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DEVELOPMENT OF COEFFICIENTS FOR CORRECTING THE MILEAGE OF TIRES OF SPECIALIZED VEHICLES, TAKING INTO ACCOUNT WORK IN CAREER CONDITIONS

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Abstract: At the moment, the scientific society is actively conducting research to address issues such as reducing transport costs on road transport, efficient use of material resources, as well as the choice of trucks and tires that are adaptive to specific operating conditions.
For the first time, coefficients for correcting the mileage of tires of specialized Kgp vehicles were developed and introduced into scientific circulation, depending on the category of rock strength on the scale of Prof. M.M. Protodiakonov, on the basis of which quarry roads were laid.
Based on the results of the study, a “Handbook on the rules of operation and rationing of the resource of motor vehicle tires in the conditions of the Almalyk Mining and Metallurgical Combine (AMMC) was introduced", developed on the basis of a universal methodology for rationing the mileage of vehicle tires, taking into account work in career conditions. As a result of the practical use of the recommendations, the mileage rate of tires of specialized vehicles has increased to 20%.
Keywords: rationing, tire wear, specialized vehicles, quarry roads, rock fortress.
摘要： 目前，科学界正在积极开展研究，以解决诸如降低公路运输运输成本、有效利用物质资源以及选择适应特定运行条件的卡车和轮胎等问题。
首次根据 M.M. Protodiakonov，在此基础上铺设了采石路。
根据研究结果，在通用方法的基础上制定了“Almalyk 矿冶联合 (AMMC) 条件下机动车辆轮胎资源操作和配给规则手册”对车辆轮胎的里程配给，考虑到工作中的职业条件，通过建议的实际使用，特种车辆轮胎的里程率提高到20%。
关键词：配给，轮胎磨损，专用车辆，采石场，岩石堡垒。

Introduction

Tire wear is generally affected by about 30 different factors, which can be grouped into the following four groups: tire quality; technical condition of vehicles (TCV); violation of the conditions and operating modes of PBX; road

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and climatic conditions. In particular, the Research Institute of the Tire Industry (RITI) it has been established that if we take the service life on paved roads in good condition for 100%, then on a hilly and winding road in good condition, the tire resource will be 76%, on an unpaved road - 65%, on mountain roads with different surfaces (paving stones, crushed stone) - only 50% [1, 2, 3].

At the moment, the scientific society is actively conducting research to address issues such as reducing transport costs on road transport, efficient use of material resources, as well as the choice of trucks and tires that are adaptive to specific operating conditions. The methods proposed in them for assessing resource savings and developing standards for trucks used in difficult conditions do not fully take into account the impact on tire resources of factors arising in operating conditions. As a result, the resource efficiency of truck tires is very low in the existing difficult operating conditions. In this regard, it is important to conduct targeted studies, including when determining the dynamics of tire destruction, on specialized vehicles operating in various categories of road conditions, especially in quarry conditions, aimed at improving the method of rationing tire mileage depending on the category of rock strength.

The operating costs for the tire of specialized vehicles operating in quarry conditions are up to 20% of the total cost of transportation work. There is still an urgent problem of studying the tire life of specialized cars in career conditions. Usually these are vehicles with a load capacity from 10 to 24 tons. used as technological transport in small quarries, where the terrain does not allow the use of heavy-duty dump trucks. They also perform important auxiliary work at large quarries: they deliver spare parts for mining equipment and technological transport, replacement equipment, special cargo, tankers and water carriers for irrigation, etc. [4, 5].

Currently, scientific research is being conducted to an insufficient extent to develop a methodology for rationing the mileage of tires of specialized vehicles in career conditions. This is due to the fact that the methods and coefficients of tire mileage correction related to the strength of the rocks that form the basis of the quarry roads have not been determined.

Therefore, it was important to develop a universal method that would justify the mileage of tires of specialized vehicles by determining the correction coefficient of tire mileage, taking into account the strength of the rock laid in the form of a road surface in quarries [6].

The scientific literature has numerous studies in the field of tire wear resistance and improving their service life. Each of these studies differs in its approach to the study of the problem and individual methods of its solution. However, all of them are aimed at improving the characteristics of tires, the condition of which determines the controllability of vehicles, its driving performance, stability and comfort. In turn, the characteristics of tires are directly predetermined by the structural elements and the physical and mechanical properties of the materials from which they are made, as well as their operating conditions and working period [7].

Tire wear is affected by various factors. Of their total number, the road surface, the condition of the wheels and the professional skills of the driver, the ambient temperature should be highlighted. These and a number of other factors affect the amount of movement of tire profile elements occurring under a certain pressure in the boundary layer and between the tire and the road [1, 8].

Despite the extensive number of studies devoted to the intensity of tire wear on various roads and operating conditions, the problem of rationing the mileage of tires of specialized vehicles, taking into account partial work in quarry conditions, still remains relevant. Usually these are vehicles with a load capacity from 10 to 24 tons, used as technological transport in small quarries, where the terrain does not allow the use of heavy-duty dump trucks. And they also perform important auxiliary work at large quarries: they deliver spare parts for mining equipment and technological transport, replacement equipment, special cargo, workers (shift buses), tankers and water carriers for irrigation, etc. Such a problem exists in Almalyk MMC.

1. Experimental research

AMMC is one of the largest metallurgical plants in Central Asia, having huge and small quarries for the extraction of non-ferrous metals. Study of the wear resistance of tires of specialized vehicles, taking into account work in quarry conditions - according to the study plan, an analysis of the condition of road surfaces on which specialized transport is operated in the Kalmakyr mining departments (MD), Angren mining departments (AMD) and Chadak mining departments (CMD) was carried out.

All roads from the gold extraction factory (GEF) to the CMD tunnels were divided into the following 2 sections:

1. Dirt roads laid on a solid, rocky foundation. Especially in poor condition are located near the tunnels themselves (Fig.1).
2. Roads that are broken asphalt, located from GEF to the tunnels of Guzaksai.

All roads to the tunnels are CMD narrow and are designed for the passage of only one dump truck, sometimes for the entrance to the tunnel it is necessary to drive the dump truck in reverse, as it happens when approaching the tunnel 54. The minimum width of the road at the turning points according to the norms (КМК 2.05.02-07) should be 10.5 m [7].

The roads to the CMD tunnels are characterized by a height difference, have many ascents with a simultaneous turn of the road, and all the ascents, although not protracted, but the bulk of them has a slope of > 12%. Especially bad here are the sections of roads before dumping into the waste rock dump.

Calculations show that the controlled dump truck MAN 33.360 10.702NAA (operated like all the other 4 dump trucks - carried out technological transportation) transported goods mainly along the roads that we designated under number 1 - on dirt roads. Runs on such roads accounted for 97% of the total mileage.

Attempts were made to fill up with forest some difficult sections of the roads of the tunnels in the CMD. Now there is practically nothing left of the forest. The terrain in CMD does not allow the construction of real dirt roads of category IV, although roads need to be constantly cleaned, as well as periodically, where possible, filled with loess.

Considering the costs incurred by the CMD due to intensive tire wear on technological transport - dump trucks MAN 33.360, ISUZU 51 KLD and KrAZ-65055, as well as no less intensive wear of the aggregates of these cars, it becomes obvious how much more profitable it is to keep the CMD roads in proper condition.

The rocky base of the unpaved roads of the CMD causes the danger of car tires hitting sharp boulders. There are especially many such road sections in the Guzaksai deposit. At the same time, the more worn out the tire, the larger the punctures may be even from small-sized sharp-angled cobblestones. That is why dirt roads require constant attention, cleaning, filling holes, leveling the formed track, etc.

Almost all roads inside quarries (up to 90%) are temporary technological ones designed for a service life of up to one year. Temporary roads continuously "move" after the front of excavator or dump work. These passages are arranged by bulldozers and graders directly on the ground without any coatings [4].

Specialized vehicles operating as technological transport in the Angren and Chadak mining departments of AMMC are usually operated on three types of roads. Only in CMD there are 5 routes for the transportation of waste ore along roads laid up to 97% on a solid rock foundation (Fig.1).

Fig.1. Road condition in the Chadak MD

In the quarries of AMMC, the strength coefficient of the breed f on the scale of M.M.Protodyakonov is 14-15 and belongs to the second category of the breed – very strong.

The analysis of the condition of decommissioned tires allowed us to draw certain conclusions regarding the causes, mechanisms of tire wear and destruction during the operation of specialized vehicles at the Kalmakyr MD, AMD and CMD.

Before the start of research on the wear resistance of tires of specialized vehicles, preparatory work was carried out according to interstate GOST 28169 "Pneumatic tires. Methods for determining the wear resistance of tires during road tests". Along with this, work was carried out on the technical condition of the controlled cars, the selection of qualified experienced drivers, calibration of devices for measuring the depth of the tire tread and the choice of routes for cars [9].

In order to ensure the reliability of the evaluation of experimental studies of tire wear, the number of measurements was justified so that the statistical error was no more than 5%.

Calculations were carried out on the basis of the methodology specified in GOST 28169. In the calculations carried out, the formulas are substituted with real initial data obtained experimentally during studies of tire wear dynamics in real career conditions of the CMD.

Tire wear measurements were carried out for 4-6 months with an interval of 2 - 8 thousand km. In total, about 220 cars and more than 1400 tires are involved in experiments to determine the intensity of tire wear. At least 6 measurements were performed for all experimental studies of tire wear resistance [10, 11].

The final results of experimental studies conducted at another of the AMMC quarries in the Chadak MD were taken as the basis for rationing the walking capacity of tires of specialized vehicles on quarry roads laid on the basis of solid rock. Due to the terrain, three-axle dump trucks MAN TGS 33.360 and KrAZ-65055 are used as technological transport of the CMD. The dump trucks are equipped with 315/80R22.5 tires manufactured by Belshin model BEL-278 and 12.00R20 model TTO-A112 TRIANGLE with a universal tread pattern. Rock strength coefficients f = 14-15 on the scale of M.M.Protodiakonov. Figure 5 shows the tire wear characteristics of the MAN 33.360 dump truck, tire size 315/80R22.5 manufacturer Belshina model BEL-278 (Fig.2).

Roads in the CMD are very narrow, routes are short, distances from 0.6 to 5.1 km, a total of 26 routes. In the AMD and CMD, all movements of dump trucks were recorded on separate cards, and changes in tire tread height, i.e. tire wear, were recorded in a special accounting card [11].

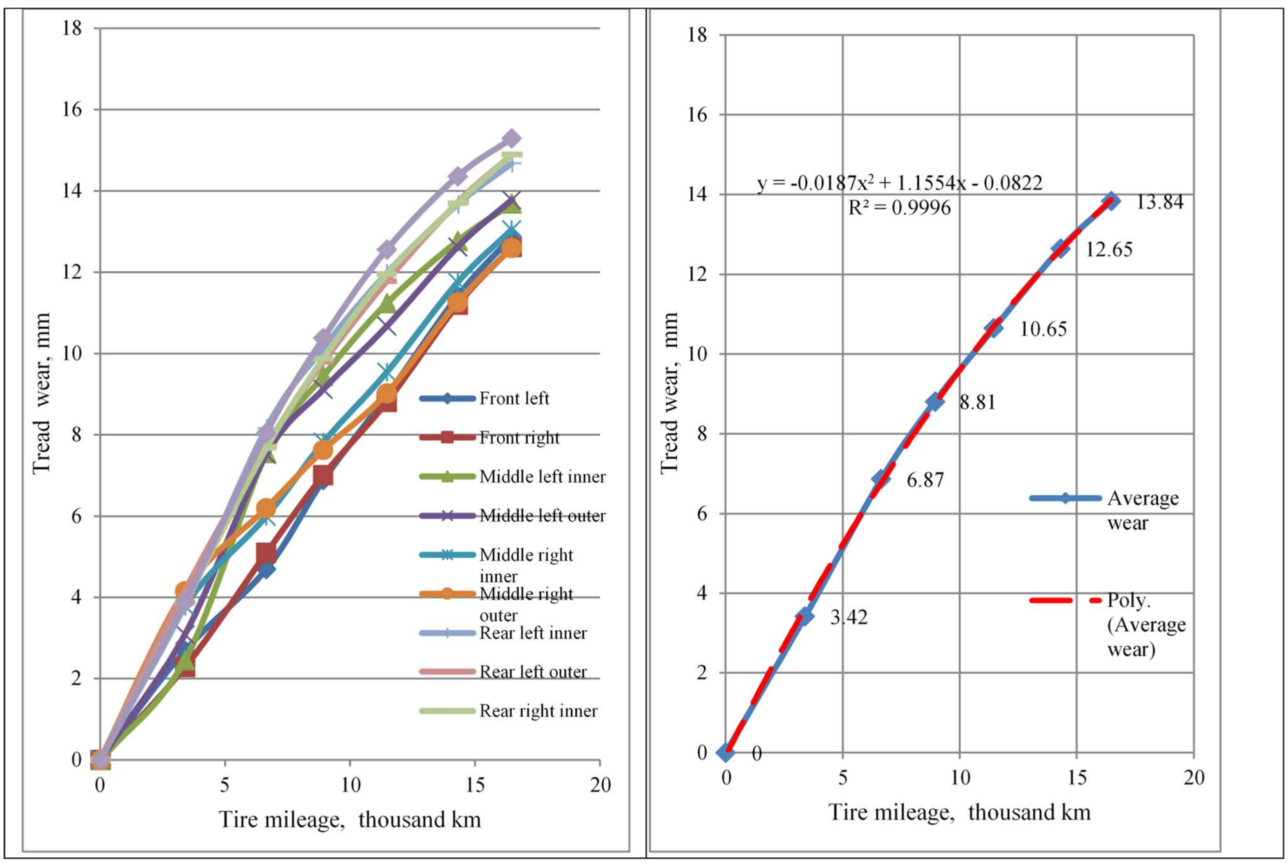

Fig.2. Characteristics of tread wear of each tire and average tire wear of dump truck MAN 33.360, No.10.702 NAA, tire size 315/80R22.5, manufacturer Belshina, Chadak MD.

2. Main text

There are three main types of tire wear: fatigue, rolling and abrasive. In quarry operating conditions, a mixed mechanism of tire wear is observed. The total intensity of wear is determined by the ratio of its individual types.

The abrasive mechanism of tire wear is manifested on gravel roads and especially on quarry roads. Abrasive wear and rolling wear are highly intensive, while fatigue wear is less intense and occurs at a low coefficient of friction between the tire and the road [3]. The results of the conducted experiments give grounds to assert a relatively low value of the coefficient of friction in rubber, characterized by high wear resistance.

The main factors affecting tire tread wear are road surface, tire pressure, coefficient of friction, vehicle speed, tread pattern, elastic modulus of rubber, tire strength and fatigue endurance.

Taking into account the influence of road pavement on tire wear, especially in quarry conditions based on hard rock, it is proposed in the classification of operating conditions [4, 5] that road pavement D6 – natural dirt roads, driveways that do not have a hard surface, temporary intracarrier and dump roads be divided into 2 categories: D6- natural dirt roads, driveways that do not have a hard surface; D7 - temporary intracarrier and dump roads (tab.1).

Table 1

Category condition s exploitati on	Outside commuter Zones (more than 50 km from the border cities)	In small towns (up to 100 thousand inhabitants) and in the suburban area	In big cities (more than 100 thousand. residents)	National economic and administrative significance of the highway
I	D_1 - P_1, P_2, P_3	–	–	Ia - main roads of national importance, including for international traffic
				Ib - highways of national (not classified as Ia), republican, regional (regional) significance
II	$D_1 – P_4$ $D_2 – P_1$, P_2, P_3, P_4 $D_3 – P_1$, P_2, P_3	D_1 - P_1, P_2, P_3, P_4 D_2 - P_1	–	Highways of national (not classified as Ia, I6), republican, regional (regional) significance
III	$D_1 – P_5$ $D_2 – P_5$ $D_3 – P_4$, P_5 $D_4 – P_1$, P_2, P_3, P_4, P_5	$D_1 – P_5$ $D_2 – P_2$, P_3, P_4, P_5 D_3 - P_1, P_2, P_3, P_4, P_5 D_4 - P_1, P_2, P_3, P_4, P_5	D_1 - P_1, P_2, P_3, P_4, P_5 D_2 - P_1, P_2, P_3, P_4 $D_3 – P_1$, P_2, P_3 $D_4 – P_1$	Highways of the state, republican (regional) (not classified into category Ia and II), local roads
IV	$D_5 – P_1$, P_2, P_3, P_4, P_5	D_5 - P_1, P_2, P_3, P_4, P_5	$D_2 – P_5$ $D_3 –P_4$, P_5	Highways of republican oblast (regional) and local

			D_4 - P_1, P_2, P_3, P_4, P_5 D_5 - P_1, P_2, P_3, P_4, P_5	significance (not assigned to categories Ib, II, III)
V_a V_6		D_6 - P_1, P_2 D_6 - P_3, P_4, P_5	D_7 - P_1, P_2 D_7 - P_3, P_4, P_5	Highways of local importance and quarry roads (except for those assigned to categories III, IV)

Road surfaces: D1 - cement concrete, asphalt concrete, paving stones, mosaic; D2 - bitumen-mineral mixtures (crushed stone or gravel treated with bitumen); D3 - crushed stone (gravel) without processing, tar concrete; D4 - cobblestone, crushed stone, soil and low-strength stone treated with binders, winter roads; D5 - soil reinforced or improved with local materials; plank and log coverings; D6 - natural dirt roads; driveways that are not paved; D7 - temporary intra-quarry and dump roads.

Terrain type (determined by the height above sea level): P1 - flat (up to 200 m); P2 - slightly hilly (over 200m to 300m); P3 - hilly (over 300m to 1000m); P4 - mountainous (over 1000m to 2000m); P5 - mountain (over 2000 m).

In addition, taking into account what effect the height and terrain has on tire wear when working in deep quarries, the V-category of operating conditions was divided into two subcategories [4]:

Va - D6 - P1, P2; D7 - P1, P2

Vb - D6 - P3, P4, P5; D7 - P3, P4, P5.

These proposals allow for a more accurate calculation of tire wear rates.

All quarry roads are filled out and laid, as a rule, from the rock of the same quarries. Depending on the category and degree of strength of the breed, the scale of Prof. M.M.Protodiakonov is used, where all breeds are classified by the strength coefficient f. For the quarries of JSC "AMMC", the rock strength coefficient is f = 14 - 15.

Research carried out in the ChMD showed that the coefficient of correction of tire mileage, if dump trucks operate only on roads with rocky soil, we determine Kgp [5]:

$$K_{gp}=L/S_n=22000/80000=0,275 \quad (1)$$

Here, L is the actual tire mileage of 10 dump trucks (100 tires) of the study; Sn - standard tire mileage established for I-category roads (Belshina, model BEL-278, tire size 315/80R22.5).

3. Methodology

Similar studies on tire wear on the same MAN 33.360 dump truck were conducted in Uzbekkumir JSC and Kizilkumcement JSC, where, respectively, f =1.0 and f=6.0, tire mileage correction coefficients Kgp = 0.8 and Kgp =0.61. Thus, the following pairs of dependences of the rock strength coefficient f and the correction of the Kgp tire mileage have been established [5, 10, 11]:

Coefficients	JSC "AMMC"	Kizilkumcement JSC	Uzbekkumir JSC

f	15	6	1
K_{gp}	0,275	0,61	0,8

An interpolation polynomial passing through these points is constructed. Calculations have shown that the linear dependence uniquely describes the line passing through these points:

(2)

In order to predict tire mileage correction coefficients for other breeds, extrapolation was carried out for all categories of breeds and the values of Kgp were determined.

Table 2

Extrapolation for all categories of rocks on the scale of M.M. Protodyakonov [12]

№	**Breed category**	**Fortress degree**	**Breeds** (scale of Prof. M.M. Protodyakonov)	**Fortress coefficient f**	**Correction factor tire mileage K_{gp}**
1	2	3	4	5	6
1.	I	Extremely strong	The strongest, densest and most viscous quartzites and basalts. Other breeds of exceptional strength.	20	0,0875
2.	II	Very strong	Very hard granite rocks. Quartz porphyry, very hard granite, siliceous shale. Less strong than the above quartzites. The hardest sandstones and limestones.	15	0,275
3.	III	Strong	Granite (dense) and granite rocks. Very hard sandstones and limestones. Quartz ore veins. Strong conglomerate. Very hard iron ore.	10	0,4625
4.	III a	Strong	Limestone (hard). Weak granite. Strong sandstones. Strong marble. Dolomite. Pyrite.	8	0,5375
5.	IV	Pretty strong	Ordinary sandstone. Iron ores.	6	0,6125
6.	IV a	Pretty strong	Sandy shales. Shale sandstones.	5	0,65
7.	V	Medium fortress	Strong shale. Weak sandstone and limestone, soft conglomerate.	4	0,6875
8.	V a	Medium fortress	Various shales (weak). Dense marl.	3	0,725

9	VI	Quite soft	Soft shale, very soft limestone, chalk, rock salt, gypsum. Frozen ground, anthracite. Ordinary marl. Destroyed sandstone, cemented pebbles, rocky ground.	2	0,7625
10	VI a	Quite soft	Crushed rock. Destroyed shale, compacted pebbles and rubble. Strong coal. Opened clay.	1,5	0,78125
11	VII	Soft	Clay (dense). Soft coal. Strong sediment, clayey soil.	1	0,8
12	VII a	Soft	Light sandy clay, loess, gravel.	0,8	0,8075
13	VIII	Earthy	Vegetable land. Peat. Light loam, damp sand.	0,6	0,815
14	IX	Loose	Sand, talus, fine gravel, bulk earth, mined coal.	0,5	0,81875
15	X	Floating	Quicksands, swampy ground, thinned loess, etc.	0,3	0,82625

We will carry out a correlation analysis of the values of the coefficients f and Kgp using Pearson linear correlation.

In general terms, the formula for calculating the correlation coefficient is as follows:

$$, \qquad r_{xy} = \frac{\sum (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \cdot (y_i - \bar{y})^2}} , \qquad (3)$$

where xi - values taken by the variable X; yi - values taken by the variable Y; - average for X; - average on Y [13].

From formula (3), it is clear that it is necessary to subtract the average value of x¯from each value xi of the variable X, which is very difficult. Based on this, calculations to determine the correlation coefficient are made according to similar formula compiled using transformations:

$$P_{xy} = \frac{n*\sum(x_i*y_i)-(\sum x_i*\sum y_i)}{\sqrt{[n*\sum x_i^2-(\sum x_i)^2]*[n*\sum y_i^2-(\sum y_i)^2]}} = \frac{15*31,93913-77,7*9,64875}{\sqrt{(15*883,59-77,7*77,7)*(15*6,883111-9,64875*9,64875)}} = -1 \qquad (4)$$

The Pearson correlation coefficient for the values of f and Kgp was -1, i.e. the coefficients of rock strength and tire mileage correction have a strong negative correlation, which confirms the correct choice of tire mileage correction coefficients depending on the breed category. Figure 3 shows the dependences of the change in the coefficients f and Kgp.

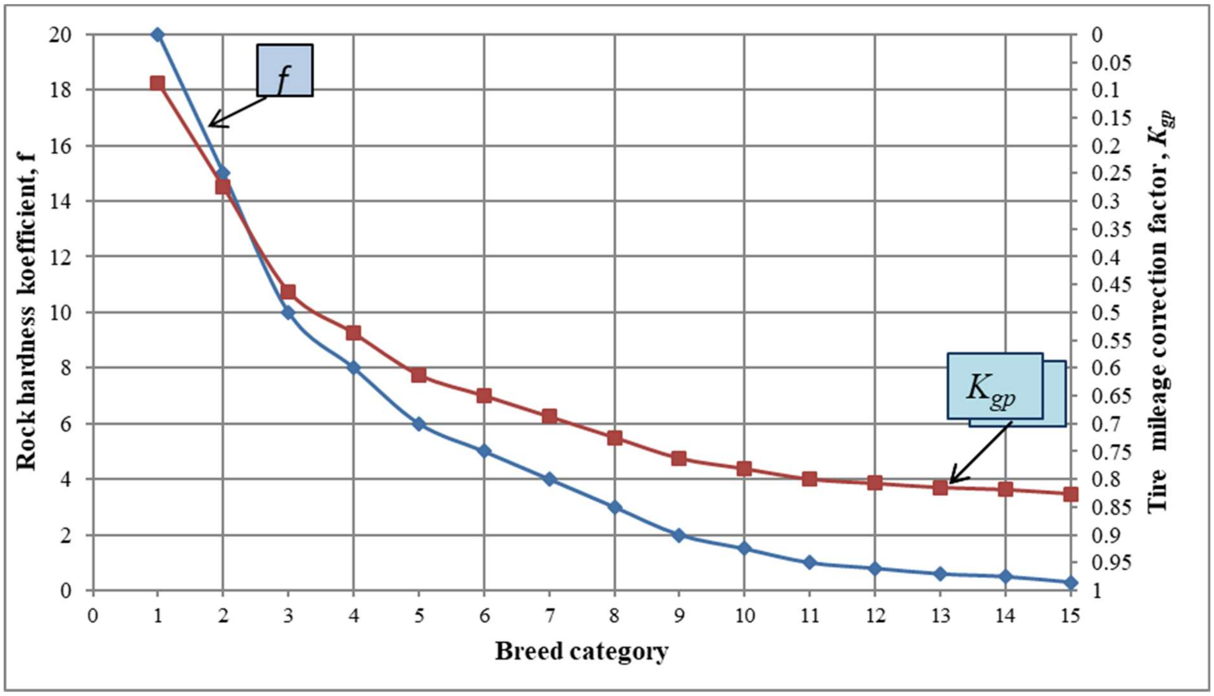

Fig. 3. Characteristics of the dependence of the coefficients f and Kgp on the breed category

The presence of the Kgp coefficient for all categories of breeds made it possible to propose an original method of standardizing the mileage of tires for vehicles with a carrying capacity of 10 to 24 tons.

4. Conclusions

1. The roads at the quarries of JSC "AMMC" are laid on the basis of solid rock. Considering that there is a lot of quartzite (up to 67%) in these quarries, which is considered the hardest rock, all wheeled vehicles operating there have intense tire wear.

2. For the first time, coefficients for correcting the mileage of tires of specialized Kgp vehicles were developed and introduced into scientific circulation, depending on the category of rock strength on the scale of Prof. M.M.Protodiakonov, on the basis of which quarry roads were laid.

3. The coefficient of reduction of the resource of tires of specialized vehicles during operation on quarry roads laid on rocky ground was Kgp = 0.275. At the same time, the rock strength coefficient according to M.M. Protodiakonov was f = 15.

4. Coefficients of correction of the mileage of tires of specialized vehicles have been developed and introduced, depending on the category of rock fortress, on the basis of which quarry roads are laid. As a result, the presence of coefficients for correcting the mileage of tires, depending on the strength of the rocks of quarry roads, ensure the rationing of the mileage of tires of specialized vehicles used in any quarries [5].

5. This methodology and all the latest recommendations on the selection and correction of tire runs were included in the "Handbook on the rules of operation and rationing of the resource of motor vehicle tires in the conditions of AMMC", transferred to JSC "AMMC" for implementation.

6. According to the results of the study, the expected annual economic effect from the

introduction of recommendations on rationing methods, operating rules and the choice of tires for specialized vehicles in JSC "AMMC" will amount to over 1.8 billion soums.

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