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THE BASICS OF DEVELOPING AN ALTERNATIVE CONCEPT FOR COMMERCIAL AND MILITARY VEHICLE OPERATION (RANDOM STRATEGY)

The efficiency of commercial automobiles and wheeled military vehicles mainly depends on the choice of maintenance (M) and current repair (CR) concept. In the paper the difficulties of adapting the (M) and (CR) planning strategies to the structural characteristics of modern transport facilities are pointed out. The advantages of using the (M) and (CR) random strategy for transport facilities based on the stochastic nature of failures and malfunctions are substantiated. Considering the failures and malfunctions as random values and identifying the patterns of their distribution based on γ percentage resources, it is proposed to develop a list of regulated maintenance and repair work, periodicity and labor intensity based on a random strategy, which will increase the efficiency of preserving the technical resource of the rolling stock throughout the entire life cycle of the vehicle.

Keywords: *random strategy, resource, regulated service, adaptation, probability of unfailing operation.*

Introduction

Current provisions on the technical operation of modern commercial automobiles and wheeled military vehicles, the underlying concept, the normative basis and technology do not correspond to the actual processes of preventing malfunctions and failures. The main reason for the situation is the discrepancy between the list of preventive maintenance, performance frequency, and labor intensity that correspond to the actual necessity. This is due to new constructive solutions for transport facilities and qualitative changes in the exploitation materials.

Materials and methods

The provisions in the current situation[1] and the "plan" for the operation of wheeled military vehicles[2], the fixed normative basis, the frequency of work, the list of works, and labor intensity often lead to unnecessary work, which increases labor and material costs and inefficient downtime, as well as reduces the vehicle readiness index. As a descriptive example, we can mention the labor intensity for the operation of automobile engines, braking systems, transmissions and other operating regulations, which is practically unnecessary, as they are solved by structural innovations (mechanisms for automatic adjustment of gaps, management of engine crankcase and transmission oil coolant levels, and electronic electromechanical control of temperature, etc.) [2,6]. The labor intensity of these works is 8 ÷ 12% in the maintenance list (M2), while the implementation frequency does not exceed the value of 0.1-0.2.

Due to lack of functionality, many auto parts of military transport facilities eventually lose their airtightness and physical and mechanical properties, especially rubber technical machine components, bushings, piston rings, valves of all types, springs, engine power system, etc., where a maintenance list for additional work and

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[1] Polozheniye o tekhnicheskom obsluzhivanii i remonte podvizhnogo sostava avtomobil'nogo transporta (approved by the Ministry of Transport of the RSFSR), 1984 (in Russian).

[2] Voyenno-tekhnicheskoye informirovaniye. Plan-konspekt komandirskoy podgotovki po voyenno-tekhnicheskoy podgotovke. Organizatsiya ekspluatatsii, remonta i khraneniya avtomobil'noy tekhniki, 2019 (in Russian). https://shtab.su/konspekt/voenno-texnicheskoe-informirovanie/organizaciya-ekspluatacii-avtomobilnoj-texniki.html

labor-intensity is necessary to develop. It follows from the presented example that the concept of technical operation of wheeled military vehicles based on the precautionary strategy no longer ensures the efficient technical operation of both commercial and military transport facilities with a high level of reliability, in particular, the required level of unfailing operation probability and γ percentage resource[3]. The latter indicator is significant for military wheeled vehicles[4]. In this respect, it is a well-known fact that the automobile engines of ZIL, Ural, GAZ series have operational difficulties after a long downtime.

The results of research carried out by our and other authors [2,3] prove that the engine crankcase oil contains particles of iron, aluminum, lead, tin, and other metals due to machine elements wear. The mentioned metal particles of these metals, when mixed with crankcase oil, increase the adhesion properties of the oil and, as a direct consequence, the engine crankshaft starting speeds are reduced and do not meet the engine operating required speed (due to increased internal resistance). This phenomenon is especially observed in military transport vehicles during operations [7].

It is obvious, that the solution of the given problem is mainly conditioned by the average value of characteristics of random X variable:

$$\overline{X} = \frac{x_1+x_2+\cdots+x_n}{n} = \frac{\sum_{i=1}^{n} X_i}{n} . \quad (1)$$

From the root-mean-square deviation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}} , \quad (2)$$

as well as from the index of variation:

$$V_x = \frac{\sigma}{\bar{x}} . \quad (3)$$

Exploratory research shows that the mileage of automobiles and their parts, as random values, the variation coefficient is [5] a minor variation $V < 0.1$, medium variation $0.1 < V < 0.33$ and major variation $V > 0. 33$.

Besides the above-mentioned values describing random quantities, there is also the possibility of another characteristic situation - P. It is accepted in statistical analysis [1] that a probability of a situation is within $0 \leq P \leq 1$. When P = 1, the situation is referred to as "reliable," and when P = 0, the situation is referred to as "less probable."

Thus, the probability of unfailing operation of an automobile and its parts is determined by the following expression:

$$R_{(x)} = \frac{n-m(x)}{n} = 1 - \frac{m(x)}{n} , \quad (4)$$

where m (x) is the number of automobile failures or malfunctions or number of auto parts during an X run (time interval).

We accept that the probability of malfunction (failure) is the inverse of the unfailing operation and is determined by the following expression:

$$F_{(x)} = 1 - R_{(x)} = \frac{m(x)}{n} . \quad (5)$$

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[3] GOST 27.002-2015, GOST 27.002-89. Nadezhnost' v tekhnike (in Russian).

[4] Tomasz Smal, Maintenance in Availability of Weapon Systems under Combat Operation - Optimization Possibilities. Advances in Military Technology, 2013. https://www.researchgate.net/publication/283837304_Maintenance_in_availability_of_weapon_systems_under_combat_operation_-_Optimization_possibilities

The probability of complex systems' and automobiles' unfailing operation is determined by the concept of γ percentage resource[5]. The γ percentage resource for automobiles and their units [5] is accepted as 0.85 (85%), 0.90 (90%), and 0.95 (95%). We can note that for automobile active safety systems the γ percentage resource is accepted as 0.95 (95%), for other systems it is from 0.85 (85%) to 0.90 (90%). This means that the value of the γ percentage resource for the automobile or its corresponding unit is greater than the X resource, or equal to the specified mileage value (time interval).

Let us consider the case, where the sequence of random variables has the law of normal distribution, that is, the probability of unfailing operation is formed under the influence of many factors (the automobile structure contains 15.0 thousand or more auto parts) [5], where the influence of each is very small. This assumption is also valid in the case of the law of large numbers.

In this case, the normal distribution function for maintenance or replacement of auto parts is as follows:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{(x-\bar{x})^2}{2\sigma^2}} \quad . \tag{6}$$

That is, the probability of providing γ percentage resource will be:

$$R(x) = \frac{1}{\sigma\sqrt{2\pi}} \int_x^{\infty} e^{\frac{(x-\bar{x})^2}{2\sigma^2}} \cdot dx \quad . \tag{7}$$

This means that the frequency of maintenance and repair of automobiles and auto parts should be determined according to the expression (7), which means drawing up the list of the regulated works and labor-intensity based on the vehicle reliability limiting and from the point of view of reliability critical auto parts and maintenance list.

The automobile reliability map is formed according to the above-mentioned reliability indices, and on that basis, the regulated list of vehicle technical maintenance is formed.

Let us consider the failure characteristics of six auto parts, which are limiting the functional reliability of the working brake system of the GAZelle type minibus, as characteristics of random value distribution consistency (Table 1).

Table 1

	Detail name	Variation series min max (shift)	Average arithmetic value X (shift)	The mean square deviation of the variation series	Variation coefficient	Parameter of failure flow	Distribution curve law
1.	Anchor pin 3105-3501216	426 ÷629	517	160.27	0.31	$1.93.10^{-3}$	Normal
2.	Brake pad 3302-3501090	6 ÷32	21	18.27	0.87	$4.76.10^{-2}$	Normal logarithm
3.	Brake Cylinder piston 3105-3501186	304 ÷458	396	83.16	0.21	$2.52.10^{-3}$	Normal
4.	Brake cylinder seal 3105-3501194	257 ÷316	307	58.33	0.19	$3.25.10^{-3}$	Normal
5.	Corrugated pipe Cover 3105-3501188	205 ÷617	421	412.58	0.98	$2.37.10^{-3}$	Exponential
6.	Caliper pistons 3105-3501190 right 3105-3501191 left	457 ÷731	578	132.94	0.23	$1.73.10^{-3}$	Normal
7.	Brake disc 3302-3501078	324 ÷425	384	82.9	0.21	$2.82.10^{-3}$	Normal

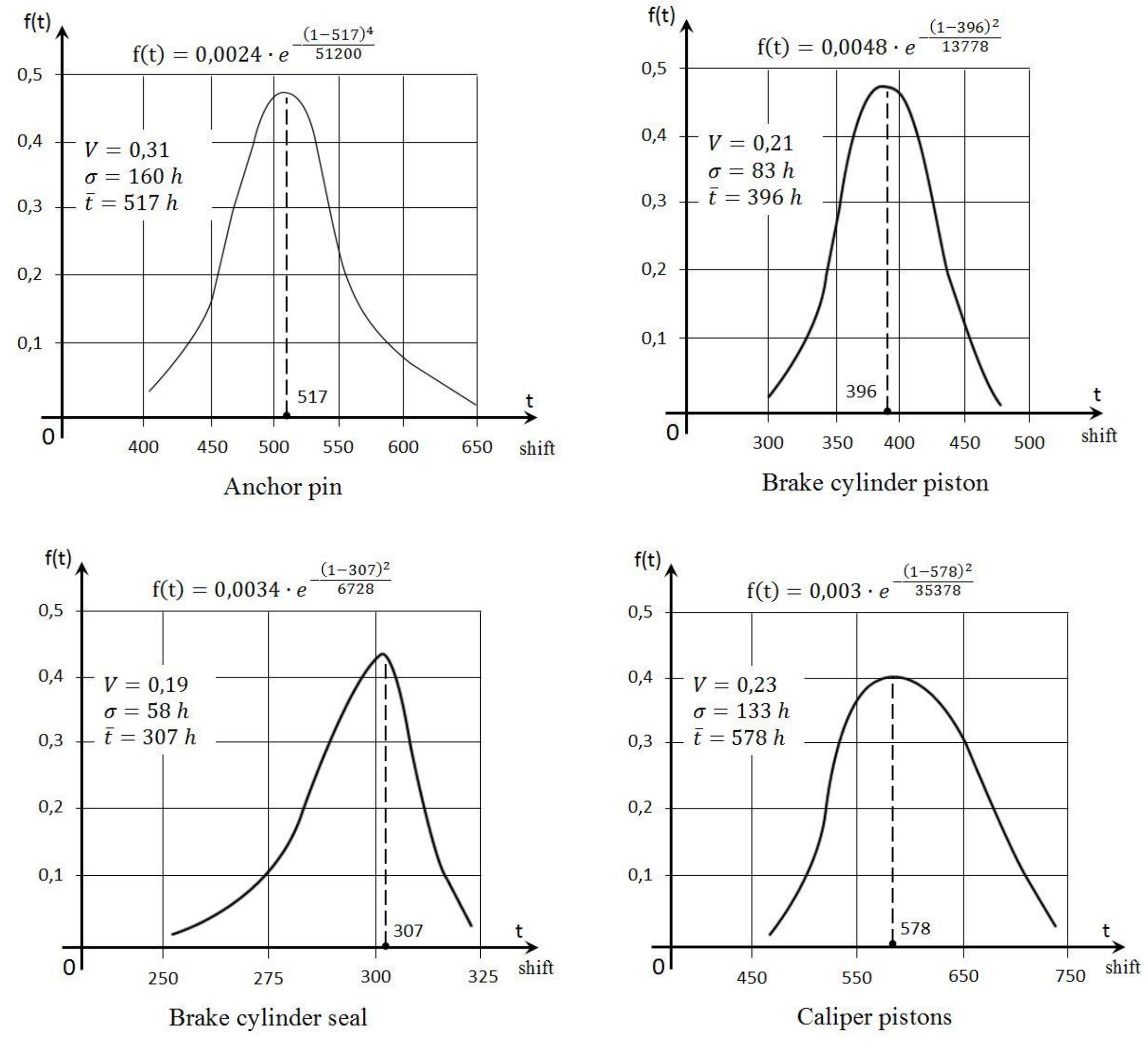
The distribution curves are shown in Fig. 1, otherwise known as the reliability map.

In Table 1 the so-called failure flow parameters ω (x) are presented according to the following expression:

[5] GOST 27.002-2015, GOST 27.002-89. Nadezhnost' v tekhnike (in Russian).

$$\omega\ (x)\sum_{k=1}^{\infty} f_k\ (X) \qquad (8)$$

where f(x) is the density of failure formation probability, k is the ordinal number of failed auto parts. A more simplified failure rate parameter is the number of automobile operation failures per unit time, fail./km. Limiting the failure rate parameter on the explicit values, it is possible to adjust the resource value of the auto parts to a certain level of unfailing operation probability. In the above example, for the braking system, it is limited to 0.93, and accordingly, the resource of auto parts is determined. For the auto parts limiting the reliability of the brake system, it is shown in Fig. 2.



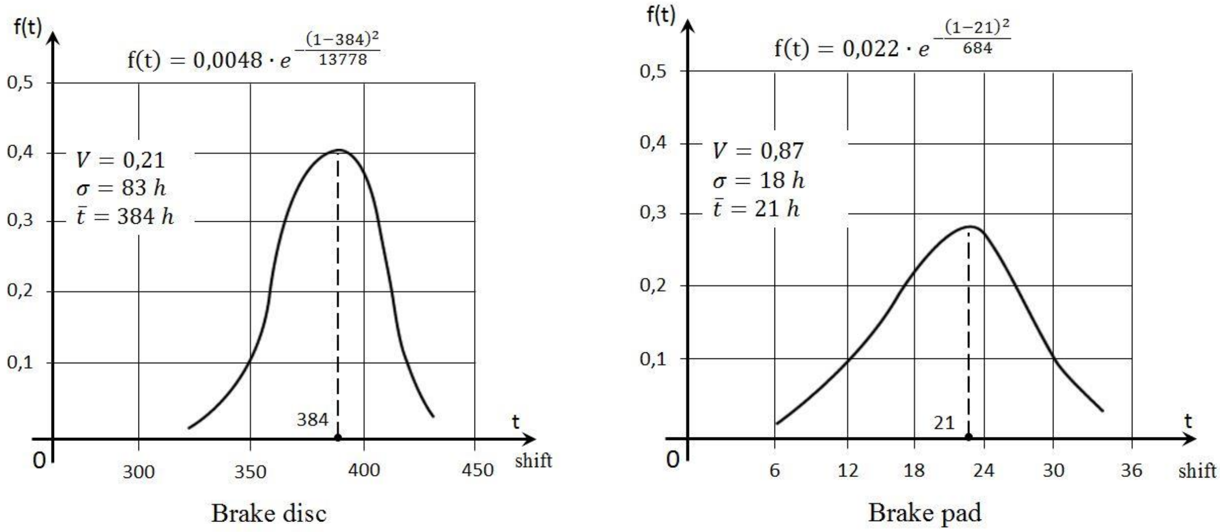
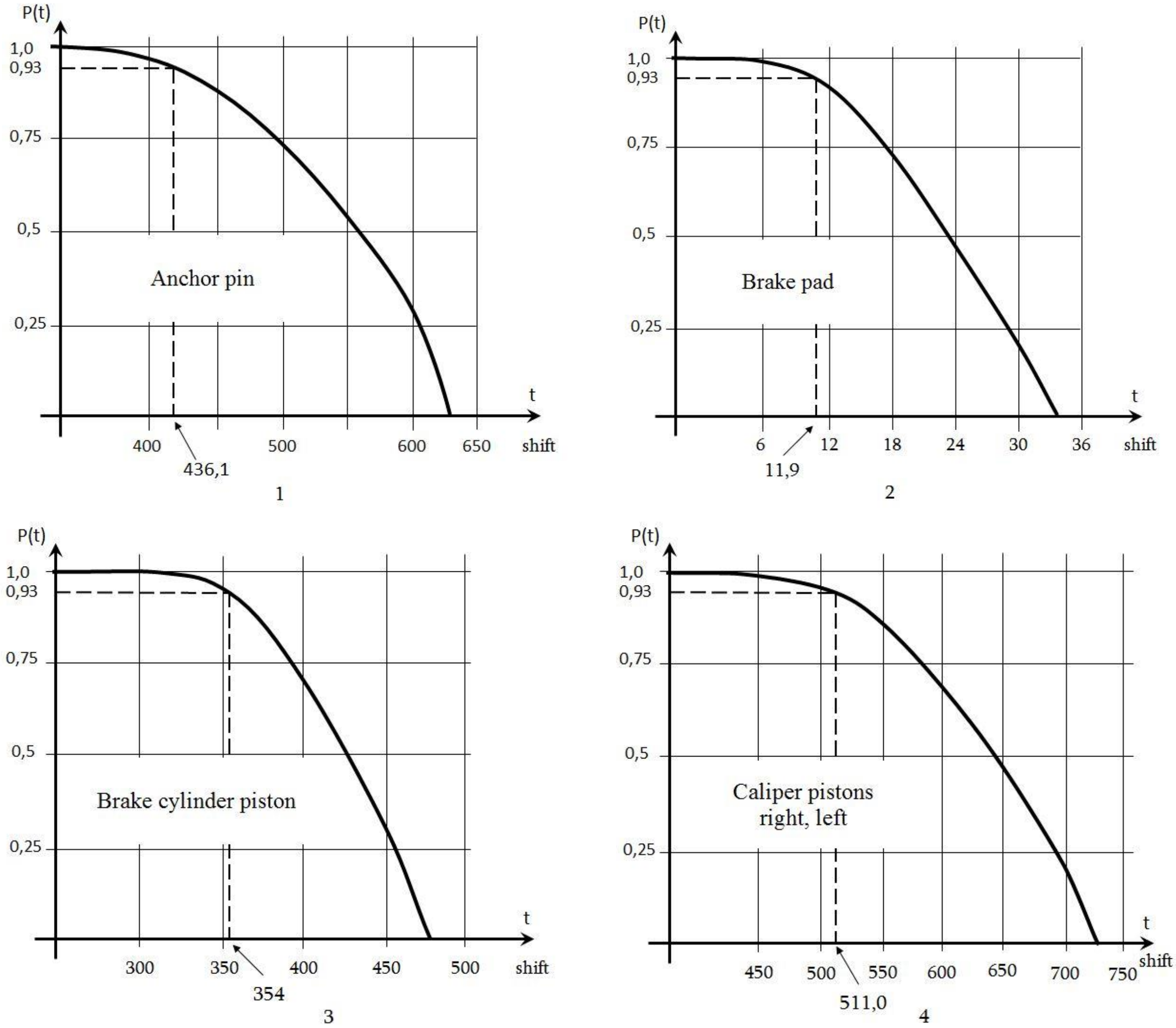


Fig. 1. *Functional failure distribution curves of GAZ-322133 minibus disc brake assembly*



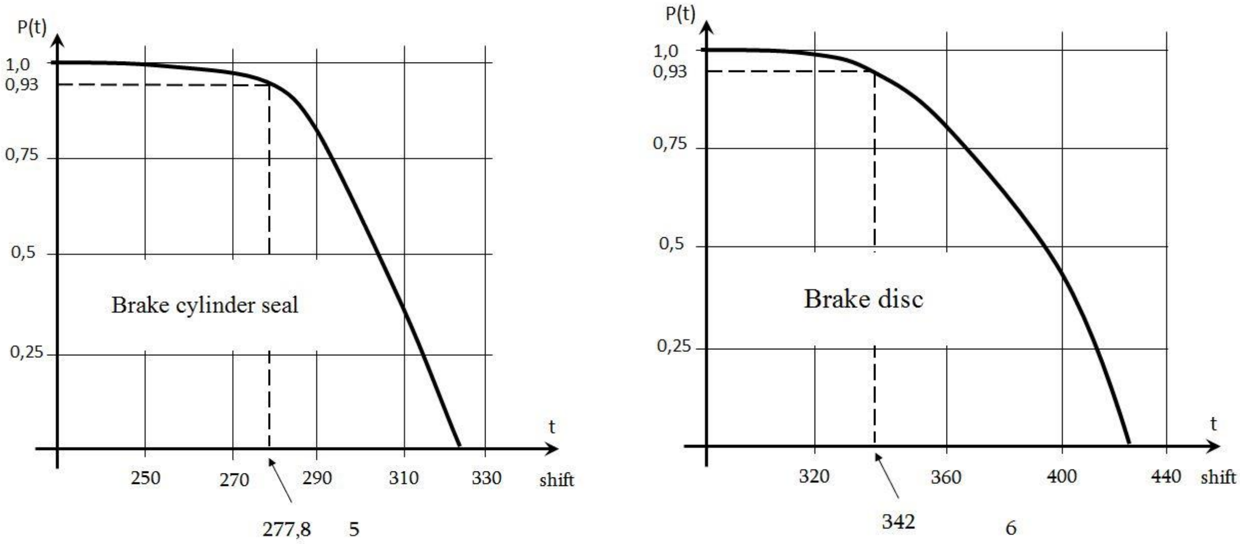


Fig. 2. *Auto part resource limiting the reliability of GAZ-322133 type minibus disc mechanism*

It follows from the above that the essence of an alternative random strategy for the exploitation of commercial and military vehicles is the amount of the resource for the actual regulated value of the probability of unfailing operation, after which it may be changed by a new one.

The advantage of regulated work based on a random strategy over a planned strategy is the traffic safety of vehicles. To achieve this goal, the regularities of failure and malfunction distribution were examined, identifying the features of reliability (mainly no-failure and longevity) using State Standard 27.002-2015 and State Standard 27.002-89 (Reliability in Technology)[6]. These standards operate in the Republic of Armenia according to the intergovernmental agreement (RF and RA), the relevant protocol, No. 84 P, 28.12.2015.

Consider the appropriateness of using a random strategy for commercial automobiles and military wheeled vehicles according to the dominant indicator. The dominant indicator for commercial automobiles is the probability of unfailing operation during the entire period of exploitation. It is formed by the automotive industry as per the scientific-technological progress. It persists through rational technical operation modes with the available technology and actual quality of the exploitation materials. Considering the current automotive equipment development level, the ordinary nature of the failures, the random strategy of technical condition restoration corresponds to the description of the stationary flow of failure recovery.

The γ percentage resource is the dominant indicator for wheeled military vehicles guaranteed for the given transport facilities. It is well known that during battle and other combat missions, the entire wheeled military vehicle must exhibit the highest coefficient of technical readiness. Military vehicles have not been used in a long time, but the list of regulatory works and a strict regular frequency ensure high technical readiness[7]. Studies show that the service of a certain number of auto parts is left out of the list of scheduled work, so it is necessary to study the most significant reliability indicator, which in this case is maintenance [8,9]. The performance of the studies is ensured according to State Standard[8] requirements, where the accuracy of the results is up to 0.95. The studies should be carried out within two years in the conditions of actual operation of the vehicles to ensure a high level of reliability of the statistical data and a high level of adequacy of the regularities obtained.

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[6] GOST 27.002-2015, GOST 27.002-89. Nadezhnost' v tekhnike (in Russian).

[7] Voyenno-tekhnicheskoye informirovaniye. Plan-konspekt komandirskoy podgotovki po voyenno-tekhnicheskoy podgotovke. Organizatsiya ekspluatatsii, remonta i khraneniya avtomobil'noy tekhniki, 2019 (in Russian). https://shtab.su/konspekt/voenno-texnicheskoe-informirovanie/organizaciya-ekspluatacii-avtomobilnoj-texniki.html

[8] GOST 27.002-2015, GOST 27.002-89. Nadezhnost' v tekhnike (in Russian).

Conclusion

Based on the current situation, let us consider an alternative concept of the technical operation of commercial automobiles and wheeled military vehicles, which is based on a random strategy and implemented by the list of regulatory work according to the guaranteed value of the γ percentage resource.

- The random vehicle technical recovery strategy is based on the principle of stationary flow recovery of ordinary failures (mainly wear).
- It is known that the operating conditions of the vehicles, the quality of staff (drivers, repairmen, service specialists), the qualitative inhomogeneity of automobiles and auto parts, and the parameters characterizing the technical condition under the influence of other factors, the intensity of their change turns out to be very different.
- If the factor describing the technical condition of the automobile is assigned to Y_P, then for different automobiles the mileage (time interval) to reach such a condition will be l_{i1}, l_{i2} ...... lin, thus the no-failure millage (time) is obtained as a variation series. This raises the question of when and at what millage value to perform a technical condition control or maintenance operation.

As a result of the research, it is possible to develop and guarantee to invest:

1. the most efficient technical operation regulation modes of commercial vehicles developed according to a random strategy, which will ensure a reduction in materials and labor costs,
2. on the basis of modern automobile structural characteristics, significant changes and additions to the list of regulatory works for wheeled military vehicles based on the technical operation random strategy.

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