Influence of Diagnostics of Axle Boxes of Freight Cars on Traffic Safety of the Railway Transport

Influence of Diagnostics of Axle Boxes of Freight Cars on Traffic Safety of the Railway Transport

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Abstract. Failures of axle boxes of freight cars due to poor-quality repair and maintenance can be reduced by applying diagnostic methods and tools. Therefore, the study carried out a study of the influence of diagnostics of axle boxes of freight cars on traffic safety of the railway transport. To reduce the magnitude of risks arising from failures of axle box units of freight cars, it is proposed to use vibration diagnostics during maintenance and repair, and to exclude the human factor, it is proposed to completely eliminate the operator's influence on the conclusions of the diagnostic process. Also, a method for assessing the risks arising from failures of axle boxes of freight cars was developed. The presented method for assessing of traffic safety the railway transport allows you to determine and predict risks. Vibration diagnostics allows reducing the risks arising from failures of axle boxes of freight cars, thereby increasing the level of traffic safety up to 3.7 times. In this regard, it can be argued that the use of vibration diagnostics during the maintenance and repair of axle boxes of freight cars makes it possible to reduce the threats to human life and possible harmful environmental consequences on the railway transport.

1. Introduction

The railway transport is of great importance in the implementation of the process of transporting goods and passengers. At the same time, in the process of transportation there are risks associated with failures of technical and transport vehicles, as well as risks associated with the human factor. The emerging risks have an impact on the state of railway traffic safety. A successful solution to the problem of ensuring the required level of traffic safety on the railway transport largely depends on the technical condition and reliability of the car fleet, since the number of freight cars is the largest among all technical means intended for the carriage of goods. The reliability and technical condition of freight cars depends on the quality of the repair and maintenance performed. Therefore, traffic safety of the railway transport can be assessed by the risks of possible failures of freight cars. To ensure low risk values during the operation of freight cars, it is necessary to perform high-quality repairs and maintenance by developing new diagnostic tools.

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

Information on failures of elements of freight cars that occur during operation is a set of statistical data. Failure analysis is provided in such data. Using the available information on failures of elements of freight cars, it can be argued that the largest number of failures is associated with axle boxes. The analysis of axle box unit failures made it possible to establish that all failures are associated with poor-quality repair and maintenance, the process of which is significantly influenced by the human factor. To reduce the risks that can be admitted during the repair and maintenance of freight cars, it is necessary to develop a method for diagnosing axle boxes and calculating risks for assessing traffic safety on the railway transport.

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

With the growth of freight traffic in the railway transport, the issue of assessing traffic safety remains open. The existing methods for assessing traffic safety do not take into account the influence of the processes of diagnostics of axle boxes of freight cars during maintenance and repair on possible risks arising from failures in operation. Therefore, it is necessary to investigate the influence of diagnostics of axle boxes of freight cars on traffic safety of the railway transport and develop a method for assessing the risks arising from failures of axle boxes of freight cars.

4. The theoretical part

In the maintenance and repair of freight cars, the main method that takes into account the reliability of human performance can be given by constructing a probability (or outcome) tree. The use of such a method assumes a certain conditional probability associated with the successful or erroneous performance of a certain technological operation by an employee of the maintenance and repair of freight cars, or the probability associated with the occurrence of a corresponding event. In this case, the result of any event will be represented by branches or links of the probability tree. It is possible to calculate the total probability of successfully completing a certain task of maintenance and repair of freight cars by summing certain probabilities that will be known for the end point (in case of a successful result) on the probability tree. In such a method, factors can be taken into account, with some clarifications, for example: stress caused by a lack of time; load, which determines the need for decision-making and their implementation in various non-standard situations; emotional stress and the like.

It should be noted that the use of this method can provide good clarity, and the mathematical calculations associated with it are quite simple, which also leads to a decrease in the likelihood of errors that may occur during the calculation.

In addition, this method makes it possible to assess the conditional probability of performing maintenance and repair work on axle boxes of freight cars, which can be obtained only on the basis of solutions of complex equations of an uncertain nature.

Let us designate the fulfillment of the task by an employee for the maintenance and repair of axle boxes of freight cars with the existing technology as x, and for the technical condition y. It is known that an employee can complete a task correctly or incorrectly. That is, the tasks they perform incorrectly - these will be errors that appear in a certain situation.

In this case, you can build a tree of possible outcomes and come to a determination of the overall probability of incorrect performance of the task. Then, it is necessary to base on statistically independent probabilities of performing the task of maintenance and repair of axle boxes of freight cars x, y.

Let us write down the formula for the probability of successful completion of the assigned task for the maintenance and repair of axle boxes of freight cars:

$$P_S = P_x(1-P_h)P_y, \tag{1}$$

P_x, the probability of successful completion of the assigned task for the maintenance and repair of axle boxes of freight cars;

P_h, the probability of an error being made by human fact;

P_y, the probability of successful completion of the assigned task for the maintenance and repair of freight cars.

The formula for the probability of failure to fulfill the task for the maintenance and repair of axleboxes of freight cars P_F, which will correspond to the risks arising from failures R, is written in the following form:

$$R = P_F = 1-P_x(1-P_h)P_y. \tag{2}$$

From the above formulas (1), (2), we can conclude that the only way to successfully complete the complex task of maintenance and repair of freight cars, which consists in the successful completion of tasks x, y and reducing the human factor.

Failures of axle boxes of freight cars due to poor-quality repair and maintenance can be reduced by applying diagnostic methods and tools. In this work, it is proposed to use vibration characteristics for diagnostics of axle boxes of freight cars. Moreover, to eliminate the human factor, it is proposed to completely eliminate the operator's influence on the conclusions of the diagnostic process. In this regard, the risk arising from failures of axle boxes of freight cars, taking into account the use of vibration diagnostics ($P_h = 0$), will be calculated by the formula:

$$R = 1-P_xP_y. \tag{3}$$

On the basis of formulas (2), (3), we construct the dependences of the risks arising from refusals on the probability of fulfilling the assigned task for the maintenance and repair of axle boxes of freight cars (Fig. 1).

Taking into account the dependence of the risks arising from failures of axle boxes of freight cars, we present practical results and compare them with theoretical values.

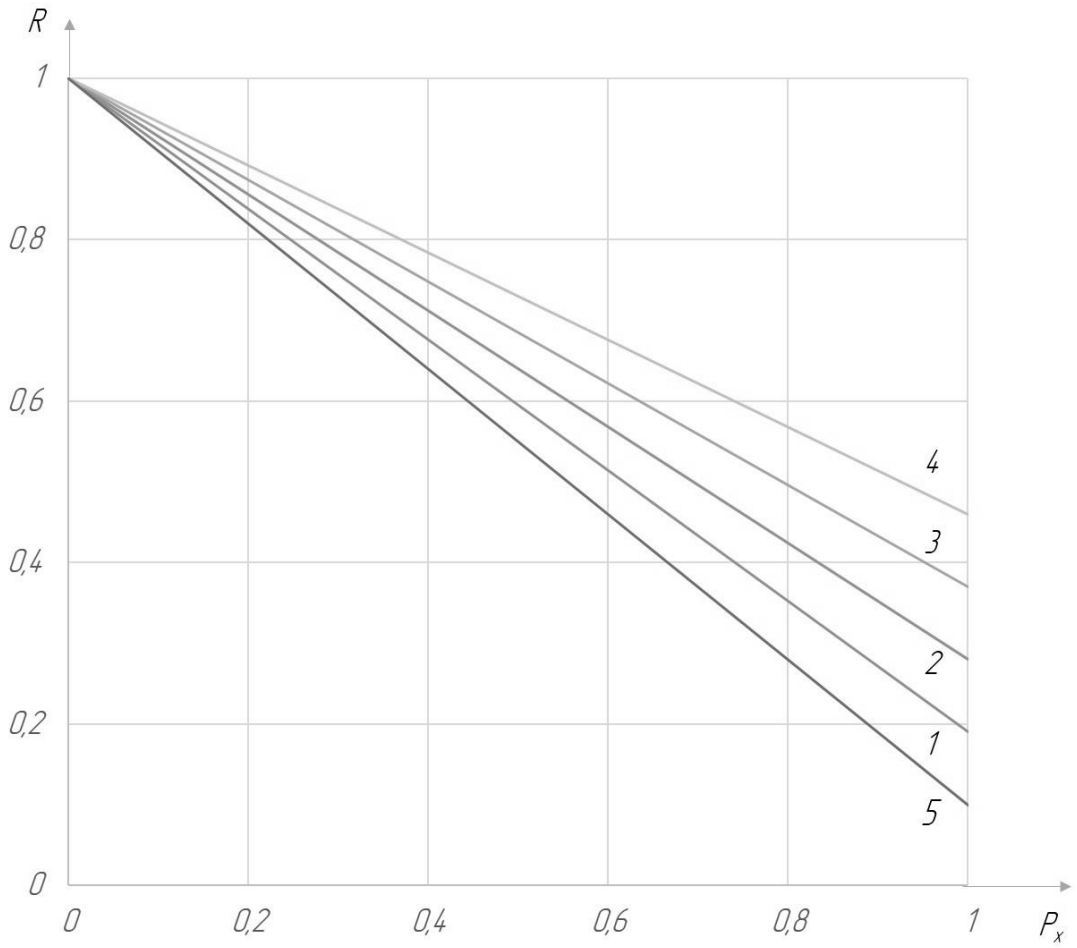

Figure 1. Dependences of risks arising from failures of axle boxes of freight cars on the probability of fulfilling the assigned task of maintenance and repair: 1 - $P_h = 0{,}1$; 2 - $P_h = 0{,}2$; 3 - $P_h = 0{,}3$; 4 - $P_h = 0{,}4$; 5 - $P_h = 0$

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

Let us present the practical results of the distribution of the axlebox unit failures of freight cars with the usual technology of maintenance and repair and with the use of vibration diagnostics (Fig. 2).

The given values of the axle box failures of freight cars in operation with the usual maintenance and repair technology (1) and with the use of vibration diagnostics (2) in comparison with theoretical values (Fig. 1) have deviations in values not exceeding 8%. This indicates a good convergence of theoretical and experimental data on the risks of failure of axle boxes of freight cars.

The practical value of the developed method for determining the risks arising from failures of axle boxes of freight cars lies in the possibility of assessing the safety of railway transport. In addition, to reduce the risks arising from failures of axle boxes of freight cars, it is proposed to use vibration diagnostics during maintenance and repair. As a result, a decrease in the risks arising from failures of axle boxes of freight cars by 1.1...3.7 times was obtained.

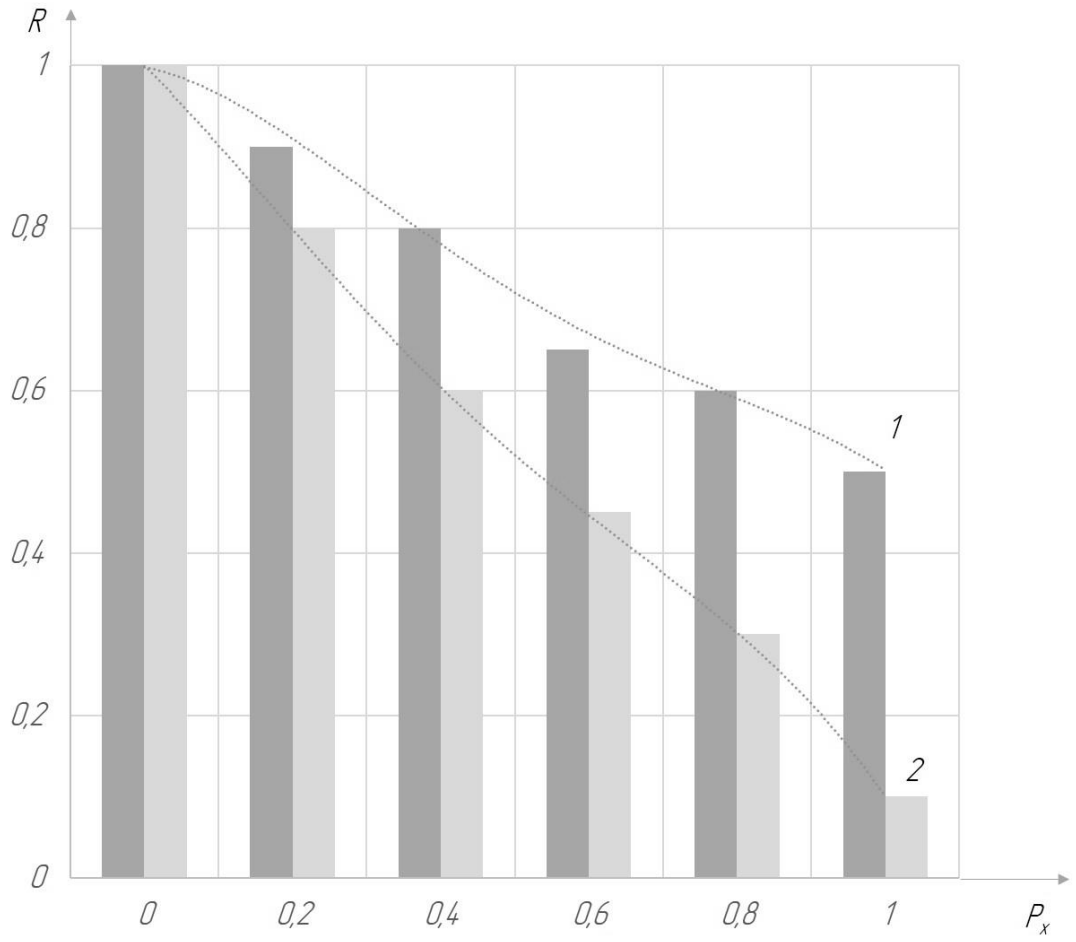

Figure 2. Distribution of failures of axle boxes of freight cars in operation with conventional maintenance and repair technology (1) and using vibration diagnostics (2).

6. Conclusions

The paper investigates the influence of diagnostics of axle boxes of freight cars on traffic safety of the railway transport. Also, a method for assessing the risks arising from failures of axle boxes of freight cars was developed. The presented method for assessing the safety of the railway transport allows you to determine and predict risks. To reduce the magnitude of risks arising from failures of axle boxes of freight cars, it is proposed to use vibration diagnostics during maintenance and repair. Vibration diagnostics allows reducing the risks arising from failures of axle boxes of freight cars, thereby increasing the level of traffic safety up to 3.7 times. In this regard, it can be argued that the use of vibration diagnostics during the maintenance and repair of axle boxes of freight cars makes it possible to reduce the threats to human life and possible harmful environmental consequences on railway transport.

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