DETERMINATION OF DEPRECIATION PERIOD OF AUTOMOBILE OPERATION THROUGH PHYSICAL WEAR COEFFICIENT

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Abstract: *The paper touches upon a newly developed methodology for determining the automobile physical wear coefficient, taking into account some technological factors during operation that compose the rolling stock life cycle in the given operating conditions. A concept for determining the operation period of an automobile has been proposed based on maintaining the smooth operation of the rolling stock throughout the life cycle. The quantitative and qualitative indicators of automobile physical wear are determined aimed at solving the problem. The theoretical and scientific experimental research has identified the analytical connections of their interactions and relations. Given the stochastic nature of physical wear coefficient variations, it has been considered as a random value, and the characteristics of its variations pattern have been determined.*

Keywords: physical wear; coefficient; function; linear; automobile; depreciation; operation; rolling stock.

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Introduction

Operation practice has shown [1,2] that two automobiles of the same brand have different levels of a residual resource after a particular mileage[1], both in terms of constituent units and the whole automobile [2].

It means that the automobile physical wear coefficient [3] needs to be considered more deeply by analyzing and taking into account some technical and technological factors during the operation, which forms the rolling stock life cycle in the given operating conditions [4]. The proposed concept for determining the automobile depreciation period is based on maintaining the smooth operation of the rolling stock throughout its entire life cycle. Technical disruptions that cause the transport process to stop, result in inefficient downtime as well as material and labour expenses [1]. To avoid accidental and sudden disruptions, the actual coefficient of the automobile's physical wear[2] should characterize the current technical condition of the rolling stock and engine constituents, ensuring the need for repair and maintenance within a given period of millage and time [5,6]. Up to date, the current methods for determining the operating life have been of analytical nature. They do not reveal how the physical wear coefficient of the automobile varies due to the increase in overall mileage, exact operating conditions, and other factors [4,10].

The paper proves the stochastic nature of variations in the automobile's physical wear coefficient, it is considered as a random value. The characteristics of its variations pattern have been determined, allowing the automobile depreciation period to be calculated based on the economic indicator value preferred by the given economic entity.

Materials and Methods

It is necessary to develop qualitative and quantitative indicators for assessing the automobile's physical wear aimed at solving the proposed problem and then discovering the analytical connections of their

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[2] R 03112194-0376-98. Metodika otsenki ostatochnoy stoimosti transportnykh sredstv s uchetom tekhnicheskogo sostoyaniya, 1998 (in Russian).

interactions and relations through theoretical and scientific-experimental research [6]. It is well-known that the resource indicators of automobile units, auto parts, and interchanges have quite different values and are of stochastic nature [7]. A scientific-experimental research has been conducted for a group of minibuses (30 units) performing intra-city passenger transportation to study the variation in the automobile physical wear coefficient and identify the distribution patterns as a random value[3].

The following indicators have been studied during the scientific-experimental research:

The number of automobile disruptions (nd) by years and hence the number of downtime (ndtp) days caused by them,

The average daily mileage of one automobile (ℓd) –per km,

The average annual mileage of one automobile (ℓa), per thousand km,

The total mileage of the automobile group (∑ ℓ) per thousand km,

The number of annual operation days of one automobile (nw) per day,

The coefficient (α) of technical readiness of the automobile group,

The disruption flow parameter (ω) of the automobile group per-thousand km,

The average mileage of automobile smooth operation (ℓ) per thousand km ℓs,

The physical wear coefficient (K) of the automobile group.

The graphs (Figs. 1, 2) based on the data presented in the Table indicate the variations in the coefficient of the automobile technical readiness, average mileage of smooth operation, number of maintenance downtimes, and physical wear coefficient. According to the presented data, the coefficient of the automobile's technical readiness during the fifth year of operation was 0.73, which is less than the average value of this coefficient (0.8). A similar solution is observed in terms of the average mileage of the smooth operation of automobiles. In case of an average value of 12.8 thousand km, the indicator for the fifth year of operation was 8.87 thousand km or decreased by 3.93 thousand km (30.9%).

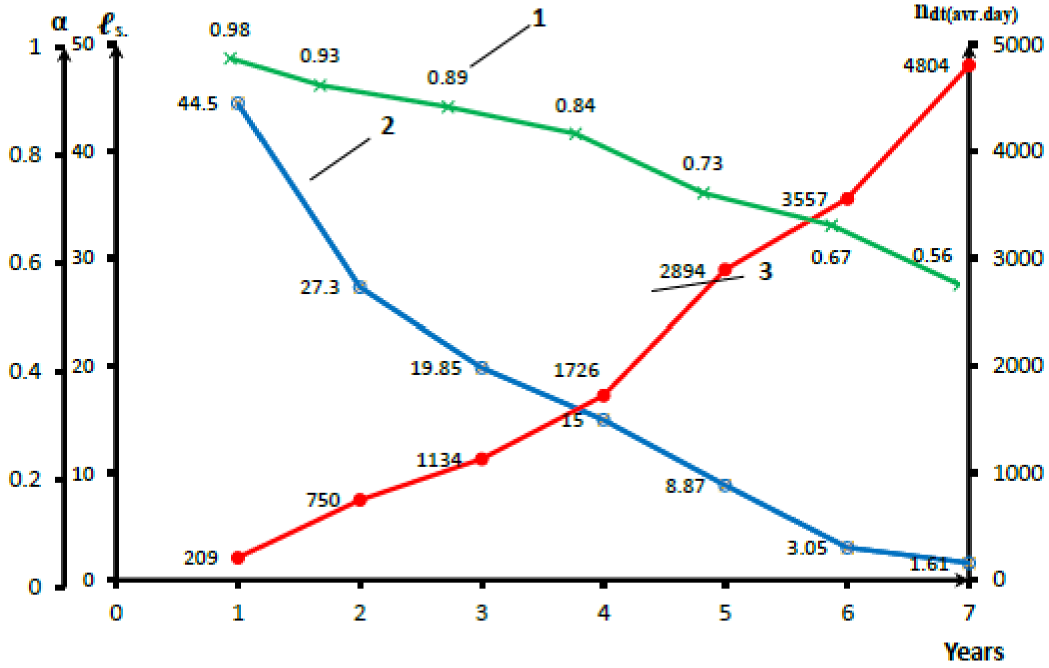

Fig. 1. *Dynamics of quantitative and qualitative variation of automobile operating indicators (α (1), ℓs. (2), ndt. (3)) by years*

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[3] GOST R 50779.10-2000

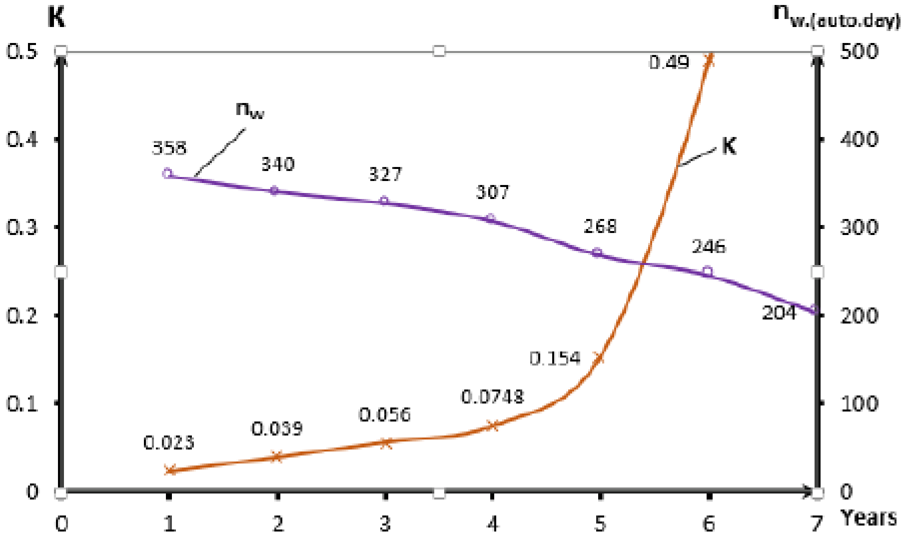

Fig. 2. *Change in the automobile physical wear coefficient (K) and the average number of working days per automobile (nw) according to the years of operation*

Further analysis of the automobile's smooth operation shows that, according to the operation results of the sixth-year, the indicator was 3.03 thousand km. The same dynamics is observed in the operation results seven year. According to the data, the automobile's technical readiness coefficient during the fifth year of operation was 0.73, which is less than the average value of this coefficient (0.8). A similar situation is with the smooth operation of automobiles. In the case of an average value of 12.8 thousand km, the index for the fifth year of operation was 8.87 thousand km or decreased by 3.93 thousand km (30.9%). It indicates the following: if we are to be directed by the dynamics of the change in the average mileage of automobiles, we must decomission the rolling stock at the end of the fifth year of operation or the beginning of the sixth year due to low technical and economic indicators.

Table. Operational indicators of the Automobile group

N	Year of operation / Indicator	1	2	3	4	5	6	7
1.	Number of disruptions n_d	60	78	92	110	148	388	516
2.	Downtime n_{dt} (automobile-per day)	209	750	1134	1726	2894	3557	4804
	TS – 2 (number)	203	164	140	127	101	91	64
	Current repair (number)	6	586	998	1599	2793	3466	4740
3.	Working days, annual average(n_w)	358	340	327	307	268	246	204
	Total	10741	10200	9816	9224	8056	7399	6146
4.	Coefficient of technical readiness, α	0.98	0.93	0.89	0.84	0.73	0.67	0.56
5.	Average daily mileage, ℓ_d (km)	218	210	186	179	163	160	135
6.	Total mileage, $\sum \ell$ (thousand km)	2341.5	2142.0	1825.8	1641.1	1313	1182.9	829.7
7.	Average mileage of smooth operation, ℓ, (thousand km)	44.5	27.3	19.85	15.0	8.87	3.05	1.61
8.	Disruption flow parameter ω(disruption per thousand km)	0.0225	0.036	0.050	0.0666	0.113	0.328	0.578
9.	Physical wear coefficient, K	0.023	0.039	0.056	0.0748	0.154	0.490	1.032

Now the problem should be considered in light of the dynamics of changing the indicator of inefficient downtime of the automobile.

The average indicator of inefficient downtime for a group of automobiles' downtime was 2150 automobiles per day, or 71.67 automobiles per day for one automobile. Moreover, during the fifth year of operation (Table, Fig. 1), the average downtime was 96.5 automobiles per day, which is about 25 automobile per day more than the average value. If we observe the variations in the number of automobiles' operation days over the years, it becomes evident that in the fifth year, there are already 8056 automobiles per day, with an average value of 8799 automobile per day. It equates to 35.9% inefficient automotive downtime in regard to the number of operation days. Naturally, the monthly number of automobiles operating by the order was 74.1%, which is inefficient from an operational standpoint (the accepted efficiency amounts to no less than 80% from a financial and economic standpoint).

Discussion of Results

To assess the efficiency of automobile operation, the physical wear coefficient should be observed on terms of quantitative and qualitative standards, as it is defined by inefficient dowtime spent on recovery and an indicator of recovery duration [3]. This is evidenced by the fact that the calculated physical wear coefficient according to the value of the automobile coefficient of technical readiness amounted to 0.154 in the fifth year, while in the sixth year it grew rapidly, amounting to 0.490. It means (Fig. 2) that the amount of inefficient downtime hasn't increased sharply, but the disruption flow parameter has increased, which has led to a sharp increase in the physical wear coefficient. If we consider the physical wear coefficient with the average millage of inefficient downtime and smooth operation, it turns out that this indicator has not undergone drastic changes.

Based on the above-mentioned analysis results, it can be firmly insisted that the automobile's physical wear coefficient should be assessed from quantitative and qualitative perspectives, firstly - taking into account the quantitative value of the disruption flow parameter[4] and seondly - the amount of ineffective downtime days spent on the recovery from disruptions.

To this end, the automobile physical wear coefficient should be considered as a random function, i.e. according to the millage or years of operation of the rolling stock [6,11].

The automobile physical wear coefficient can be represented as a function of the rolling stock mileage $\boldsymbol{\ell}$, in that case [6]:

$$K = \eta(\ell). \tag{1}$$

At the same time, the automobile mileage is a variable with a probability density function of **f (ℓ)**, which causes variation of **K** parameters. Let use the Laplace transformation (1), which for the normal probability distribution law of random variables is [2]:

$$f(\ell) = \frac{1}{\sigma\sqrt{2\pi}} exp\left[-\frac{(\ell-\bar{\ell})^2}{2\sigma^2}\right], \tag{2}$$

where $\boldsymbol{\sigma}$ is the root-mean-square deviation, km (dispersion), $\boldsymbol{\pi}$ - constant (3,14), $\boldsymbol{\ell}$ - milage, km, $\bar{\boldsymbol{\ell}}$ - milage mean path, km, and has the following form:

$$\varphi(z) = exp\left[-\ell \cdot Z + \frac{\sigma^2 Z^2}{2}\right], \tag{3}$$

where **Z** is the constant function for normal distribution, $\boldsymbol{\varphi}(\mathbf{z})$ is the function of $\boldsymbol{K}$ value.

It can be assumed that the first two members of the function are the automobile physical wear coefficient **K**, and it is a linear function:

$$K = a_0 + a_1 \cdot \ell\ , \tag{4}$$

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[4] GOST R 50779.10-2000

where a_0 is the resource of the new automobile, a_1- is the specific value of automobile resource change per mileage (1000 km).

In this case, the function Laplace transformation (4) for the linear function is as follows:

$$\varphi_{\mathrm{K}}(\mathrm{z}) = \varphi_{\ell}(a_1 \cdot \mathrm{z}) \exp(-a_0 \cdot z) , \tag{5}$$

or

$$\varphi_{\mathrm{K}}(\mathrm{z}) = \left\{ exp\left[-\overline{\ell} \cdot \mathrm{a}_1 \cdot \mathrm{z} + \frac{\sigma^2 \cdot Z^2 \cdot a_1^2}{2} \right] \right\} \exp[-a \cdot z] , \tag{6}$$

Thus:

$$\varphi_{\mathrm{K}} \cdot Z = exp \left\{ \left[1 - \left(\overline{\ell} \cdot \mathrm{a}_1 + \mathrm{a}_0 \right) z \right] + \frac{(\sigma \cdot \mathrm{a}_1)^2 \cdot Z^2}{2} \right\} . \tag{7}$$

Comparing the expressions (7) and (3), it follows that the expression (7) is also considered a Laplace transformation for a new normal distribution value K, the average value of which is:

$$\overline{K} = a_0 + a_1 \cdot \ell , \tag{8}$$

where $\overline{K}$ is the mean physical wear coefficient.

Root-mean square deviation is:

$$\sigma_K = a_1 \sigma , \tag{9}$$

and the coefficient of variation is

$$V_K = \frac{1}{\frac{a_0}{a_1 \sigma} + \frac{1}{V_1}} . \tag{10}$$

The coefficient variation for the new random variable is dependent on the coefficient of variation of argument and the intensity of the parameter change, particularly on its increase.

Considering the change in the automobile’s physical wear coefficient along with the increase in the total mileage (1), it becomes evident that the dynamics of the change in the physical wear coefficient has increasing nature. It means the probability density function of the automobile physical wear coefficient f (K), taking into account the expression (6) will have the following form:

$$f(K) = \frac{1}{a_1 \cdot \sigma \sqrt{2\pi}} exp\left[1 - \frac{(K - a_0 - a_1 \cdot \ell)^2}{2\sigma^2 \cdot a_1^2} \right] . \tag{11}$$

It is also evident from the graph presented in Fig. 2, which comes to prove along with the automobile's physical wear coefficient (**K**), the number of operation days decreases as the maintenance downtime for the rolling stock repair increases. While solving the practical problems, if the function $\boldsymbol{\eta}(\boldsymbol{\ell})$ is not linear, but is continuous in the range of $\boldsymbol{\ell_1} - \boldsymbol{\ell_2}$ millage and is close to being linear, it can be replaced by a linear function [6].

Summarizing the results of the theoretical and experimental research, it becomes evident that the change in the physical wear coefficient under the specific conditions of an automobile operation has a stochastic nature with a normal distribution pattern. Considering the change in physical wear coefficient as a random value and determining the characteristics of its change pattern - mathematical expectation, dispersion, and variation coefficient, allow to determine the depreciation period of the automobile according to the value of the technical and economic indicator preferred by the economic entity.

Conclusion

The research on the changes in the automobile’s physical wear coefficient in the actual operating condition allows to identify the pattern of actual change of the coefficient, its mathematical expectation, root-mean-square deviation, and variation coefficient, as well as allows to assess the current value of the indicator in a definitive range. It will be possible if the density of the function f (K) is calculated, which in fact is related to intensity of operation (a_0 *and* a_1), and it is the main and dominant factor in the change of the automobile’s physical wear coefficient, and the milestone of the developed methodology.

References

[1]. Ye.S. Kuznetsov, Tekhnicheskaya ekspluatatsiya avtomobiley. Nauka, Moscow, 2001 (in Russian).

[2]. K.H. Mosikyan, V.S. Kochiev, A.M. Jinyan, Operating Experience and Reliability Performance of Internal Combustion Engine when Operating on Compressed Natural Gas. Stavropol State Agrarian University, 2 (14), 2014, 75-78.

[3]. A.V. Yudin, Otsenka stoimasti transportnykh sredstv. Moskovskaya finansovo-promyshlennaya akademiya, Moscow, 2005 (in Russian).

[4]. Y.V. Vardanyan, V.M. Harutyunyan, K.H. Mosikyan, V.S. Kochiev, The Basics of Developing an Alternative Concept for Commercial and Military Vehicle Operation (Random Strategy). Journal of Architectural and Engineering Research, 1 (2), 62-69, 2021.
Doi: https://doi.org/10.54338/27382656-2021.2-4

[5]. I. Bazovsky, Nadezhnost'. Teoriya i praktika. Mir, Moscow, 1965 (in Russian).

[6]. E.S. Wentzel, Teoriya veroyatnostey. Vysshaya shkola, Moscow, 1999 (in Russian).

[7]. B.L.Van der Waerden, Mathematical Statistics. Publishing House of Foreign Literature, Moscow, 1960 (in Russian).

[8]. C. Rohlfs, R. Sullivan, The Cost-Effectiveness of Armored Tactical Wheeled Vehicles for Overseas US Army Operations. Defence and Peace Economics, 24 (4), 2013, 293-316.
Doi: https://dx.doi.org/10.2139/ssrn.1916818

[9]. C.R. Harz, Problems in Army Vehicle Maintenance: Results of a Questionnaire Survey, Rand Corporation, 1981.

[10]. V. Loan, D. Viorel, G. Constantin, Research on Improving the Maintenance Activities for Military Vehicles. International Conference Knowledge - Based Organization, 21 (3), 2015, 896-903.
Doi: https://doi.org/10.1515/kbo-2015-0152

[11]. R. Haider, Al. M. Kakar, S. B. Khattak, S. Rehman, S. Maqsood, M. Ullah, R. Akhtar, A. Sikandar, Development of Optimized Maintenance System for Vehicle Fleet. Journal of Engineering and Applied Sciences, 34 (2), 2015, 21-27.

[12]. V. Mickunaitis, S. Nagurnas, The Improvement of the Technical Exploitation of Automobiles. Transport, 17 (4), 2002, 143-146.
Doi: https://doi.org/10.3846/16483840.2002.10414031

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