Resource-Saving Maintenance and Repair of Special Self-Propelled Rolling Stock

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Abstract:The article provides the issues of improving the modelsof reliability and optimization of maintenance and repair of special self-propelled rolling stock (SPRS) with a compatiblesystem of diagnostics. A new maintenance strategy is proposed, taking into account the new requirements of the self-propelled rolling stock. Examples of solving practical problems of reliability indices are considered.

The study of thereliability of SPRS, as an object, is advisable to start with its presentation in the form of a system of assembly units. In this sense, the level of consideration is important. Figure 1 gives a structural diagram of SPRS, as a system consisting of elements.for several possible levels of consideration. SPRS, as a system of elements, makes it possible to concretize the task of analyzing and improving the reliability model and developing measures to perfect it.

Keywords:rail service cars, resource, models, track motorcars, various equipment, maintenance, special diagnostics.

Introduction

The development of a reliability model for special self-propelled rolling stock (SPRS), which unites a class of different types of rail service cars, track motorcars, provides for the solution of the tasks aimed at ensuring the good condition of the equipment, economical operation, carried out with a certain frequency and sequence at optimal labor and material costs, and in the final stage of maintenance aimed to prevent the downtime of the transportation process.

The study of thereliability of SPRS, as an object, is advisable to start with its presentation in the form of a system of assembly units [1,2]. In this sense, the level of consideration is important. Figure 1 gives a structural diagram ofSPRS, as a system consisting of elements.for several possible levels of consideration. SPRS, as a system of elements, makes it possible to concretize the task of analyzing and improving the reliability model and developing measures to perfect it.

Methods of research

The diagram of the interrelation of the system and elements of SPRS is insufficient to determine the dependencies and quantitative characteristics of reliability since it is provided only as constructive and functional links.

Therefore, in the study of reliability, it is advisable to use structural and logical block diagrams and determine the qualitative and quantitative effects on the structural and parametric reliability of the object [3,4].

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If the elements of the system are logically connected in series, then each element predetermines all reliability indices, and if the elements are connected in parallel, then the failure of one element may not affect the failure of the object or its units.
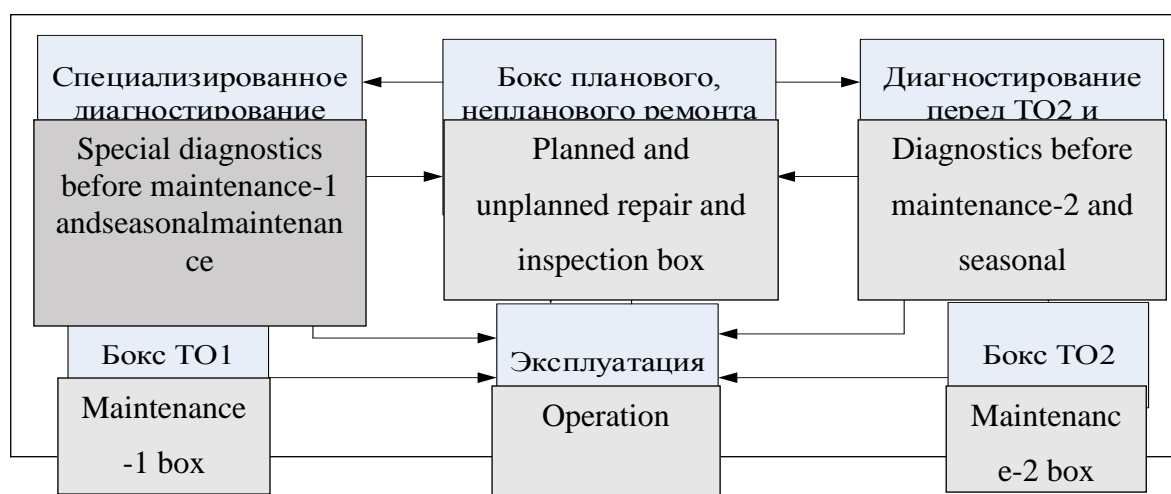

Fig. 1. An approximate diagram of relations of various equipment and elements for the analysis of the SPRS reliability.

Generally, units of the same type have a non-deterministic random operating time to failure, which has a variance relative to the mean mathematical value of the mileageL_{av}, described by a certain distribution law *f (l)*. In practice, if we assume that the overhaul period isL_{av}, then during this mileage more than half of the units will have failures with certain consequences, and the other part of the units replaced during scheduled repairs will have the remaining resource underutilized [5].

As already mentioned, SPRS is an object that has different equipment: mechanical, hydraulic, electrical equipment, and brake units; they have different maintenanceperiods. For example,the shift-time technical inspection (SI) -technical maintenance-1 is conducted every 140 hours of platform operation, maintenance-2 is conducted every 420 hours of platform operation, seasonal technical maintenance is conducted twice a year, technical inspection is conducted at least once a year, and complete technical inspection is conducted at least once in 3 years [6]. At the same time, according to our observations, each type of equipment has an average mileage L_{av}. As a result, a contradictory situation arises: a certain number of units will have failures, leading to emergencies with corresponding costs, while others will have underutilized remaining resources, leading to certain reduced costs.

The above conditions and the inconsistency of the average mileage of each type of equipment put at the forefront the urgent problem of developing a mathematical model to optimize the overhaul period L_{av} ofSPRS, which would correspond to the minimum total costs, taking into account the increase of the object reliability by using modern methods and means of

technical diagnostics combined with the maintenance and repair [7] (Fig. 2).

Fig. 2. Diagram of the combined organization of diagnostics, maintenance and repair.
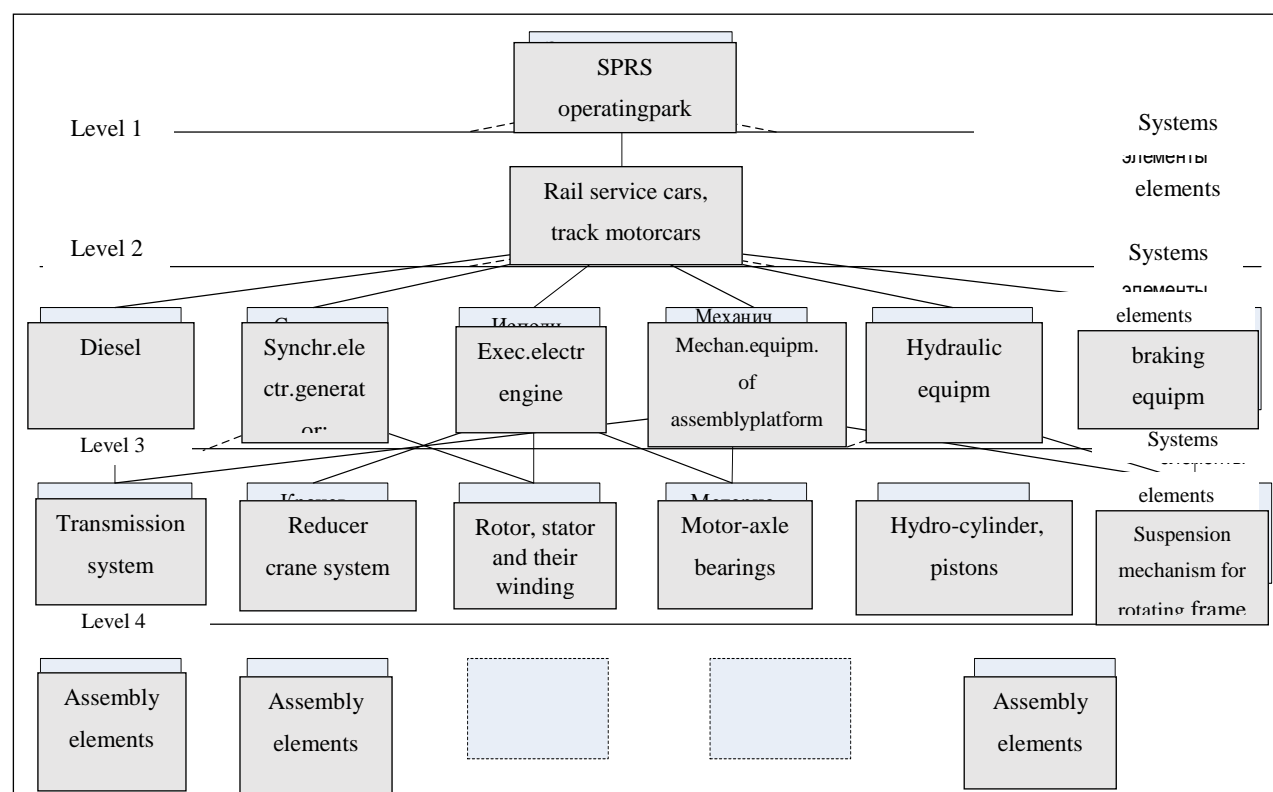
In the process of SPRS diagnostics, apart from identifying the values of the operability and reliability parameters and numerical characteristics of reliability, ensuring a high level of quality condition and functioning of the equipment and units specified in the operation manual [2], the following technical and operational parameters arenecessaryto control the modern rolling stock [8]:

- mileage, speed, acceleration of driven and driving links of a mechanism or a drive;

- insulation of working and transition platforms and insulation of electrical equipment;

- the end positions of the links of mechanisms, the spread of their position, positioning;

- nonuniform rotation or translational movement of the links of mechanisms;

- forces and moments acting on the links of mechanisms and drives;

- pressure in the hydraulic and pneumatic systems;

- power consumed by electric engines;

- points of timeof giving commands for switching on gears, couplings, and devices;

- starting and ending time of the mechanisms;

- temperature and areas of temperature fieldchange;

- parameters of rigidity and elastic deformations of individual links of mechanisms;

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- the level of noise and vibrations during the operation of hydraulic and electrical equipmentmechanisms;

- operation and smoothness of movement of spools, solenoids, and control system devices;

- unitsof rotation and accuracy of the cam, pinion, rotary-locking mechanisms.

When diagnosing and assessing the monitored parameters, a differentiated method to determine machine conditions is possible, taking into account the modes of operation, the degree of technical and operational parameters effect on the durability and reliability.

Analysis of the results of operation of various types of SPRS[9], and long-term exchange of domestic and foreign experiences make it possible to formulate the main tasks and methods for improving the maintenance and repair with a combination of methods and technical means of diagnostics, to significantly increase their reliability (Fig. 3).

Consider an example of assessing the reliability standards indices, taking into account the fact that the operating time to failure for each type of mechanical and hydraulic electrical equipment is subject to an exponential distribution law [6]. In 2017-2019, 18 assembly units of the ADM1 type rail service cars were observedon an assembly platformaccording to the inspection plan [*N, U, T*], based on the materials presented by the Railway Engineering Department of the Mechanization Directorate of JSC "Uzbekistontemiryullari", where N is the number of objects determined by the formula

$$\delta + 1 = 2N/\chi^2_{(1-\beta,2N)},$$

whereδ is the reduced relative error, $\chi^2_{(1-\beta,2N)}$ is the distribution quantile*xu*- a square at the number of degrees of freedom; after the failure, assembly units of the assembly platform were not replaced; tests were conducted until all units failed. The observations were performed for T = 2000 hours. During this time, d = 8 of different types of assembly units (parallelograms of the lifting mechanism, pumping station, hydraulic cylinder, and adjustable throttles) failed.

The operating hours of each assembly unit are shown below

d	1	2	3	4	5	6	7	8
t_i, h	120	150	230	380	521	683	1097	1509

As is known from the reliability theory, if the operating time to failure is subject to an exponential distribution law, then taking failure as a limiting state, we can talk about the resourceinstead of operating time to failure.

The following estimates of reliability indices [10] are calculated:

Average resource atγ =95%:

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$$\hat{\lambda} = \frac{d}{\sum_{i=1}^{d} t_i + (N-d)T} = \frac{8}{4820 + (18-8)*2000} = 0,00032 \; 1/\text{hour}.$$

Let us determine the confidence two-sided bounds with a confidence probability $\beta = 0.95$; according to Table 1 of State standards GOST 17509-72 we have:

Lower bounds

$$\lambda_N = \frac{\hat{\lambda} N \chi^2_{\frac{1-\beta}{2},2d}}{d(2N - d + \frac{1}{2}\chi_{\frac{1-\beta}{2},2d}} = \frac{0,00032 * 20 * 8,12}{8(2*18 - 8 + \frac{1}{2}*8,12)} = 0,00026 \; 1/\text{hour}.$$

Upperbounds

$$\lambda_V = \frac{\hat{\lambda} N \chi^2_{\frac{1-\beta}{2},2d}}{d\left(2N - d + \frac{1}{2}\chi^2_{\frac{1-\beta}{2},2d}\right)} = 0,00044 \; 1/\text{hour}.$$

Thus, the interval (0.00012-0.00044) with probability covers the unknown parameter λ.

Let us determineone-sided confidence bounds with a confidence level of $\beta = 0.95$ [3]:

$$\lambda_{a\text{н}} = \frac{\hat{\lambda} N \chi^2_{1-\beta,2d+2}}{d\left(2N - d + \frac{1}{2}\chi^2_{1-\beta,2d+2}\right)} = \frac{0,00032 * 18 * 10,01}{8(2*18 - 8 + \frac{1}{2}10,01)} = 0,00023 \; 1/\text{hour}.$$

Therefore,$\hat{\lambda} > 0,00022$, that is, the interval (0.00022-∞) with a probability of 0.95 covers the unknown parameter λ

$$\lambda_{\text{о.в}} = \frac{\hat{\lambda} N \chi^2_{\beta,2d+2}}{d\left(2N - d + \frac{1}{2}\chi^2_{\beta,2d+2}\right)} = \frac{0,00032 * 18 * 25,8}{8(2*18 - 8 + \frac{1}{2}25,8)} = 0,00055 \; 1/\text{hour}.$$

Average resourceis$\hat{\lambda} < 0,00055$, i.e. the interval (0-0.00055) with a probability of 0.95 covers the unknown parameter λ.

According to Table 7 [10],we determine estimates of the reliability indices of the assemblyplatform and their confidence bounds using the data calculatedabove:

$$T_{\text{p.cp}} = \frac{1}{\hat{\lambda}} = \frac{1}{0,00032} = 3125 \text{ h}.$$

$$T_{\text{p.cp.н}} = \frac{1}{\lambda_{\text{в}}} = \frac{1}{0,00044} = 2272 \text{ h}.$$

$$T_{\text{p.cp.в}} = \frac{1}{\lambda_{\text{н}}} = \frac{1}{0,00026} = 3846 \text{ h}.$$

Thus, the interval (2272-3846) with a probability of 0.95 covers the true value of the average resource

$$T_{\text{p.cpo.в}} = \frac{1}{\lambda_{\text{о.н}}} = \frac{1}{0,00023} = 4347 \text{ h}.$$

In accordance with the above, we consider a method for improving the TOP model, combined with increased reliability indices, using technical means for diagnosing main

equipment.

It is known that the probability of replacing parts at the maintenance-1 by the conditional probability of increasing reliability as a result of using the i-th diagnostic tool equal to P_g is determined as [4, 6]:

$$P = (1 - Q) * P_g = \left[1 - \int_0^{L_{cp}} f(l)dt\right] P_g, \qquad (1)$$

where (1-Q) is the probability that the equipment will not fail over the period L_{av}; $f(l)$ is the density of the probability distribution of failure under the exponential law [9, 10], and is defined as

$$T_{p.cp.в} = \frac{1}{\lambda_{н}} = \frac{1}{0{,}00026} = 3846 \text{ h.}$$

$$f(l) = \frac{1}{L_{av}} exp\left(-\frac{L}{L_{av}}\right). \qquad (2)$$

Then, $Q = \int_0^{L_{av}} f(l)dl = \int_0^{L_{av}} \frac{1}{L_{av}} exp\left(-\frac{1}{L_{av}}\right) dl = -\frac{1}{L_{av}} l^{-\frac{l}{L_{av}}} \Big|^{L_c}$.

For example, at $L_{av} = 200 * 10^3$ km, and P = 0,98, we obtain

$$P = \left[1 - \frac{1}{200 * 10^3}\left(e^{-\frac{200*10^3}{200*10^3}} - e^{-\frac{0}{200*10^3}}\right)\right] * 0{,}98 = 0{,}977.$$

Conclusion

Taking into account the above aspects and conducting calculations based on the principal indices of reliability, which are the most important components of the SPRS technical operation system, based on a system of maintenance and repair; due to fundamental changes in designs, the emergence of new materials and repair technology requires the improvement of new technologies for maintenance and repair and the perfection of the reliability indices by introducing new monitoring and diagnostic systems.

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