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The Method of Assessing Traffic Safety in Railway Transport

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Abstract. To identify and predict risks in the work, a method for assessing traffic safety in railway transport is proposed. On the basis of statistics on the failure of freight cars during operation, the characteristic distribution laws for types of wear were determined. As a result, the dependences of the probability of failure-free operation of freight cars on the operating life were obtained and the centers of gravity of the areas that are used to characterize and assess the risk were determined. When designing a freight car, it is possible to establish risk values obtained on the basis of statistical data, which opens up the possibility of improving traffic safety in railway transport. In the developed method for assessing traffic safety in railway transport, the use of a graphical risk matrix is proposed. It is also proposed to combine the dependencies of the probability of failure-free operation of freight cars to calculate the total risk. This allows you to get a graphical risk matrix taking into account three types of wear of a freight car to assess traffic safety. The number of dependencies of the probability of failure-free operation of freight cars can be increased if failures are observed for other reasons.

1. Introduction

The railway transport occupies a significant part of the market of transport services related to the organization and support of the process of transportation of goods and passengers. One of the main tasks of railway transport, as well as an important component of its effective work and development, is ensuring traffic safety, which is directly affected by the reliability of the rolling stock and infrastructure elements. A successful decision to ensure the necessary level of traffic safety on the railway transport is largely determined by the technical condition and reliability of the rolling stock. In turn, traffic safety can be assessed by the risks of possible failure of freight cars. Therefore, to ensure low risk values during the operation of freight cars at the stage of their design, it is necessary to establish sufficient indicators for structural strength, taking into account manufacturing technology, and also take into account operational factors.

2. The relevance, scientific significance of the issue with a brief review of the literature

The operational experience of different types of freight cars is not fully used in the design process, which ultimately affects the quality of operation, reliability and traffic safety. Information on the



failure of freight cars that occur during operation should be processed before the start of designing a new design. In addition, designers at the initial stage of operation of a freight car can prevent the occurrence of risks of critical failures based on existing statistical information and the possibility of redistributing them to less critical ones. To do this, you need a way to assess traffic safety of railway transport, which will include risk values.

In [1], [2], [3], methods for analyzing a fault tree for assessing traffic safety are presented. Such techniques are used to improve the efficiency of railway maintenance and reduce risks. Several methods in [4], [5], [6] present improved fault tree analysis techniques for decision making.

In [7], [8], [9], [10] risk models for assessing traffic safety are presented. Works [7], [8] are based on accident scenarios taking into account the human factor. Experts are involved in [9], [10]. In [11], [12], traffic safety is associated with the processes of the maintenance system of the elements of the transport system.

In [13], [14] a system for identifying risks in the railway transport is given. In [15], [16], the probability of railway failures is used to evaluate traffic safety. In [17], the operational reliability method was used to assess traffic safety. In [18], railway power supply systems are considered critical for traffic safety of the transport system. Risk analysis [19] made it possible to use stochastic methods for assessing traffic safety. In [20], risk assessment methods and the possibility of improving traffic safety during the design, operation and maintenance of railway vehicles are presented. Particular attention is paid to the design of freight cars and their impact on traffic safety. In works [13], [21] traffic safety is described using risk matrix with predefined values in the transport chains.

3. Statement of the problem

In the conditions of continuous improvement of transport and technical means, the issue of assessing traffic safety remains open in the railway transport. Existing methods for assessing traffic safety are complex and time-consuming. Therefore, it is necessary to develop a simple way to assess the safety of railway traffic.

4. The theoretical part

There are a number of cases where there is information about failures of freight cars with a different nature. Let us consider the cases of failures of freight cars with mechanical and corrosion wear, as well as fatigue failure, since such failures are more widespread. Moreover, on the basis of experimental data, the distribution of the probability functions of freight car failures $F(t)$ by the indicated types of wear has been established. So, for the case of freight car failures due to mechanical wear, the distribution density obeys an exponential distribution. For the case of freight car failure due to corrosion wear, the distribution is subject to normal law. In the case of investigating the failure of freight cars on fatigue failure, the distribution is subject to Weibull's law.

In accordance with the collected statistics, Figure 1 shows the graphical dependences of the probability of failure-free operation of freight cars on the service life $P(t)$ for the corresponding types of wear. Based on the obtained statistics on failures, the probability of failure-free operation of freight cars was determined by the formula:

$$P(t) = 1 - F(t). \quad (1)$$

With the corresponding operating life of freight cars, there is a decrease in the probability of failure-free operation, which indicates a high probability of a critical failure risk. Establishing a risk value at the design stage will allow implementing measures to increase the existing physical, mechanical or physic-chemical properties of structural elements of a freight car at an appropriate life. In this regard, Figure 1 shows the centers of gravity of the areas R_M, R_K, R_B bounded by the probability curves of the failure-free operation of freight cars. The assumption is made that the centers of gravity of the indicated area R_M, R_K, R_B will act as an assessment of risks that characterize the level

of traffic safety. In the proposed method for assessing traffic safety in railway transport, it is necessary to draw vertical and horizontal lines from the risk points R_M, R_K, R_B (Fig. 1), which, when intersected with the probability curves of failure-free operation, give several areas. To assess and forecast traffic safety of railway transport, it is proposed to color the corresponding areas in the colors of risks: red - critical risk, yellow - acceptable risk; green - conditionally absent risk.

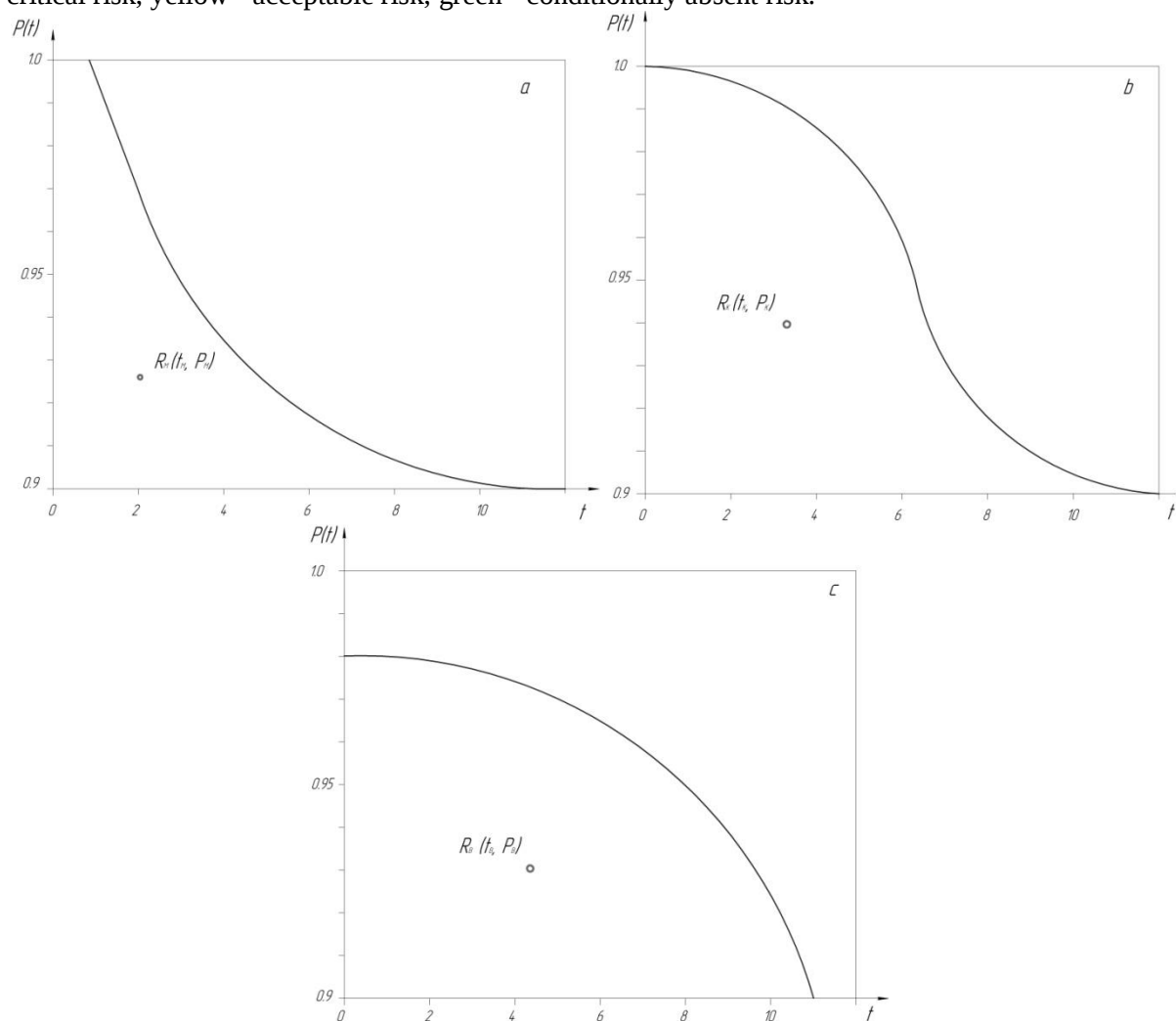


Figure 1. Dependences of the probability of failure-free operation of freight cars on the service life (a - mechanical wear; b - corrosion wear; c - fatigue failure).

We combine the previously given graphical dependences of the probability of failure-free operation of freight cars and calculate the total risk (center of gravity) of the combined curves according to the formulas:

$$R_t = \frac{\sum_{i=1}^n P_i \cdot t_i}{\sum_{i=1}^n P_i} = \frac{P_M \cdot t_M + P_K \cdot t_K + P_B \cdot t_B}{P_M + P_K + P_B}; \quad (2)$$

$$R_P = \frac{\sum_{i=1}^n P_i \cdot t_i}{\sum_{i=1}^n t_i} = \frac{P_M \cdot t_M + P_K \cdot t_K + P_B \cdot t_B}{t_M + t_K + t_B}. \quad (3)$$

5. Practical relevance, suggestions and implementation results, experimental research results

Here are the practical results of a method for assessing traffic safety in railway transport (Fig. 2).

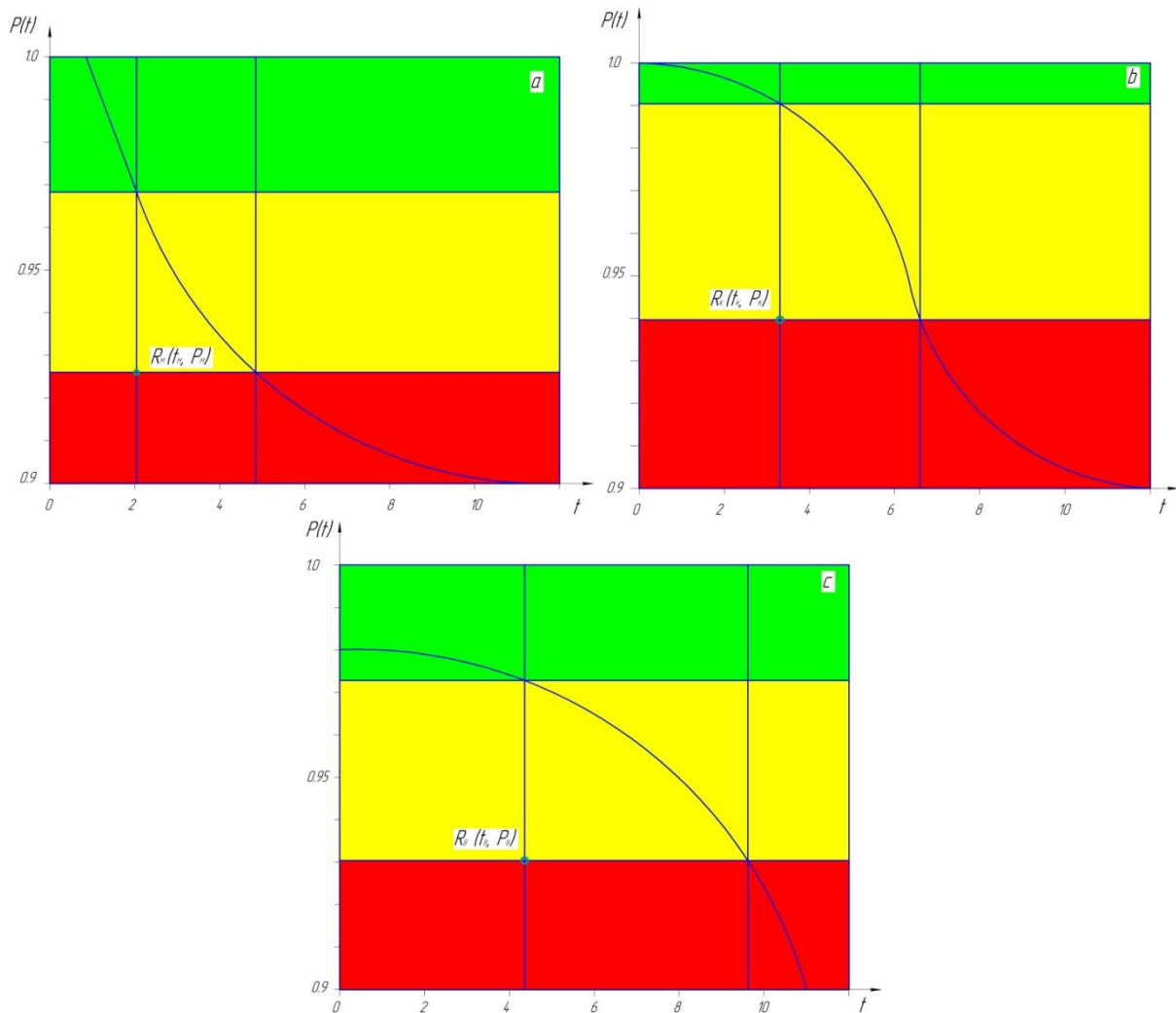


Figure 2. A graphic matrix of risks for freight cars (a - mechanical wear; b - corrosion wear; in - fatigue failure).

Using formulas (2), (3), we determine the point of general risk $R(t, P)$ for 3 types of wear of freight cars and draw lines intersecting with the point and denote the color of the risk zone (Fig. 3).

The intersection of the horizontal line drawn from the point $R(t, P)$ with the probability curves of failure-free operation $P(t)$ for the corresponding types of wear of the freight car gives points that are decisive. The point $R(t, P)$ corresponds to the freight car operating life of 3.5 years and the probability of failure-free operation - 0.9333 (Fig. 3). The area below the point is colored red, which

characterizes the critical value of the risk. With a probability of failure-free operation in the range of 0.9333-0.9766, the area is colored yellow, which characterizes acceptable risk values. Green indicates a conditional lack of risk.

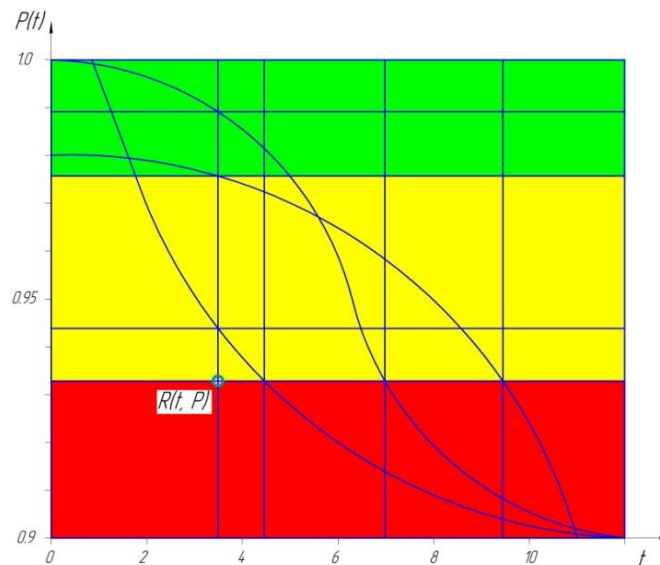


Figure 3. Risk areas of freight cars on the distribution plan of the probability of their failure-free operation.

It is possible to reduce the risk of freight car failures by using new designs and materials that provide higher values for the probability of failure-free operation.

This method of assessing traffic safety in railway transport allows you to identify and predict risks and can be used in the design of new designs of freight cars, as well as during repairs during operation to improve traffic safety. This will reduce the threat to human life and possible harmful environmental consequences in railway transport.

6. Conclusions

The paper presents a method for assessing traffic safety of railway transport, on the basis of which risks can be determined and predicted. Based on statistics on freight car failures, characteristic laws were determined for the three types of wear. Having built the dependences of the probability of failure-free operation of freight cars on the operating life, it is proposed that the centers of gravity of the areas be used as a risk characteristic. At the stage of development of a freight car, it is possible to establish risk values obtained on the basis of statistical data, which will make it possible to apply measures to improve traffic safety in railway transport. The proposed method for assessing traffic safety in railway transport proposes the use of a graphical risk matrix. In addition, it is proposed to combine the dependencies of the probability of failure-free operation of freight cars with the calculation of the total risk. This allows you to get a graphical risk matrix taking into account three types of wear of a freight car to assess traffic safety. The number of dependencies of the probability of failure-free operation of freight cars can be increased if failures are observed for other reasons.

7. References

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