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ESTIMATION OF RELIABILITY OF THE AUTOMOBILE AS COMPLICATED RESTORING SYSTEM

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Abstract: The reliability of a technical object is determined by its design,manufacturing technology and conditions of use, maintenance, repair, storage and transportation.

Maintenance includes operations regulated in the design andoperational documentation to maintain a working and serviceable condition. Maintenance includes technical condition monitoring, cleaning, lubrication. Recovery involves the identification of a failure (definition its location and nature), adjustment or replacement of the failed element, regulation and control of the technical condition of the elements of the object and the final operation of monitoring the operability of the object as a whole. The transfer of the object from the limit state to the operational state is carried out by means of repair, in which the resource of the object as a whole is restored. Repairs may include disassembly, defecation, replacement or restoration of individual units, parts and assembly units, assembly, etc. Content of individual repair operations it may coincide with the content of maintenance operations. Automobile being repaired currently, its standing idle time considered accidentally quantitative, the element (of the spare part) depends on damaged character, damaged parts being in the store - house of the enterprise and another factors.

In order considered to value automobiles reliability, it is considered as a mass maintenance service. The mass maintenance systems mathematical equation is given. The motor - cars standing idle is being accidentally quantitative and can be determined by Erlangen equation.

Keyword: reliability, design, adjustment, technical condition, maintenance, improving, increasing complexity, equation system, probabilities

Introduction. To improve the quality of technical means, in particular vehicles and technical means of traffic management, and to reduce the cost of their maintenance, it is necessary to ensure the optimal reliability of these means. The development and improvement of the theory and practice of calculation and experimental determination of reliability is aimed at solving these problems. Automobile consists of many elements, rejecting of which during exploitation is avoided with the rutting repairs.

A characteristic feature of the modern development of technology is widespread introduction of methods and means of automation and telemechanics, caused by the transition to automated and automatic control of various production and technological processes, the creation of flexible production modules, systems, complexes, and the like. In the modern economy, automation is one of the main directions of technological progress. And, of course, improving the efficiency and quality of the designed automated control systems, ACS, GPM, GPS, etc. is impossible without improving the reliability of technical controls (TSU). Thus, the above is the first reason for the increase in the reliability factor in modern conditions of technology development and, in particular, the design of technical systems (TS) for various purposes.

The second reason that requires increasing reliability is the increasing complexity of the vehicle, the equipment for their maintenance, the rigidity of their operating conditions and the responsibility of the tasks assigned to them.

The lack of reliability of the vehicle leads to an increase in the share of operating costs compared to the total cost of designing, manufacturing and using these systems. At the same time, the cost of operating a vehicle can be many times higher than the cost of their development and manufacture. In addition, vehicle failures lead to various kinds of consequences: loss of information, downtime of other devices and systems connected to the vehicle, accidents, etc.

Thus, the third reason for increasing the role of reliability in modern conditions is the economic factor.

Power systems have evolved over decades. Their primary emphasis has been on providing a reliable and economic supply of electrical energy to their customers [1]. Spare or redundant capacities in generation and network facilities have been inbuilt in order to ensure adequate and acceptable continuity of supply in the event of failures and forced outages of plant, and the removal of facilities for regular scheduled maintenance. The degree of redundancy has had to be commensurate with the requirement that the supply should be as economic as possible.

System behavior is stochastic in nature, and therefore it is logical to consider that the assessment of such systems should be based on techniques that respond to this behavior (i.e., probabilistic techniques). This has been acknowledged since the 1930s [2-5], and there has been a wealth of publications dealing with the development of models, techniques, and applications of reliability assessment of power systems [6-11]. It remains a fact, however, that most of the present planning, design, and operational criteria are based on deterministic techniques. These have been used by utilities for decades, and it can be, and is, argued that they have served the industry extremely well in the past. However, the justification for using a probabilistic approach is that it instills more objective assessments into the decisionmaking process. In order to reflect on this concept it is useful to step back into history and recollect two quotes: A fundamental problem in system planning is the correct determination of reserve capacity. Too low a value means excessive interruption, while too high a value results in excessive costs. The greater the uncertainty regarding the actual reliability of any installation the greater the investment wasted

And finally, the last one. Ultimately, the reliability of the vehicle is determined by the reliability of the components.In tum by chance automobile from fault conditions (S_0) can be transferred keys in the condition of satiety the first element (S_1) or the second element and so words on up to till S_n. The time of standing idle in current repairs also is accidental value (quantity) depending on the character of damaged unit, number of spare parts and so on. If to receive flow of repudiation and restoration in simple way, in that case automobile can be considered as the system of mass maintenance (CUO) shown in figure 1.

For the settled conditions graph system of mass maintenance it is possible to describe with the equations.

$$\rho\lambda_1 + \rho_1\mu_1 = 0$$
$$\rho_0\lambda_2 + \rho_2\mu_2 = 0$$
$$\rho_0\lambda_n + \rho_n\mu_n = 0$$
$$\rho_0 + \rho_1 + \rho_2 + \ldots + \rho_n = 1$$

Solving equation system it is possible to express the probability all the conditions.

$$\rho_0 = \rho_0\frac{\lambda_1}{\mu_1}, \ldots; \;\; \rho_n = \rho_0\frac{\lambda_n}{\mu_n}; \;\; \rho_0 = \left[1 + \frac{\lambda_1}{\mu_1} + \frac{\lambda_2}{\mu_2} + \ldots + \frac{\lambda_n}{\mu_n}\right]^{-1}$$

Intensity of the production line of restoration elements determined with the magnitude (value) opposite of the average time vested during repair.

Intensity of the production line of refused elements analogically can be expressed through average time of defect elements, determined dividing average resources to on average speed of automobile, which presents average twenty four running to the average time in warrant. For example considered probability conditions of automobile in the well - known average enough work for the refused parts its systems and average means of time standing in maintenance average twenty - four running hours of the automobile 240 km - time in roster - 8 hours, from here the average speed of the automobile is 30 km/h.

Diagram of the automobile as the complicated restoration system.

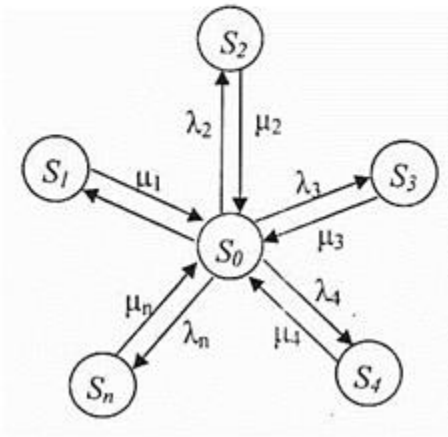

Figure. 1. Graph of the vehicle as a complex system of renewable.

The purpose and objectives of the study. The main goal that we set for the solution is to conduct an analysis of the reliability assessment of the technical means of the car, conduct a mathematical analysis of the idle state of the car and determine the probability of the condition

Research methodology. At first we determined the intensively production line till refusal and restoration automobile system, knowing which according to found out formula we discover probability of conditions, when the automobile in good state P_0 = 0,969, and then probability disrepair on systems.

From the analysis of probability condition systems can be considered that the least reliable in considered example is the motor (engine) then cab and body. Probability of standing idle of automobile for the disrepair of steering wheel and break system is less.

Found out on the base of theory of mass service the probability of automobiles in good repair conditions could be interpreted as the co efficiency of technical readiness of automobile widely used in practice in technical exploitation of automobiles production line V_1 average time of operation of the disrepair element till the moment of its complete repudiation we shall get

$$a_T = \frac{\overline{T_0}}{\overline{T_0} + \overline{T_p}} = \left(1 + \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}\right)^{-1}$$

From the analyses of formula 6 comparatively automobiles due to reducing probability (part) disrepair automobiles in exploitation will be observed in the following conditions.

The total drop in production intensively of high speed work refused parts and automobile system work (increase their reliability and resources). Reduction of value, that is to say under the through control (diagnosis) units and systems, which have high intensively of faults. Reduction of time spent for the restoration of units and systems, specially very often refused parts.

Exception of conditions of the early emergency of faults and appropriate limiting the time from the moment of beginning fault of parts as far as it will go, (it is mainly determined by design features of elements).

In the exploitation of automobile practice the co efficiency of technical readiness of automobile park a_T, which is determined with regards with the number of days in a year, when automobiles can be send to exploitation (warrant). to the sum of these days with the numbers of days in a year when automobiles stayed in technical maintenance and reparse

$$a_T = \frac{\overline{T_0}}{\overline{T_0} + \overline{T_p}} = \left(1 + \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}\right)^{-1}$$

where $\overline{T_0}$ - average work enough (time) for the repudiation of automobile$\overline{T_p}$ average time of standing idle during automobile repair.

The car consists of a large number of elements, the failure of which during operation is eliminated by the current repair. Alternately, at random points in time, the car can go from a serviceable state (S_0) to a failure state of the first element (S_1) or the second element, etc.up to Sn.

The probability of vehicle conditions is calculated for the known average operating time for failure of its systems and the average values of downtime in repair (table 1). The average daily mileage of the car is known-240 km, the time on the outfit - 8 hours, hence the average speed of the car - 30 km/h.

Table 1

Probability calculate the conditions of automobile

utomobile ystems ssembly	'ork rough for the pudiation	verage time for pair hour.	tensity of line production		ortably ondition P1
			$\lambda_1, 4^{-1}$	$\mu_1, 4^{-1}$	
ngine	10	9	271 · 10-3	025	01
ear box	10	5	272 · 10-3	117	002
riving heel	5	1	316 · 10-3	91	003
eering heel	40	9	214 · 10-3	204	001
rake ystem	50	1	200 · 10'3	141	001
lectrical quipment	5	8	315 · T0-3	147	002
uspension ackets	0	7	375 · 10-3	175	002
ody, cab	05	9	285 · 10-3	034	008

If the flow rate of failures on all components and systems $\lambda = \sum \lambda_1$, then $\overline{\grave{O}_o} = \frac{1}{\lambda}$. Transforming the expression ratio of technical readiness, we are getting

$$\overline{T_o} + \overline{T_p} + \overline{T_o} + \overline{T_o} \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}.$$

Given that $\mu_1 = \frac{1}{\overline{T_{P\iota}}}$, the average downtime o the car at repairs

$$T_p = \frac{1}{\lambda} \sum_{i=1}^{n} \lambda_i \overline{T_{P\iota}}.$$

Hence, the average downtime at the car repair is p = 13.95 hours

It should be noted that the assumption of a simple flow system failure, consisting of a large number of parts that may fail independently of each other, is quite convincing. The repair time is a random variable distributed according to an arbitrary law, but it had proved that in this case, single-channel queuing system with failures can be described by the equations of Erlang [7]. Thus, the considered method allows us to objectively assess the reliability of the car as a complex restored system.

A car, consisting of many units and parts, is a complex system, in the elements of which malfunctions (latent failures) can occur. By external manifestations of faults can be detected at the time of their appearance, and if the diagnostics are not ideal, then the operation of a complex system continues for some random time, leading to the further development of latent failures until the moment of the final loss of performance of the element and the system. After a failure, the system is restored by repairing the failed element [9].

If we denote λ_i - the intensity of the failure flow of a certain element, v_i - is the intensity of the failure flow of a faulty element, μ_i - is the intensity of the element recovery flow, and take the fraction of objects for which faults of the element are not detected q_i - and the fraction of objects for which faults are detected according to the results of diagnostics - b_i, $(a_i + b_i = 1)$, then the system can be represented by a graph (fig.2) [11-13]

For any $i = 1, 2, 3, \dots, n$ the Erlang-Kolmogorov equations can be written:
Working condition

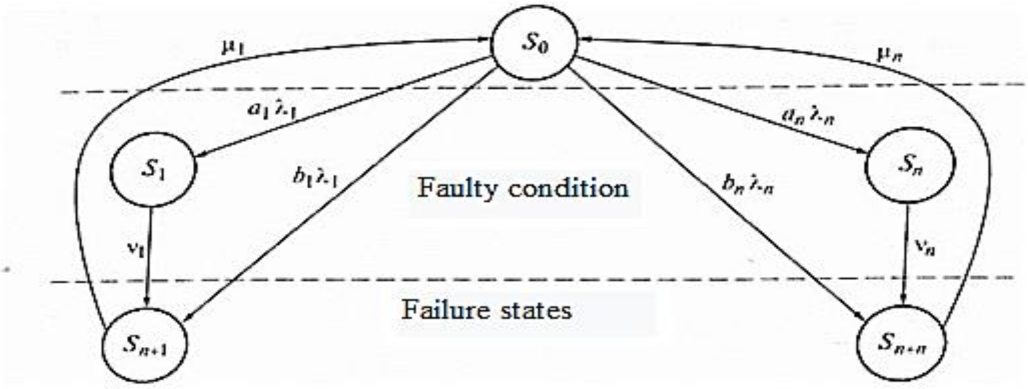

Fig. 2. Queuing system with imperfect state control

$$\mu_i p_{n+i} - a_i\lambda_i p_0 - b_i\lambda_i p_0 = 0;\ \ a_i\lambda_i p_0 - v_i p_i = 0;\ \ v_i p_i - b_i\lambda_i p_0 - \mu_i p_{n+i} = 0;$$
$$p_0 + p_1 + \ldots + p_i + p_{n+1} + \ldots + p_{n+i} + \ldots + p_{n+n} = 1.$$

Expressing from here

$$p_i = p_0 \frac{a_i\lambda_i}{v_i}\ and\ p_{n+i} = \frac{p_0}{\mu_i}(a_i\lambda_i + b_i\lambda_i) = \frac{p_0\lambda_i}{\mu_i}.$$

you can write the sum of the probabilities by taking the common factor out of the parenthesis:

$$p_0\left(1 + \sum_{i=1}^{n}\frac{\lambda_i}{\mu_i}(1 + a_i\frac{\mu_i}{v_i})\right) = 1.$$

Thus, the probability of a healthy state of the system

$$p_0 = \left[1 + \sum_{i=1}^{n}\frac{\lambda_i}{\mu_i}\left(1 + a_i\frac{\mu_i}{v_i}\right)\right]^{-1}. \quad (1)$$

The likelihood that the system in operation is actually in a faulty due to diagnostic errors,

$$p_{d.e} + \sum_{i=1}^{n} p_i$$
$$\sum_{i=1}^{n} p_i = \left(\sum_{i=1}^{n}\frac{a_i\lambda_i}{v_i}\right) / \left[1 + \sum_{i=1}^{n}\frac{\lambda_i}{\mu_i}\left(1 + a_i\frac{\mu_i}{v_i}\right)\right]. \quad (2)$$

Substituting in the obtained formula instead of the recovery flow intensity μ_i the average recovery time of the element of the system T and instead of the flux intensity v_i the average operating time of the faulty element until its complete failure T, we finally get

$$p_{d.e} = \frac{\sum_{i=1}^{n} a_i\lambda_i\bar{T}_{ni}}{1 + \sum_{i=1}^{n}\lambda_i\,(\bar{T}_{bi} + a_i\bar{T}_{ni})}. \quad (3)$$

From the analysis of formula (3) as applied to cars, it follows that the decrease the probability (share) of faulty vehicles in operation will be observed under the following conditions:

- a general decrease in the rates of failure flows of units and systems of the vehicle (an increase in their reliability and resource);

- a decrease in the value of a a_i i.e., with the most thorough control (diagnostics) of units and systems that have a high failure rate;
- reducing the time spent on restoring units and systems, especially often failing;
- elimination of the conditions of early occurrence of malfunctions and a corresponding reduction in the time from the moment of occurrence of a malfunction of an element to its complete failure (this is mainly determined by the design features of the elements).

Results of calculations of the probabilities of failure-free operation of elements A, B, C, D, E, F and G.

Figure 3 shows a graph of the dependence of the probability of failure-free operation of the PS system on the time (operating time) t. According to the graph (fig. 3, the PS curve), we find for γ=50 % γ- - the percentage operating time of the system Tγ=1,9·106 h. The test calculation for t=1.9·106 h shows that PS(Tγ)≈0,5

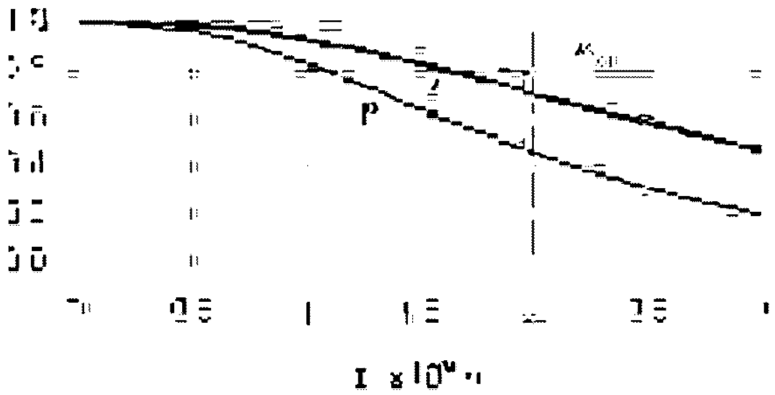

Fig. 3. Probabilities of failure-free operation of the initial system(PS), the system consisting of elements with increased reliability(PSover), and the system with structural redundancy of elements (PSrez)

Conclusion. In the practice of operating cars, the coefficient of technical readiness of the car park atg is widely used, which is determined by the ratio of the number of days in a year when cars can be put into operation (outfit) to the sum of the same number of days with the number of days when cars are idle. in TO and P. Using the previously obtained formulas for the probabilities of states (1) and (2), we can write

$$\alpha_{tq} = p_0 + p_{n.s} = \frac{1 + \sum_{i=1}^{n} \frac{a_i \lambda_i}{v_i}}{1 + \sum_{i=1}^{n} \frac{\lambda_i}{\mu_i}\left(1 + a_i \frac{\mu_i}{v_i}\right)}$$

Substituting in the obtained formula instead of the recovery flow intensity μ, the average recovery time of the element of the system Tm and instead of the flow intensity V, the average operation time of the faulty element until the moment of its complete failure Tm, we obtain

$$\alpha_{tq} = \frac{\sum_{i=1}^{n} a_i \lambda_i \bar{T}_{ni}}{1 + \sum_{i=1}^{n} \lambda_i \left(\bar{T}_{bi} + a_i \bar{T}_{ni}\right)} . \quad (4)$$

Based on formula (4), it is possible to analyze the influence on the vehicle's technical readiness factor or, in the general case, a complex system, the reliability (reliability and maintainability) of its elements, as well as the effectiveness of control (diagnostics) of the state of the elements.

1. Figure 3 shows the dependence of the probability of failure-free operation of the system (PS curve). The graph shows that the 50% operating time of the original system is 1.9·106 hours.

2. To increase the reliability and increase the 50% operating time of the system by 1.5 times (up to 2.85·106 hours), two methods are proposed:

a) improving the reliability of elements 12, 13, 14 and 15 by reducing the failure rate from 0.5·106 to 0.322·106 h^{-1};

b) loaded redundancy of the main elements 12 and 13 with identical reliability backup elements 14, 15, 16, 17 and 18

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According to the probability of failure-free operation of the upgraded system, the second method is preferred, since the PS curve (fig. 3) is located above the PS over curve

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