 7.5 km long and divide them into 5 groups (table 5).

Table 5. Routes included in the first group (average slope of the road up to 1%)

Number routes	Excavators		Stocks		Distances, km	Average slope of the road,%
	№	horizon	№	horizon		
1	67	525	Stock 7Г 11	530	3.6	0.14
2			DPP-5	567	4.4	0.96
3			DPP-6	567	4.3	0.98
4	69	580	Stock 7Г 11	530	4.9	-1.02
5	72	545	Sector VIII	545	1.6	0.00
6	73	490	Sector I	567	7.6	1.01
7			Sector III	567	7.5	1.03
8			Sector V	567	7.5	1.03
9			Sector VIII	545	7.9	0.70
10			Stock 7Б 7/9-1	575	7.2	1.18
11	82	510	Dump 6-1	530	2.9	0.70
12	84	545	Sector VIII	545	1.7	0.00
13	92	530	Sector I	567	7.7	0.48
14			Sector III	567	7.6	0.49
15			Sector IV	567	7.8	0.47
16			Sector V	567	7.9	0.47
17			Sector VIII	545	8.1	0.19
18			Sector XI	552	3.7	0.59
19			Sector XIII	565	3.4	1.04
20			Sector XVIII (area XX)	565	3.6	0.97
21			Sector XX	565	3.7	0.94
22			Stock 7Б 7/9-1	575	7.7	0.58
23			Stock 7Г 11	530	2.4	0.00

Before the start of the study, the technical condition of the dump trucks on which the controlled tires were installed was checked, the tire pressure was measured and adjusted to the norm, and the tread heights of the controlled tires were measured.

Qualified drivers and dump trucks were selected for testing in each group. On the dump trucks included in the first group, on February 2-4, 2022, new tires were installed (table 6).

Table 6. Komatsu HD785-7 dump trucks allocated for the first group, numbers and positions of tires installed on them

№	Tipper garage number	Tire mounting location, 27.00R49MichelinXDR3 B4					
		front left	front right	rear left inner	rear left outer	rear right inner	rear right outer
1.	№207	4799	4197	4117	4801	4658	2280
2.	№271	7577	7543	7545	7536	7578	7579
3.	№272	7852	7985	7880	7851	7861	7865
4.	№277	7912	8459	7979	7858	8278	8632
5.	№281	3443	2256	2733	6633	4196	1042

Routes included in the second group (average slope of the road - from 1 to 3%). The routes included in the second group are given. On february 6–8, 2022, new tires were installed on dump trucks included in the second group.

Routes included in the third group (average slope of the road from 3 to 5%). On march 3–7, 2022, new tires were installed on dump trucks included in the third group.

Routes included in the fourth group (average slope of the road - from 5 to 7%). On march 10–12, 2022, new tires were installed on dump trucks included in the fourth group.

Routes included in the fifth group (average slope of the road - over 7%). On april 6–7, 2022, new tires were installed on dump trucks included in the fifth group.

In agreement with the operation department, the drivers of each group were assigned routes of movement.

Experiments for the first group of dump trucks began on february 3, for the second – on february 7, for the third – on march 4, for the fourth group on march 11 and for the fifth – on april 7.

Once every 2 weeks, the distance traveled, the residual tread height, air temperature, and tire pressure were measured. In addition, the condition of the tires was checked. In case of mechanical damage, cuts in the tread or sidewall, etc. repairs were made after which they were again used in the experiment. If the tires were damaged, an act was drawn up and they were removed from the experiment.

The dynamics of tire wear of each dump truck included in the group was studied, graphs were built and compared with other dump trucks of the same group. Along with this, the average mileage of the tires installed on them was calculated and entered into the graph. This was realized in all five groups.

Calculations of wear intensity were carried out according to the method of determining the expected operating time by establishing the intensity of tire wear.

All tire wear resistance research data were summarized in special “Tire Life Experimental Research Record Cards”. They also provide the results of calculations of the predicted tire mileage until the tread is completely worn out, which is the basis for normalizing the operational mileage of controlled oversized tires.

The initial tread height of the new Komatsu HD785-7 tires installed on february 3, 2022 was 90mm. All calculations were made on tires that had natural wear, without taking into account tires that were prematurely removed from service due to mechanical damage or tread separation.

The results of measurements of the tread height and calculation of tire wear are presented in the experimental studies card in table 7.

Table 7. Accounting card for experimental studies of the influence of road slope on tire resources Komatsu HD785-7 No. 207 of the 1st group

№	Installation location	Manufacturer	Date of measurement																
			03.02. 22y.		17.02.22y.			03.03.22y.			18.03.22y.			…			29.06.22y.		
			mileage, km																
			0		4926			4778 (9704)			4504 (14208)			….			4063 (44308)		
			initial tread height, mm	tread wear, mm	tread height, mm	tread wear, mm	average intensity wear, mm/thousand km	tread height, mm	tread wear, mm	average intensity wear, mm/thousand km	tread height, mm	tread wear, mm	average intensity wear, mm/thousand km	tread height, mm	tread wear, mm	average intensity wear, mm/thousand km	tread height, mm	tread wear, mm	average intensity wear, mm/thousand km
1	F.L.	Michelin , 27.00R49	90	0	86,6	3,4	0,71	83,4	3,2	0,68	80,0	3,4	0,74	…	….	…	51,1	4,5	1,11
2	F.R.				86,4	3,6		83,1	3,3		79,8	3,3		…	…		50,9	4,5	
3	R.L.I.				86,1	3,9	0,78	82,3	3,8	0,78	79,0	3,3	0,74	…	…	…	46,7	4,9	1,25
4	R.L.O.				86,2	3,8		82,6	3,6		79,1	3,5		…	…		46,4	5,1	
5	R.R.I.				86,1	3,9		82,3	3,8		79,0	3,3		…	…		45,5	5,2	
6	R.R.O.				86,2	3,8		82,4	3,8		79,1	3,3		…	…		45,8	5,1	

Using the table above, we can plot the graphs in fig. 3, 4. This dump truck is operated on routes belonging to the 1st group, that is, on roads with a longitudinal slope of up to 1%.

At the end of the experiment in the first group, the average mileage of 5 dump trucks was 120,000 km. The tire wear rate was about 0.7 [mm/1000 km] at air temperatures up to $+15^0$C. On hot summer days with air temperatures above $+30^0$C, the tire wear rate reached 1.27 [mm/1000km].

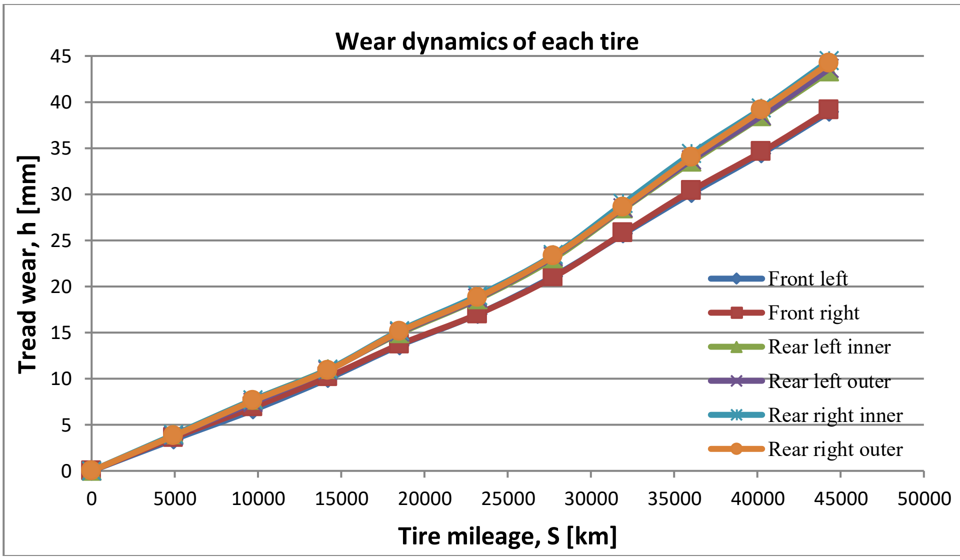

Fig. 3. The dynamics of wear of each tire Komatsu HD785-7 No. 207

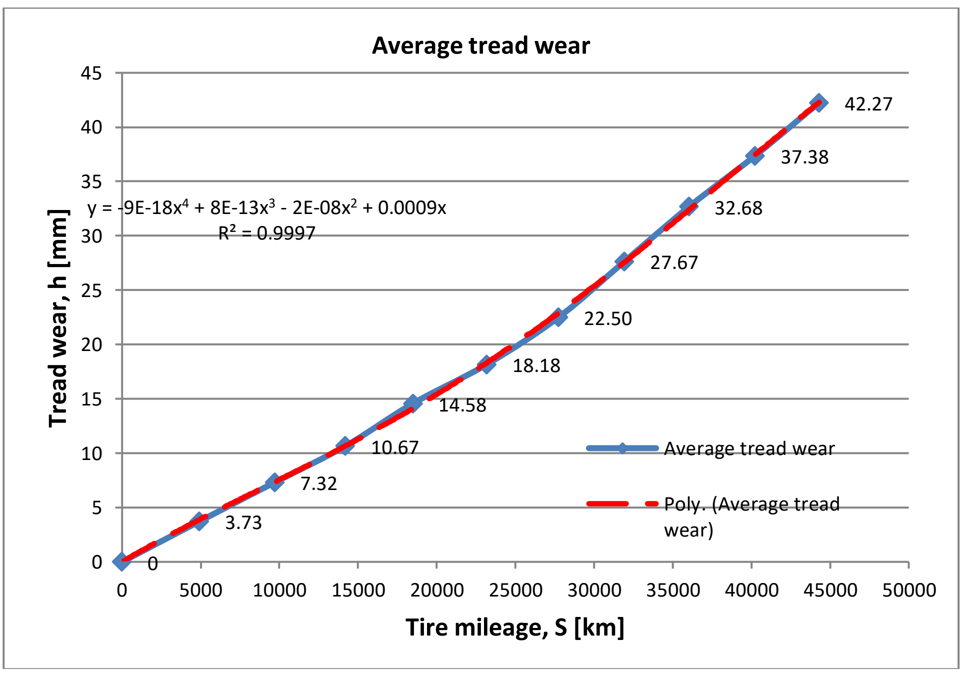

Fig.4. Dynamics of average tire wear Komatsu HD785-7 №207

7 Analysis of the results of experimental studies

During the experiment, the intensity of tire wear of the front and rear axles of the dump truck was separately studied and analyzed.

We assumed that the average slope of the first group is 0%, the average slope of the second group is 2%, the average slope of the third group is 4%, the average slope of the fourth group is 6%, and the average slope of the fifth group is 8%. On the routes of the first group, the influence of the longitudinal slope of the road on the tire life is taken equal to 1.

As a result of the experiment, the average operating mileage of dump trucks in each group was determined. The average mileage of 5 dump trucks in the first group was 120,000 km, in the second group – 98,400 km, the average mileage of 12 dump trucks in the third group was 78,000 km, the average operating mileage of 5 dump trucks in the fourth group reached 62,400 km, and the average dump trucks in the fifth group – 46,800 km. The correlation of the found values was expressed by the following formula:

$$y = e^{0,113x} \quad (3)$$

Using this formula, by predicting, coefficients are found that reduce tire life, corresponding to each percentage of the longitudinal slope of the route. These values are shown in table 8.

Table 8. Tire life reduction coefficients corresponding to each percentage of longitudinal slope

Average slope of the road,%	Coefficients taking into account the influence of the average road slope on the tire life $K_{ук}$	Operational mileage of tires, km
0	1	120000
1	1,10	109090
2	1,22	98400
3	1,39	86330
4	1,54	78000
5	1,74	68965
6	1,92	62400
7	2,24	53570
8	2,56	46800

According to this Table 8, graphs were built (Fig. 5).

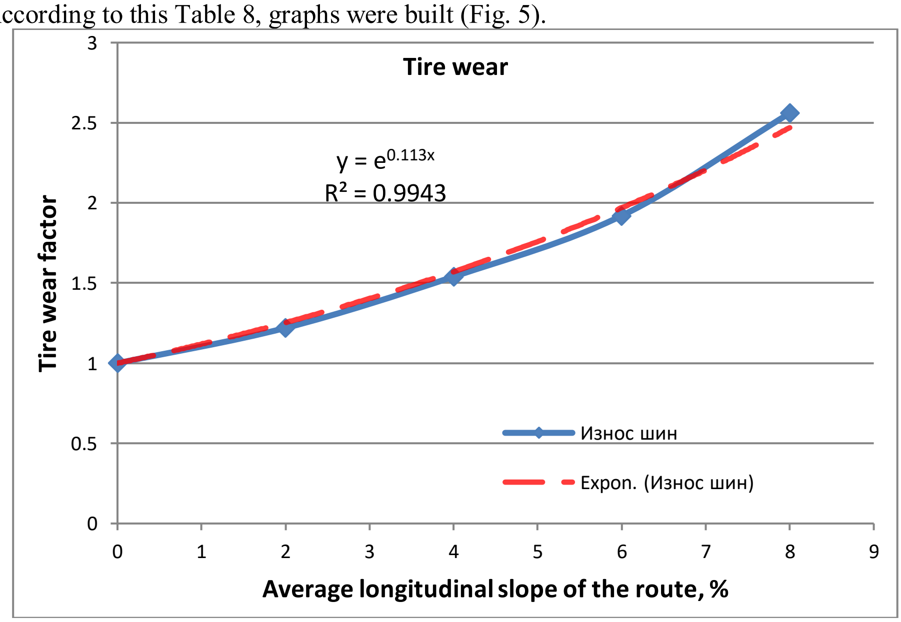

Fig. 5. Influence of the longitudinal slope of quarry roads on the resource of tires

8 Conclusions

1. The coefficient of rolling resistance in quarry conditions was approximately f=0.05 – 0.06. In such road conditions, on routes with a slope of 6%, a 2-fold decrease in tire life was observed.
2. The average speed of Komatsu HD785-7 dump trucks in the Muruntau quarry was 14–16 km/h when loaded, and 35–40 km/h when empty.
3. The loading control system on Komatsu HD 785-7 dump trucks was fixed from the parameters of the pressure sensors on the machine's suspension cylinders (all 4 sensors). The mass of cargo loaded into dump trucks ranged from 87 to 94 tons (95 – 105%).
4. Cool weather from October to April (up to 150C) helped compensate for the internal heating of the tires and did not lead to thermal delamination [20].
5. On hot days (temperatures above 30^0C), running the tires beyond the capacity of heat dissipation inevitably led to the formation of internal delaminations, mainly in the shoulder area of the tires.
6. The experiment involved 30 dump trucks and 180 tires. Of these, 24 (13.3%) tires were withdrawn from service due to mechanical damage and delamination.

References

1. Topalidi V.A., Yusupov U.B. Standardization of the resource of tires of typical cars in open pit conditions. Automotive industry. No. 11. pp. 27 - 29.(2019).
2. 2. Yusupov U.B., Kasimov O.K., Narziev Zh.Sh. Rationing the tire mileage of NefAZ shift buses in the conditions of "AMMC". In International, scientific, electronic journal "Transport of the Silk Road". No. 3 - 4. pp. 94 - 101.(2019).
3. Topalidi V.A., Yusupov U.B., Babaev A.M. Wear resistance of specialized vehicles tires on quarry roads. International journal of mechanical and production engineering research and development (IJMPERD); Vol. 10(5),pp.643 - 658. (2020).
4. Topalidi V.A., Yusupov U.B. Wear resistance of tires of specialized vehicles depending on the category of the fortress of quarry roads. Automotive industry. No. 12, pp. 20 - 22.(2020).
5. U. Yusupov, O. Kasimov, A. Anvarjonov. Research of the resource of tires of rotary buses in career conditions. ICPPMS-2021.AIP Conference Proceedings Vol.2432, p.030072 (2022).
6. V. Topalidi, U. Yusupov, S. Allaberganov**.** Improving the efficiency of transport logistics support.ICPPMS-2021. AIP Conference Proceedings Vol. 2432. 030073. (2022).
7. Yusupov U.B. Tire resource rationing in quarry conditions // Railway transport: Topical issues and innovations. No. 3.pp. 35 - 42.(2021).
8. Topalidi V.A., Yusupov U.B. Wear resistance of tires of specialized vehicles in quarry conditions. Monograph. Avtomsan Publishing Housep.132.(2021).
9. Topalidi V.A., Yusupov U.B. Analysis of mileage of oversized tires of heavy dump trucks operating in the Kalmakyr mining department. Scientific journal of vehicles and roads. No. 1. pp. 73 - 81.(2022).
12. Yusupov U.B., Otamurotov F., Baratov I. Road studies of wear resistance of large tires // Scientific journal of vehicles and roads. No. 1. pp. 36 - 46.(2022).

13. Yusupov U.B., Topalidi V.A., Anvarjonov A.A. Development of coefficients for correcting the mileage of tires of specialized vehicles, taking into account work in career conditions.Journal of Hunan University Natural Sciences.Vol. 49. p. 276 - 286.(2022).
14. Yusupov U.B., Anvarjonov A. Rating of the operational massage of the tires of large-loaded mining dump trucks operating at the objects of the Almalyk mining and metallurgical combine.Galaxy International Interdisciplinary Research Journal (GIIRJ). Vol. 10(1). pp. 36 - 40.(2022).
15. Yusupov U. B., and Urinboev K. U. Analysis of the results of theoretical and experimental studies on the wear resistance of tires of specialized vehicles. Oriental renaissance: Innovative, educational, natural and social sciences (ORIENS)»Vol.2(1), 1216-1224. (2020).
16. Tsytsenko N.A. Investigation of the dependence of operating costs on the movement of a car on the speed of movement and the magnitude of the slope of the road. Improving the economic efficiency of construction and operation of highways in Kazakhstan - Alma-ata, pp. 48-56.(1971).
17. U. Yusupov, A. Muxitdinov, F. Otamuradov. Rationing of tire mileage in the operating conditions of the Kalmakyr quarry. International Jounal of Multidisciplinary Research and Analysis (IJMRA). Vol. 05(05). May. pp. 929 – 934. (2022).
18. Yusupov U.B., Narziev J., Zafarov K. Peculiarities of operation of oversized tires for technological vehicles. Oriental Journal of Technology and Engineering.Vol. 2(1). 2022May.pp. 20 - 29.
19. Boltaevich Yu. U., Anvarovich M. A., and Sobir ugli T. S. Influence of ambient temperature on tire wear rate.Miasto Przyszłości,Vol. 31, pp. 293-299. (2023).