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DETERMINATION TIRE MILEAGE FOR VEHICLES OPERATING IN DIFFICULT CONDITIONS

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Abstract:
The article discusses the factors affecting the service life of tires of vehicles operated in the republic. The influence of such factors as tire loading and road conditions on tire wear is revealed.

Keywords: specialized vehicles, tire, tread, wear, operation, load, pressure, road conditions, bearing surface, fatigue, rolling, abrasive.

INTRODUCTION

The intensive socio-economic development of the Republic of Uzbekistan requires raising the work of road transport to a more modern level.

The main objectives of the developing road transport is to increase the efficiency of its work, the quality of transportation. At the same time, studies aimed at determining the resource of spare parts, including tires of motor vehicles operated in extreme conditions, deserve special attention.

Tire failure can be caused by more than just tread wear. The specificity of tire operation lies in the extreme variety of load, road, climatic and other conditions. Even with the strictest observance of the operating rules, as a result of random causes that arise in specific traffic situations, damage (defects) are possible that prevent further operation (punctures, breakdowns, cuts, etc.).

Special climatic and road conditions for the operation of specialized vehicles of JSC "Qizilqumsement", JSC "Jarqo'rg'onneft", JSC "Uzburneftegas", AGMK, NGMC, JSC "Neft va gaz quduqlarini sinash", SUE "PU Maxsustrans" negatively affect the performance of vehicles , their units and mechanisms, especially on pneumatic tires.

Intensive tire wear occurs due to heavy loading, vibration of operating units, off-road driving.

An analyzing the operation of tires in the conditions of the above enterprises showed that their actual mileage is below the norms established in the governing document O'z Rh 52.006:2009 "Norms of tire operating mileage". Based on this, it became necessary to determine the actual scientifically based tire mileage of specialized vehicles operated in special climatic, loading and road conditions in order to improve the reliability and safety of vehicles.

The operating mileage rate is obtained by multiplying the average mileage by correction factors [1]:

$$H_i = H * K_1 * K_2$$

where H is the average tire mileage, thousand km; K_1 - correction factor taking into account the category of operating conditions; K_2 - correction factor, taking into account the operating conditions of vehicles.

The classification of operating conditions takes into account the type of road surface, the type of terrain, and the size of the settlement. The same categories of operating conditions are taken into account when calculating various indicators of technical operation, technological calculation of motor transport enterprises [2].

At the same time, for new tire models and car brands for which there are no standards, the manager is given the right to introduce by order a temporary norm for the enterprise based on the average mileage of decommissioned tires.

Tire mileage standards for transport enterprises in the oil and gas industry were developed by VNIIOENG [3]. The standards are given for trucks, oil and gas equipment, special vehicles, as well as for road construction machines and wheeled tractors. At the same time, for transport equipment, the norm is set in kilometers, for special equipment in calendar terms.

The standards for transport equipment differ significantly in size from those indicated in the documents and to a smaller extent. In addition, they are not differentiated depending on the operating conditions [1].

Thus, the analysis of regulatory documents showed that the current standards are not differentiated by climatic regions, do not take into account the type of rolling stock and its modification, tire life is not differentiated depending on operating conditions; do not take into account the size and model of the tire.

To determine the resource of tires by the calculation method, the prediction of the performance of tires at a certain point in time is used. Since the only gradual tire failure is tread wear, this parameter is most often used to establish the operating mileage rate.

Wear is the process of destruction and separation of material from the surface of the tire tread and the accumulation of its residual deformation during friction, which manifests itself in a gradual change in its size and shape [4]. Wear is the end result of wear, expressed in units of length, volume, or mass.

Among scientists, there is an idea that there are three types of tire wear [5,6,7]: fatigue, rolling, abrasive.

Fatigue is the main type of wear, while no visible traces of abrasion are formed on the surface of the treadmill, while destruction occurs during repeated deformations of the protrusions of the abraded surface.

Wear by rolling occurs at high temperatures and with soft rubbers. As the temperature rises in the contact zone, the rubber softens, sticks to the road surface and rolls into small bundles.

When tires are used on gravel roads, abrasive wear is observed. The external manifestation of this type is scratches, tears, cuts, etc.

In real operation, wear occurs according to a mixed mechanism, while various types are combined and manifestations of changes occur depending on external conditions [8].

Wear intensity - the speed of the wear process. The wear intensity determines the moment when the limit state of the tire is reached in terms of tread wear.

Mileage before decommissioning (life) *L* is the operating time of the tire in kilometers until reaching the limit state.

The instantaneous wear rate ***u*** represents the increment of wear ***И*** with a small change in operating time ***L*** [9]:

$$u = \frac{dИ}{dL}$$

The intensity of resource consumption u_L is similar in physical sense to the wear rate, but takes into account all the reasons for removing tires from service. For its calculation, the formula [9] is used

$$u_L = \frac{dИ}{dL}$$

There are several approaches to determining the resource of tires. So Karpenko V.A. in his work [10] proposes to regulate the resource according to the criterion of fatigue life. The author obtained the following calculated dependence:

$$L = 2*10^{-6}*\pi*r_k*k*\left[\frac{2*W_p}{K_0*E*\left(\frac{\varepsilon_{ct}*K_d}{K_t*K_c}\right)^2}\right]^{n_w}$$

where *L* - tire resource, thousand km; r_k - wheel rolling radius, m; *k* is the number of loading cycles per wheel revolution, cycles; W_p is the sample fracture energy under single loading, MJ/m^3; K_o - stress concentration factor; *E* - dynamic modulus of elasticity, MPa; ε_{st} – maximum deformation of the most loaded tire elements under static loading, %; K_d - coefficient of dynamism, taking into account the speed of movement and the condition of the road surface; K_t - coefficient taking into account temperature change; K_c - coefficient of environmental influence.

The intensity of tire fatigue wear under the action of shear loads of any direction on the wheel is usually estimated using the following relationship [11]:

$$И = \frac{C_1*S*\tau^{1+\beta t}}{2\pi*R_c*a*(2+\beta t)}\left(\frac{k}{C_2*\sigma_0}\right)^t\left(\frac{E*f_t}{1-\mu^2}\right)^{t-\beta t-1}$$

where *S* - slippage; τ is the value of shear stresses; β - coefficient of roughness of the supporting surface; *t* is the coefficient of rubber fatigue; C_1, C_2 - constants depending on the roughness of the supporting surface; R_c - static tire radius; *a*, *k* - experimental coefficients; σ_0 - tear resistance; *E* is the modulus of elasticity; f_t is the coefficient of friction; μ is Poisson's ratio.

This dependence can be used in assessing the influence of various factors on the wear rate and tire life.

In the work of Petrov A.I. [12] shows the dependence of wear rate on temperature and load on the tire:

$$И_{cp} = И_0 + S_1((t_{cp}-t_0)^2+\sigma_t^{\,2}) + S_2G_{cp} + S_3\frac{1}{D}$$

where $И_0$ is the optimal (minimum) wear intensity realized under ideal conditions; S_1 is the parameter of tire sensitivity to a change in t according to the intensity of tire wear; t_{cp} - the average value of the ambient air temperature for the period under consideration; t_o is the optimum ambient temperature; σ_t^2 - ambient air temperature dispersion; S_2 is the sensitivity parameter of wear rate change to G_{cp} change; G_{cp} is the average tire load over the service life; S_3 is the parameter of sensitivity of changes in wear intensity to changes in D. D is a generalized indicator of road conditions.

Ustarov R. M. in his work [13] determined a number of operational factors influencing the wear rate and tire life under conditions of variable terrain. On the basis of bench tests, the author obtained a linear dependence, which makes it possible to calculate the mileage of bus tires depending on the specific work of the forces of resistance to movement in conditions of variable terrain.

$y = 165{,}686 - 0{,}02107 \cdot A_{уд}$

where $A_{уд}$ is the total work of the forces acting in the contact patch of the tire with the road.

The author also derived a coefficient that takes into account the terrain to predict tire mileage. So, according to the variety of road conditions for the operation of cars, it is possible to break down the characteristic areas where the tire loading parameters and operational factors will be quasi-stationary. According to the specific gravity of these areas, it is possible to determine the average intensity of wear in a particular area of the terrain. In this case, the average intensity of tire tread wear can be found in the form

$$J_{CP} = J_{РП} \cdot \Delta l_{РП} + J_i \cdot \Delta l_i + J_j \cdot \Delta l_j + J_{ПР} \cdot \Delta l_{ПР.}$$

where $J_{РП}$, J_i, J_j, $J_{ПР}$ is the intensity of tire wear on a curved section, rises (slopes), when the car is moving with accelerations (decelerations) and on straight sections, respectively mg/km; $\Delta l_{РП}$, Δl_i, Δl_j, $\Delta l_{ПР}$ is the specific gravity (work) of characteristic areas.

In [14], the authors propose to determine the intensity of tire wear based on the dependence of tread wear resistance on one or another operational parameter established for reference tires. Using the superposition principle on the independence of the influence of individual operating parameters on tire wear, the equation expressing the effect of normal load on wear rate can be written for the tire in the following form:

$$I = a_\sigma + b_\sigma \cdot G + \Delta I_p + \Delta I_M + \Delta I_\delta + \Delta I_v + \Delta I_h$$

where I is the wear rate of the tire at given values of the load G; internal pressure p, torque or braking torque M, slip angle δ, rolling speed v, tread pattern projection h, a_σ, b_σ - coefficients depending on the tire design ($a_\sigma = 4{,}5\text{-}20$; $b_\sigma = 0{,}05\text{-}0{,}06$).

$\Delta I_p = b_p\left(p - p_э\right)$; $\Delta I_M = m_M\left(м^{n_м} - м_э^{n_м}\right)$; $\Delta I_\delta = m_\delta(\delta^{n_\delta} - \delta_э^{n_\delta})$; $\Delta I_v = m_v\left(v^{n_v} - v_э^{n_\delta}\right)$; $\Delta I_h = m_h\left(h^{n_h} - h_э^{n_h}\right)$; $\Delta I_p \ldots \Delta I_h$ – tire wear increments due to the fact that the parameters p, m, δ, v and h have different values than when testing the reference tire; m and n - coefficients and exponents, for the design of a particular tire $b_p = -15 \ldots -22$; $m_м = 0.19\ldots0.22$; $n_м = 1.5\text{-}1.6$; $m_\delta = 28\ldots 49$; $n_\delta = 2.12$; $m_v = 0.0011\ldots0.0017$; $n_v = 2.4$; $m_h = 0.48\ldots0.68$. $n_h = 1.4$.

However, tires fail not only because of tread wear. In [15,16], a calculation model of tire durability is proposed in the presence of a number of reasons for their failure. The author puts forward a hypothesis about the independence of various tire failure mechanisms and introduces the concept of the tire reliability function in the presence of only one group of defects.

The average probable tire mileage according to [17, 18] is related to the reliability function:

$$\overline{S} = \int_0^\infty P(s)ds$$

where P(s) is the product of non-destruction probabilities over all defects.

The paper [17] introduces the concept of a conditional mean run - S_k, i.e. probable mileage if the tires could fail only due to one defect, and all the others except for someone were absent:

$$\overline{S} = \int_0^\infty P_k(s)ds$$

The pneumatic tire has a very complex design, and a comprehensive tire theory has not yet been developed. All attempts to improve the method for calculating tires (especially radial tires) are achieved through the use of the theory of orthotropic multilayer systems, which contains many simplifying assumptions that affect the calculation errors.

Tread wear is the main cause of tire failure. 80-90% of tires used in Uzbekistan are discarded after the tread is completely worn out.

The durability of tires depends not only on the type of road surface, but mainly on its condition. Both an increase in tire load in excess of the maximum recommended and an increase in vehicle speed lead to a decrease in tire mileage.

The internal air pressure in the tire should also be monitored. An increase in internal pressure entails a decrease in the amplitude of stress changes, and the magnitude of the maximum stress increases. If tires with increased internal pressure run into an obstacle, then cases of carcass rupture are possible, since the cords are overstressed.

With a decrease in the internal pressure, the deformations of the cord threads become sign-alternating, and the amplitude of the change in deformations increases. With this mode of operation of the tire, the fatigue failure of the cord threads occurs faster. When driving a car on tires with a reduced pressure compared to the recommended one, the heating of the tires sharply increases, which significantly affects their service life. When the car is operated on bad, rough roads, it is advisable to reduce the internal pressure, as this helps to reduce dynamic loads, increases the vehicle's flotation and tire durability.

The maximum pressure in the contact zone and the contact length are determined by the Hertz formulas derived from considering the compression of two cylinders along the generatrix [19]:

$$q_{\max} = 0{,}54\sqrt{\frac{2EQ}{BD}}; \qquad l_0 = 2{,}15\sqrt{\frac{DQ}{2BE}},$$

where q_{max} is pressure; E is the elastic modulus of rubber; Q is the load on the tire; B - tire width; D - tire diameter; l_0 is the contact length.

Heat generation (°C) in the tire array is determined [6]:

$$T = 80K\frac{Q \cdot V}{E \cdot b} + tb$$

where T is the temperature of the heated tire; Q is the static load on the tire; V is the speed of movement; E is the elastic modulus of rubber; b is the width of the tire tread; t_b is the ambient air temperature; K is a coefficient that takes into account the influence of the geometric dimensions of the tire.

$$K = \frac{1-\left(1-\frac{0{,}555h}{R}\right)^2}{1-\left(1-\frac{h}{R}\right)}\left[0{,}5 - \frac{2\left(1-\frac{1-0{,}555h}{R}\right)^2}{\left(2-\frac{h}{R}\right)}\right]$$

where h is the thickness of the tire rubber massive; R is the tire radius; *0.555* is an empirical coefficient characterizing the position of the point with the maximum temperature in the array. (According to Biderman V.L. M., Moscow State Technical University named after N.E. Bauman).

The equatorial load on the belt of a radial tire, equal to the product of the internal pressure and the radius of the tire in the center of the belt for a typical tire with an *H/B* ratio of 0.70, is 56 kgs per 1 mm of width [20].

There are 72 wires with a diameter of 1 mm in the board.

The cross-sectional area of the wire is f = 0.785 mm^2.

Wire tension: $\sigma = \frac{P_0}{n_1 f} = \frac{1500}{72 \cdot 0{,}785} = 26{,}53 \,{}^{\text{кГс}}\!/_{\text{мм}^2}$

Safety margin of wire: $\frac{\sigma_b}{\sigma} = \frac{140}{26{,}53} = 5{,}27$

The simplest relationship between the load capacity Q of a tire and its profile width B is expressed by the formula

$$Q = k \cdot B^2$$

Consider the methodology for calculating the wear rate and the calculated tire mileage using the example of some vehicles operated under the conditions of JSC "Qizilqumsement".

1. Calculation of the intensity of wear and mileage of tires 21.00-33 Belshina, VF-166AM of Belaz-7648A dump trucks.

To determine the tire mileage until tread wear of 37 mm at E= 150 kgs/sm^2 = 15*10^6 Pa, t=5 (cyclic coefficient), k=3 (reserve coefficient for tread rubber), we determine the intensity of tread wear on a crushed stone road from stone materials and slag with a friction coefficient f = 0.5.

Considering that rubber is an elastic highly elastic material, we will start calculating the tire mileage with the formula for elastic contact: tire-road.

$$\frac{h}{r} = 1{,}1\left(\frac{p_c}{E}\right)^{2/7} \cdot \left(\frac{h_{\max}}{r}\right)^{6/7}$$

where p_c is the specific load on the tire (7.25 *kg/sm²*), E is the modulus of elasticity of the tread rubber (*kgs/sm²*), h_{max}=1.3mm, *r*=65mm are the roughness parameters of the tread and the road.

$$\frac{h}{r}=1{,}1\left(\frac{7{,}25}{150}\right)^{2/7}\cdot\left(\frac{1{,}3}{65}\right)^{6/7}=0{,}01636$$

Let us check the applicability of the elastic contact formulas for this case. With $\sigma_s=\sigma_0$ it should be

$$\frac{h}{r}<\left(\frac{\sigma_0}{f\cdot E}\right)^2=\left(\frac{270}{0{,}5\cdot 150}\right)^2=1296$$

Substituting these values, we have

$$\frac{h}{r}=0{,}01636<1296$$

indicates the presence of elastic contact of the tire with the road.

Determine the number of cycles when the tire is rolling

$$n=\left(\frac{\sigma_0}{\sigma}\right)^t,$$

where $\sigma=k\cdot f\cdot p_r$; find the actual pressure

$$p_r=0{,}3E\sqrt{\frac{h}{r}}=0{,}3\cdot 150\sqrt{0{,}01636}=5{,}755\,кгс/см^2$$

Accordingly, the stress σ will be

$$\sigma=3\cdot 0{,}5\cdot 5{,}755=8{,}6325\ \ кгс/см^2.$$

The number of car tire cycles to the limit of tread wear

$$n=\left(\frac{270}{8{,}6325}\right)^5=2{,}9932\times 10^7$$

Wear intensity of tires operated at JSC "Qizilqumsement" in conditions of limestone and shale quarries

$$I=0{,}7\cdot\frac{p_r}{E\cdot n}=\frac{0{,}7\cdot 5{,}755}{150\times 2{,}9932\times 10^7}=8{,}97\cdot 10^{-10}$$

Let us determine the estimated mileage of tires operated at JSC "Qizilqumsement" in conditions of limestone and shale quarries

$$L=\left(\frac{h_{pr}}{I}\right)=\frac{37}{8{,}97\cdot 10^{-10}}=4{,}03\cdot 10^{10}\,мм\approx 40\,тыс.км$$

h_{pr} – tread wear, *mm*.

Thus, the calculated values of the standard tire mileage are ≈ 40 thousand km.

2. Calculation of the intensity of wear and mileage of tires 35/65-33 Belshina, FBel-283 wheel loaders Belaz-7822, 78221, 78231.

To determine the tire mileage to 66 mm tread wear at *E*= 150 *kgs/sm²* = 15*10⁶ Pa, *t*=5 (cyclic coefficient), *k* = 3 (reserve coefficient for tread rubber), we determine the intensity of tread wear on a crushed stone road from stone materials and slag with a friction coefficient *f* = 0.5.

According to the elastic contact formula: tire-road, we determine:

$$\frac{h}{r}=1{,}1\left(\frac{p_c}{E}\right)^{2/7}\cdot\left(\frac{h_{\max}}{r}\right)^{6/7}=0{,}01862$$

where p_c = 6.12 *kg/sm²*, h_{max} = 1.6 mm, *r* = 64 mm.

Let us check the applicability of the elastic contact formulas for this case.

$$\frac{h}{r}=0{,}01862<1296,$$

which indicates the presence of elastic contact of the tire with the road

Actual pressure: $p_r=0{,}3E\sqrt{\frac{h}{r}}=0{,}3\cdot 150\sqrt{0{,}01862}=6{,}141\,кгс/см^2$

Stress σ: $\sigma=3\cdot 0{,}5\cdot 6{,}141=9{,}21\ кгс/см^2.$

Let's determine the number of cycles when the tire is rolling:

$$n = \left(\frac{\sigma_0}{\sigma}\right)^t = 2{,}165 \times 10^7.$$

Tire wear rate: $I = 0{,}7 \cdot \frac{p_c}{E \cdot n} = \frac{0{,}7 \cdot 6{,}141}{150 \times 2{,}165 \times 10^7} = 13{,}25 \cdot 10^{-10}$

Normative tire mileage:

$$L = \left(\frac{h_{pr}}{I}\right) = \frac{66}{13{,}25 \cdot 10^{-10}} = 4{,}981 \cdot 10^{10}\,мм \approx 50\,тыс.км$$

Thus, the calculated values of the standard tire mileage are ≈ 50 thousand km.

The transfer of the standard tire mileage from thousand km to the hour is carried out as follows.

According to the methodology for determining the mileage of a vehicle [21]:

$$L = \tau \cdot k_L$$

where *L* is the mileage component, taking into account the operation of the main engine in stationary conditions, km; τ is the actual operating time of the main engine during its operation in stationary conditions, engine hours; k_L is the coefficient of reduction of the operating time of the main engine in stationary conditions to the actual mileage (for tracked vehicles, special wheeled chassis and tractors k_L = 15), *km/motor hour*.

$$\tau = \frac{L}{k_L} = \frac{50000}{15} = 3333 \quad моточас.$$

Thus, the calculated value of the standard tire mileage for a bulldozer is 3333 motor hours.

3. Calculation of wear rate and mileage of tires 11.00R20 (300R508) Forward, Traction310 of truck cranes XCMG QY16B.5

Let us determine the mileage of tires with a tread height of 20 mm at *E*=150 *kgs/sm*^{2}/15*10^6 Pa/, *t*=5 (cyclic coefficient), *k* = 3 (reserve coefficient for tread rubber), determine the intensity of tread wear on a dry dirt road with a coefficient friction *f* = 0.45.

Let's start calculating the tire mileage with the formula for elastic contact: tire-road.

$$\frac{h}{r} = 1{,}1\left(\frac{p_c}{E}\right)^{2/7} \cdot \left(\frac{h_{max}}{r}\right)^{6/7} = 1{,}1\left(\frac{8{,}4}{150}\right)^{2/7} \cdot \left(\frac{0{,}6}{32}\right)^{6/7} = 0{,}01545$$

where p_c = 8.4 *kg/sm*^{2}, h_{max} = 0.6 mm, *r* = 33 mm.

Let's check the applicability of the elastic contact formulas for this case:

$$\frac{h}{r} = 0{,}01545 < 16$$

which indicates the presence of elastic contact of the tire with the road.

Actual pressure: $p_r = 0{,}3E\sqrt{\frac{h}{r}} = 5{,}593\,кгс/см^2$

Stress: σ: $\sigma = 7{,}55\ кгс/см^2.$

Let's determine the number of cycles when the tire is rolling:

$$n = \left(\frac{\sigma_0}{\sigma}\right)^t = 5{,}849 \times 10^7$$

Tire wear rate:

$$I = 0{,}7 \cdot \frac{p_r}{E \cdot n} = \frac{0{,}7 \cdot 5{,}593}{150 \times 5{,}849 \times 10^7} = 4{,}46 \cdot 10^{-10}$$

Normative tire mileage:

$$L = \left(\frac{h_{pr}}{I}\right) = \frac{20}{4{,}46 \cdot 10^{-10}} = 4{,}48 \cdot 10^{10}\,мм \approx 45\,тыс.км$$

Thus, the calculated values of the standard tire mileage are ≈ 45 thousand km or 2900 motor hours.

4. Estimated mileage of tires 315/80R22.5 Ling Long for MAN TGS 26.400 cement trucks.

Let us determine the mileage of tires with a tread height of 20 mm at *E*=150 kgs/sm^2/15*10^6 Pa/, *t*=5 (cyclic coefficient), *k* = 3 (reserve coefficient for tread rubber), determine the intensity of tread wear on a dry dirt road with a coefficient friction *f* = 0.45, p_c = 8.*67 kg/sm*^{2}, h_{max} = 0.6 mm, *r* = 28 mm.

According to the elastic contact formula: tire-road, we define.

$$\frac{h}{r} = 1{,}1\left(\frac{p_c}{E}\right)^{2/7} \cdot \left(\frac{h_{\max}}{r}\right)^{6/7} = 1{,}1\left(\frac{8{,}67}{150}\right)^{2/7} \cdot \left(\frac{0{,}6}{28}\right)^{6/7} = 0{,}01807$$

Let's check the applicability of the elastic contact formulas for this case:

$$\frac{h}{r} = 0{,}01807 < 16$$

which indicates the presence of elastic contact of the tire with the road.

Actual pressure: $p_r = 0{,}3E\sqrt{\frac{h}{r}} = 6{,}05\, кгс/см^2$

Stress: σ: $\sigma = 8{,}1675\ \ кгс/см^2$.

Let's determine the number of cycles when the tire is rolling:

$$n = \left(\frac{\sigma_0}{\sigma}\right)^t = 3{,}945 \times 10^7$$

Wear intensity for these tires:

$$I = 0{,}7 \cdot \frac{p_c}{E \cdot n} = \frac{0{,}7 \cdot 6{,}05}{150 \times 3{,}945 \times 10^7} = 7{,}12 \cdot 10^{-10}$$

Normative tire mileage: $L = \left(\frac{h_{pr}}{I}\right) = \frac{21}{7{,}12 \cdot 10^{-10}} = 2{,}96 \cdot 10^{10}\, мм \approx 29\, тыс.км$

Thus, the calculated values of the standard tire mileage are ≈ 29 thousand km.
Similar calculations were made for other types of tires. The calculation results are summarized in Table 1.

Table 1

№	Vehicle brand	Type of transport	Tire sizes, tire brand and model	Estimated tire wear rates	Estimated values of standard tire mileage, thousand km (motor hours)
1.	Belaz–7822	Front loader	35/65-33 Belshina, ФБел-283	1,325	50 (3333)
2.	Belaz–7648A	water carrier	21.00-33 Belshina, ВФ-66АМ	0,897	40
			21.00-33 Kendala, ВФ-166АМ	0,897	40
3.	MAN CLA 26.280 KTA-25	Truck crane	315/80R22.5 Ling Long, D980	0.667	30
4.	XCMG QY16B.5	Truck crane	11.00R20 (300R508) Forward, Traction310	0,446	45
5.	Isuzu FVR 33 L	Fuel truck	11R22.5 Dunlop, SP 350	0,227	75
6.	MAN TGS 26.400	Cement carrier	315/80R22.5 Ling Long, D980	0,71	30
			315/80R22.5 Continental, SR1 (HDR+)	0,629	32
7.	ЧМЗАП-5530	Heavy trailer	9.00R20 (260R508) Омскшина, О-40 БМ-1	0,356	45
8.	Hardox 450 HB	Semitrailer	385/65R22.5 Ling Long, RS-609	0,689	29
			385/65R22.5 Ling Long, LLA18	0,689	29
9.	SHACMAN F2000	Fuel truck	12.00R20 Uraturn, Y601	0,322	62

10.	HOWO Sinotruk 290 CNHTC	Boiler	12.00R20 Yinlun, YA115	0,33	61

Experimental determination of tread wear of controlled tires

To determine the experimental values of tire mileage under the conditions of JSC "Qizilqumsement", we used the method of computational and experimental studies, which includes determining the wear of the tire tread and its hardness.

Laboratory tests have shown that the steel cord of a sample of worn and unusable tires has high strength, low elongation and aging resistance.

When measuring and inspecting the tires, there were no radial ruptures of the rubber mass starting from its inner circumference. This suggests that the compressive, tensile and shear stresses (tangential stresses) did not exceed the permissible limits during operation.

Tire tread wear was measured by selecting and putting into operation a batch of the following tires operated under the conditions of JSC "Qizilqumsement".

1. 35/65-33 model ФБел-283 BELSHINA Made in Belorussia.
2. 21.00-33 model ВФ-166AM BELSHINA Made in Belorussia.
3. 9.00R20 (260R508) model Омскшина О-40 БМ-1 Made in Russia.
4. 315/80R22.5 model Ling Long D980 Made in China.
5. 11.00R20 (300R508) model Forward Traction310 Made in Russia.
6. 11R22.5 model Dunlop SP 350 Made in Japan.
7. 315/80R22.5 model Continental HDR+ Made in Germany.
8. 315/80R22.5 model Continental HSR1 Made in Germany.
9. 385/65R22.5 model Ling Long RS-609 Made in China.
10. 385/65R22.5 model Ling Long LLA18 Made in China.
11. 12.00R20 model URATURN Y601 Made in China.
12. 12.00R20 model YINLUN YA115 Made in China.

Over the selected controlled batch of tires, constant monitoring of wear and damage was carried out.

The expected mileage for the above tires is determined by the formula:

$$L_{\text{ожид.}} = \frac{(h - h_{\min}) * 1000}{\gamma_{\text{ср}}}$$

where h is the initial height of the tread; h_{min} - minimum allowable tread height, for truck tires, h_{min} =1 mm; γ_{cp} is the wear rate of the tread.

For convenience, the data obtained are summarized in Table 2.

Table 2

№	Brand and type of vehicle	The size, tire model	Wear intensity, mm/thousand km	Average expected mileage $L_{ожид}$, km (motor hour)	Standard deviation
1.	Belaz–78221 Front loader	35/65-33 Belshina, ФБел-283	1,116…1,372	53610 km (3574 motor hour)	5520 km (368 motor hour)
2.	Belaz–7648A water carrier	21.00-33 Belshina, ВФ-166AM	0,843…0,973	40126 km	2099 km
3.	MAN TGS 26.400 cement truck	315/80R22.5 Ling Long, D980	0,584…0,706	30179 km	1840 km
4.	MAN TGS 26.400 cement truck	315/80R22.5 Continental, HSR1 (HDR+)	0,535…0,655	33681 km	1636 km
5.	MAN CLA 26.280 KTA-25 Truck crane	315/80R22.5 Ling Long, D980	0,575…0,642	30750 km (2050 motor hour)	1777 km (118 motor hour)
6.	Hardox 450 HB Semitrailer	385/65R22.5 Ling Long, LLA18	0,520…0,665	27203 km	2137 km
7.	Hardox 450 HB Semitrailer	385/65R22.5 Ling Long, RS-609	0,519…0,653	27118 km	2153 km

8.	XCMG QY16B.5 Truck crane	11.00R20 (300R508) Forward, Traction310	0,404…0,469	43455 km (2900 motor hour)	2031 km (135,5 motor hour)
9.	SHACMAN F2000 Fuel truck	12.00R20 URATURN, Y601	0,288…0,322	61261 km	1848 km
10.	HOWO Sinotruk 290 CNHTC Boiler	12.00R20 YINLUN, YA115	0,289…0,333	60434 km	3067 km
11.	ЧМЗАП-5530	9.00R20 (260R508) Омскшина, О-40 БМ-1	0,36…0,391	42646 km	1725 km
12.	Isuzu FVR 33 L Fuel truck	11R22.5 Dunlop, SP 350	0,227…0,251	62749 km	2389 km

CONCLUSION

Based on the analysis of the obtained statistical, theoretical and experimental data, it is possible to recommend the actual norms of tire operating mileage, which are summarized in Table 3.

Table 3

№	Brand and type of vehicle	Size, type of tread pattern and tire model	Estimated values of standard tire mileage, thousand km (motor hours)	Average expected mileage (based on measurements) $L_{ожид}$, thousand km (moto hour)	Deviation of calculated values from experimental ones (in percentages)
1.	Belaz–78221 Front loader	35/65-33 Belshina, ФБел-283	50 (3333)	53,6 (3574)	≈ 6,72
2.	Belaz–7648A water carrier	21.00-33 Belshina, ВФ-166АМ	40	40,1	≈ 0,25
3.	MAN CLA 26.280 KTA-25 Truck crane	315/80R22.5 Ling Long, D980	30 (2000 motor hour)	30,750 (2050 motor hour)	≈ 2,44
4.	XCMG QY16B.5 Truck crane	11.00R20 (300R508) Forward, Traction310	45 (3000 motor hour)	43,455 (2900 motor hour)	≈ 3,56
5.	Isuzu FVR 33 L **Fuel truck**	11R22.5 Dunlop, SP 350	60	62,7	≈ 4,31
6.	MAN TGS 26.400 Cement truck	315/80R22.5 Ling Long, D980	30	30,2	≈ 0,66
		315/80R22.5 Continental, HSR1 (HDR+)	32	33,7	≈ 5,04
7.	ЧМЗАП-5530 Heavy trailer	9.00R20 (260R508) Омскшина, О-40 БМ-1	45	42,6	≈ 5,63
8.	Hardox 450 HB Semitrailer	385/65R22.5 Ling Long, LLA18	29	27,2	≈ 6,6
		385/65R22.5 Ling Long, RS-609	29	27,1	≈ 7
9.	SHACMAN F2000 Truck crane	12.00R20 URATURN, Y601	62	61,3	≈ 1,14
10.	HOWO Sinotruk 290 CNHTC Boiler	12.00R20 YINLUN, YA115	61	60,4	≈ 1,0

Thus, our studies to determine the actual tire mileage of vehicles operated under the conditions of JSC "Qizilqumsement" showed the adequacy of the proposed methodology for calculating the wear rate and tire mileage to the experimental values. The average deviation of the results of theoretical and experimental values does not exceed 7%.

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