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HUMAN FACTOR INFLUENCE ON PERFORMING TECHNICAL MAINTENANCE AND REPAIR OF FREIGHT CARS

Purpose. The scientific work is aimed to: 1) study the indicators and criteria for evaluating the influence of human factor on failure-free operation of freight cars; 2) theoretically describe the probabilistic model of the human factor role during the maintenance and repair of freight cars according to technical state; 3) consider the model of situation development for the case of a critical defect of the freight car unit taking into account the human factor. **Methodology.** In order to achieve this purpose, the methodological approaches were considered: 1) to evaluation of the reliability indicators in the system «man – freight car» during maintenance and repair; 2) to evaluation of the level of traffic safety in case of transition from the existing system of maintenance and repair of freight cars to the system according to technical state. The model of the situation development for the case of a critical defect of the freight car unit with the consideration of the human factor was described. **Findings.** The approach to the evaluation of risk indicators of potential failures of freight cars is given. The probability of occurrence of negative events (risks) and possible economic damage from their manifestation were taken as the indicators. In the developed model of situation development for the case of a critical defect of the freight car unit with the consideration of the human factor, three possible states are shown: workable and limited workable, unworkable and emergency. Each initial state is characterized by the development of events, which is associated with designers` errors, with defects during manufacture of parts and units, with human factor. **Originality.** It is proposed to consider the value of the failure probability, which is related to the human factor, as a certain proportion of the overall probability of failure of the system «man – freight car». The interpretation of Harrington's desirability function for the case of application to freight cars is given. During maintenance and repair, it is suggested to introduce an indicator that characterizes the observance of the technology of use of maintenance services for freight cars, taking into account the human factor. **Practical value.** Based on the conducted research it is possible to evaluate the influence of the human factor on the maintenance and repair of freight cars. According to the developed model of situation development for the case of a critical defect it is possible to determine the critical level of the defect of the freight car unit taking into account the human factor to limit the risk of an accident or transport event.

Keywords: freight car; reliability; human factor; critical defect; maintenance; repair

Introduction

The main duties of the railway transport workers are the satisfaction of the requirements for the passengers and cargo transportation subject to unconditional compliance with traffic safety [9].

Many scientific works are devoted to the improvement of designs, maintenance, repair technology and rolling stock diagnostics, which greatly affect the traffic safety [1, 3, 5, 15]. According to research data, the human factor significantly influences the traffic safety level [16, 18].

The activities of railway transport workers, which are aimed at ensuring traffic safety in the system «man – freight car», are connected with mental and physical functions. At the same time, a man carries out his/her activities according to deterministic and random procedures or rules, instructions, technological schedule. In the first case, this activity is strictly regulated. In the second case, during the maintenance or repair process the occurrence of unexpected events is possible, for example, the deterioration of the natural environment. In some processes, such events predict and prepare the appropriate guiding activities [4, 6, 17].

Mental work (intellectual activity) is associated with the reception and processing of information, and mainly requires concentration of attention, exertion of the sensory apparatus, memory, as well as the activation of thinking processes and emotions. The work of inspectors and mechanics during

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maintenance and repair requires increased responsibility and high nervous-emotional tension. Such work is recognized by the high degree of information dynamism, its volume, the lack of time to prepare and make the right decisions, the need to resolve the conflict situations that arise occasionally during the maintenance and repair of freight cars [8].

The role of the human factor manifests itself in the influence on the process of training inspectors and mechanics for the maintenance and repair of freight cars (operation process) and in evaluating the results of its implementation. The human factor can be defined as a set of peculiar psychophysiological features that must be taken into account in order to exclude the causes of wrong actions [2, 11].

The human factor that caused erroneous actions is not always due to the psychological and psychophysiological characteristics of a person and does not always correspond to the level of complexity of tasks or problems. Mistakes caused by a human factor, as a rule, occur unintentionally. A person performs actions that are regarded by he/she as the most appropriate or correct.

The reasons for the erroneous actions of a person can be classified in the following groups:

– limitations of information provision, absence or lack of information support;

– mistakes caused by external factors;

– errors caused by the physical and psychological state and human properties;

– the limited resources of support and implementation of the taken decision;

– emotional tension;

– loss of attention that occurs when performing the necessary actions, especially in the event of unexpected equipment failure or a sudden change of situation.

It is necessary to improve the methods of facilitating the work of inspectors and mechanics and to take the necessary measures to reduce the human factor influence. For this purpose, it is necessary to develop a methodology for assessing the influence of the human factor on performing maintenance and repair.

Purpose

The scientific work is aimed to: 1) study the indicators and criteria for evaluating the influence of human factor on failure-free operation of freight cars; 2) theoretically describe the probabilistic model of the human factor role during the maintenance and repair of freight cars according to technical state; 3) consider the model of situation development for the case of a critical defect of the freight car unit taking into account the human factor.

Methodology

The main indicator of the reliability of work in the system «man – freight car» during the maintenance and repair is the probability that the time between failures will not exceed the given temporal restriction. It can be determined by the following expression:

$$P(T \le t) = \{P_{\mathrm{FP}}(T \le t) \cdot P_{\mathrm{HF}}(T \le t)\}, \qquad (1)$$

where P_{FP} and P_{HF} – the value of the failure probability, which is determined by the reliability of the freight car and the influence of the human factor, respectively;

T – is the time of freight car operation to the first failure; t – is the period of time during which the failure probability of freight car is established.

The regularities of the dependencies of the failure probability P_{FP} and P_{HF}, when T is less or equal to t for the inspector or mechanic of the freight car, are determined by the biological nature of the human body, on the one hand, and the design, material properties and conditions of freight car operation – on the other.

During analysis of the reliability of the system «man-freight car», the research objects are different occasional events and values that influence respectively both the state of a person and the freight car. The typical failure rate function of the freight car is shown in Fig. 1. One can distinguish in it three characteristic areas:

– from the beginning of operation to t_1 – the time interval at which the failure rate function decreases as a result of design improvements of freight cars in the process of production tests, running of parts and units and other technical reasons;

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– t_1–t_2 – the time interval at which the failure rate function is practically constant and characterizes the stable operation of freight car;

– from t_2 to the limiting state – the time of the failure rate increasing due to the physical wear of freight car.

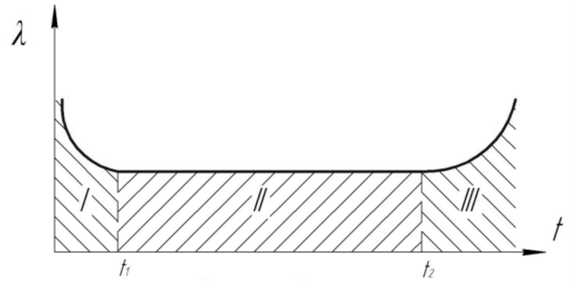

Fig. 1. Dependence of the failure rate function of freight car on the time between failure at λ = const

The human body, in accordance with the 1-st and 2-nd laws of thermodynamics of biological systems, is in a steady unbalanced thermodynamic state, unlike freight cars, which are always in an unstable unbalanced thermodynamic state. It is provided by human biorhythms throughout his/her work. In this regard, a person is periodically in workable and unworkable state. Researchers distinguish a daily alternation cycle of these states. As a result of loadings, after a change of workable state to unworkable one, a person needs rest for restoration.

The failure rate of freight cars due to the human factor during the workable period, consisting of erroneous solutions or actions, in the form almost coincides with the graph shown in Fig. 1.

The work of the inspector or mechanic, as well as the freight car failure rate, can also be divided into three time intervals [7]:

– characterizes the period of operative adaptation of man to the working process after the rest;

– characterizes the basic working process, during which it takes place a smooth, close to linear transition of person`s thermodynamic state from weakly to a highly unbalanced one;

– characterizes a highly unbalanced thermodynamic state as a result of fatigue, in which the body loses its ability to work and goes to rest.

Graphically, daily changes in the failure rate of the inspector`s or mechanic`s body are shown in Fig. 2

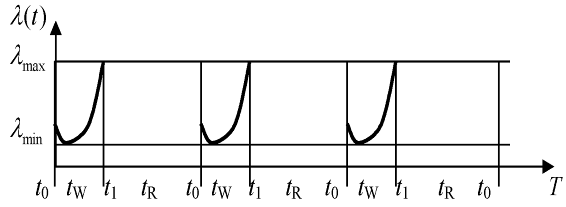

Fig. 2. Dependence of changes in the failure rate of inspector`s or mechanic`s body during the day:
t_W – work; t_R – rest

One can see from the dependence (Figure 2) that during the t_W time in the work of the system «man – freight car» there is a change in the thermodynamic state of the body of inspector or mechanic from a weakly unbalanced at the beginning of work to a highly unbalanced one at the end of it. During the rest t_R in the body of inspector or mechanic there is a complete restoration of its state, and from the beginning of the next day the processes are repeated. From the position of failure rate, the most favourable time of work in most cases is the work that begins in the morning, because before this, during sleep, usually the most complete restoration of all functions of the body occurs. However, the production processes associated with the maintenance of freight cars are around the clock, and inspectors and mechanics who carry out such maintenance tend to work double shifts. In this case the failure rate due to the human factor will correlate with the time of shift. Dependences of daily changes in the failure rate of inspector or mechanic, performing the freight car maintenance in the case of double-shift work, are shown in Fig. 3.

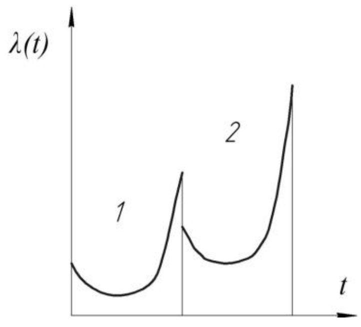

Fig. 3. Dependences of daily changes in the failure rate of inspector or mechanic, performing the freight car maintenance in the case of double-shift work:
$\lambda (t)$ – probability of failure rate;
t – work shifts duration

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The work of inspectors and mechanics in night shift during the freight car maintenance is characterized by significant fatigue, which reaches the maximum value until the end of the shift.

As can be seen from the dependences shown in Fig. 3, the first shift of work is characterized by the minimum failure rate function, the greater one falls to the second shift. The average ratio of the failure rate function is determined by the work conditions of inspector and mechanic, who carry out technical maintenance, technical parameters and operation conditions of freight cars [7, 19].

The value of failure probability associated with the human factor (P_{HF}) can be presented as a proportion of the overall failure probability of the system «man – freight car» in this form:

$$P_{HF} = \sum k_{HF} P_P , \qquad (2)$$

where k_{HF} – is the significance coefficient the human factor affecting the reliability of the freight car during maintenance.

Failure indicators that have occurred under the influence of the human factor are almost the same as reliability indicators of freight cars. Here are the main ones:

– number of failures or violation of organizational and technological processes of freight cars maintenance, caused by negative events associated with the human factor;

– the probability of failure or violation of the organizational and technological process of freight car maintenance at a time interval less than the predetermined P ($T \le t$) caused by a negative event associated with the human factor;

– the failures rate or violation of organizational and technological processes of freight car maintenance due to the human factor;

– time of restoration of the workable state or organizational and technological processes of freight car maintenance after the influence of negative factors that arose as a result of the human factor;

– failure rate function of freight cars caused by negative events related to human factor (number of failures per unit time);

– failure rate function of freight cars, which occurred under the influence of the human factor (the rate of failure per t/km).

In this case, to control the human factor, it is necessary to consider and account the following indicators:

– the probability of negative event associated with human factor potentially capable of causing a freight car failure;

– the probability that in the freight car failure the human factor will not be detected;

– the probability of erroneous attribution of the freight car failure to the human factor cause;

– costs for restoration of the workable state of freight car after the failures that occurred under the influence of human factor.

Let us give one of the possible approaches to evaluating the above-mentioned indicators of the risks of potential freight car failures. We take the probability of occurrence of negative events (risks) and possible economic loss from their manifestation as indicators. By risk, we mean the events identified as probabilistic (stochastic) factors of negative influence on freight cars, causing violations of the maintenance process, reducing the reliability and durability of the structural elements of freight cars, traffic safety, financial and economic losses of the railway.

The probability of risks of freight car failures may serve as a criterion for quantifying additional financial costs for their elimination. In the first approximation of the zone of qualitative risks assessment one can take the generalized Harrington`s desirability functions for the processes of freight car maintenance [12]. The Table 1 shows the interpretation of Harrington's desirability function for the case of application to freight cars.

Table 1

Scale ranges of risk assessment

Desirability	Probability of risk
Unlikely critical risk	1.00–0.80
Expected minor risk	0.80–0.63
Expected moderate risk	0.63–0.37
Possible critical risk	0.37–0.20
Expected critical risk	0.20–0.00

The quantitative assessment of the risk of potential freight car failures is now hampered by the lack of information on the costs necessary for their

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recovery. In the first stage, the assessment of economic losses can be determined expertly.

The maximum economic loss averaged by experts will be determined by the formula:

$$C_i = \sum_{j=1}^{R_{ij}} P_{ij} C_{ij}, \qquad (3)$$

where i – is the certain number of freight car, i = 1, 2, 3 …; P_{ij} – the probability of potential risk for the i-th freight car; j – number of risk type, j = 1, 2, 3 …; C_{ij} – economic damage from the j-th number of the risk type for the i-th freight car.

We can also propose to assess the quality of indicator of the train traffic safety in the form of a coefficient, which will be determined by the ratio of the probability of freight car being in the working condition and the design probability of failure-free operation of freight car at the appropriate time interval [20]:

$$K_{\text{DSI}} = P_{\text{P}} / P_{\text{O}}, \qquad (4)$$

where K_{DSI} – is the coefficient of decrease of traffic safety indicator (failure-free) P_{O} – is the design probability of failure-free operation of a freight car.

In addition, during maintenance and repair, one can enter an indicator characterizing compliance with the technology of carrying out maintenance work for freight cars taking into account the human factor:

$$T_{\text{M}} = \frac{P_{\text{HF}}}{n} \sum_{i=1}^{n} \left(1 - \frac{t_i}{t_{ki}}\right), \qquad (5)$$

where t_i – is the number of violations of the work technology of the i-th maintenance of the freight car; t_{ki} – is the number of parameters and modes of technology, which is controlled during the works of i-th maintenance of freight car; n – is the number of maintenance of freight car.

Then, in order to compare the maintenance and repair of freight cars according to the available technology and technical state, it is possible to obtain an assessment as follows:

$$O_{\text{M}} = \frac{P_{\text{HFexs}}}{P_{\text{HFtc}}} \sum_{i=1}^{n} \frac{\left(1 - \frac{t_{i\text{exs}}}{t_{ki\text{exs}}}\right)}{\left(1 - \frac{t_{i\text{tc}}}{t_{ki\text{tc}}}\right)}, \qquad (6)$$

In the last expression, the indices exs and tc denote the existing maintenance and repair system and according to the technical state.

Then the coefficient (4), taking into account the expression (6), will have the following form:

$$K_{\text{DSI}} = \frac{P_{\text{P}}}{P_{\text{O}}} \frac{P_{\text{HFexs}}}{P_{\text{HFtc}}} \sum_{i=1}^{n} \frac{\left(1 - \frac{t_{i\text{exs}}}{t_{ki\text{exs}}}\right)}{\left(1 - \frac{t_{i\text{tc}}}{t_{ki\text{tc}}}\right)}. \qquad (7)$$

The obtained expression allows assessing the traffic safety level during the transition to the system of maintenance and repair of freight cars according to the technical state [10].

Findings

The available methods of forecasting the influence of the human factor during the analysis of the freight car reliability should include the following stages, which lie in [13, 14]:

– compilation of the lists of basic failures of freight car units;

– compilation of technology works for inspectors and mechanics, and similarly for other involved employees;

– estimating the frequency of human errors during the execution of technological operations;

– determining the effects of the frequency of human errors on the failure rate of the freight car units;

– developing recommendations and making the necessary changes in normative documentation.

The basic method, which takes into account the reliability of human work, can be set by constructing a probability tree (or results). The use of such a method involves some conditional probability associated with the successful or erroneous implementation of a particular technological operation by inspector or mechanic, or the probability associated with the occurrence of the relevant event. In this case, branches or links of the probability tree can represent the result of any event. It is possible to calculate the full probability of successful com-

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pletion of a certain task by summarizing certain probabilities that will be known for the end point of the path (in the case of a successful result) on the probability tree.

In this method, one can consider the factors with some refinements, for example: stress caused by lack of time; a load that determines the need for decision-making and its implementation in different non-standard situations; emotional load, etc.

It should be noted that the application of this method can provide a good visibility, and the mathematical calculations associated with it are quite simple, which also leads to a decrease in the probability of errors that can occur in this case.

In addition, the given method allows us to assess the conditional probability of performance of maintenance and repair work, which otherwise can only be obtained on the basis of solutions of complex equations of undefined nature.

We give an example related to the task performance by inspector or mechanic for the maintenance and repair of freight cars according to the available technology *x* and the technical state *y*. It is known that an inspector or mechanic can perform the task correctly or incorrectly. That is, the tasks performed incorrectly are errors that appear in a particular situation.

In this case, one can construct a tree of possible finals and reach the definition of the overall probability of improper performance of the set task. Then it is necessary to take statically independent probabilities of the task performance *x*, *y* as the basis.

In the tree of possible results, it is necessary to provide the following designations related to:

– probability of successful performance of the task (P_S);

– probability of non-performance of the task (P_F);

– successful performance of the task *s*;

– non-performance of the set task *f*;

– probability of successful performance of the set task *x* (P_x);

– probability of successful performance of the set task *y* (P_y);

– probability of non-performance of the set task *x* (P_{fx});

– probability of non-performance of the set task *y* (P_{fy}).

According to the tree of possible results, the probability of successful performance of the set task will be equal to: $P_S = P_x(P_y)$. Similarly, it is possible to find the probability of non-performance of the set task, which will have the following form: $P_f = 1 - P_x(P_y)$.

From the given formulas and the tree of possible solutions, one can conclude that the only way of successful performance of the complex maintenance and repair task is to perform successfully both tasks – the *x* and *y*. In addition, the above mentioned formulas show that for the probability of correct performance of the complex task there is a definition in the form $P_x(P_y)$.

The assessment of the work reliability, including the human factor (inspectors and mechanics), should be performed taking into account the factors associated with:

– the quality of teaching and practical training;

– the availability of quality instructions that exclude misinterpretation;

– the ergonomics of work stations;

– adequate work environment;

– the degree of independence of the actions of inspector or mechanic;

– psychological stresses.

It should be noted the need for human error databases to analyze and further forecast correctness of the maintenance and repair of freight cars with traffic safety compliance, as well as to prevent dangerous situations.

Such information bases are divided into categories:

– experimental data, including experimental results. However, despite the thoroughness of the formation of such databases, a subjectivity is inherent in them;

– operational data obtained in real operating conditions. Formation of such bases is difficult to implement, since registration of actions must be carried out in different conditions of freight cars` operation. Such databases are characterized by satisfactory results, better than the previous ones;

– subjective data based on expert assessments.

While creating such databases, one can do relatively small financial costs, and obtaining a large amount of information is possible from a small number of interviewed experts.

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To use subjective data in order to analyze the work reliability of inspector or mechanic one needs to bring into compliance:

– the required level of data accuracy;

– the reliability of expert assessments.

Subjective data should come from individuals who are highly skilled and able to cope with such work.

The main advantage of a database with subjective data is the multifaceted coverage of various parameters requiring availability of the information on errors.

We will construct a model of the situation development for the case of critical defect of the freight car unit taking into account the human factor, Fig. 4

At this, the types of technical states of freight cars are as follows:

W – workable;

LW – limited workable;

U – unworkable;

E – emergency;

P_1, P_2, P_3 – are the probabilities of the relevant events.

The developed model shows 3 possible states: workable and limited workable, unworkable and emergency. Each initial state is characterized by the development of events associated with designers` errors, with defects during manufacture of parts and units, with the human factor.

Then the border level of defect in the freight car unit q_0, taking into account the human factor with the limiting of the risk of accident or transport event at the railway, can be determined as follows:

$$q_0 = \frac{P_r(A)}{[P_{\text{D}}P_{\text{HF}}(1-P_{\text{d}}) + P_{\text{d}}P_{\text{HF}}(1-P_{\text{D}}) + P_{\text{D}}P_{\text{d}}(1-P_{\text{HF}})]}, \quad (8)$$

where $P_r(A)$ – is the probability of transition of design, a freight car unit or a technology into a failure state of different gradation.

In this case, the failure probability due to human factor, in the case of improper actions of inspector or mechanic for the maintenance and repair of freight cars, are determined by expression (i = 1, n; j = 1, n; $j \neq i$):

$$P_{\text{OHF}} = P_i \prod_{j=1}^{n} (1 - P_j), \quad (9)$$

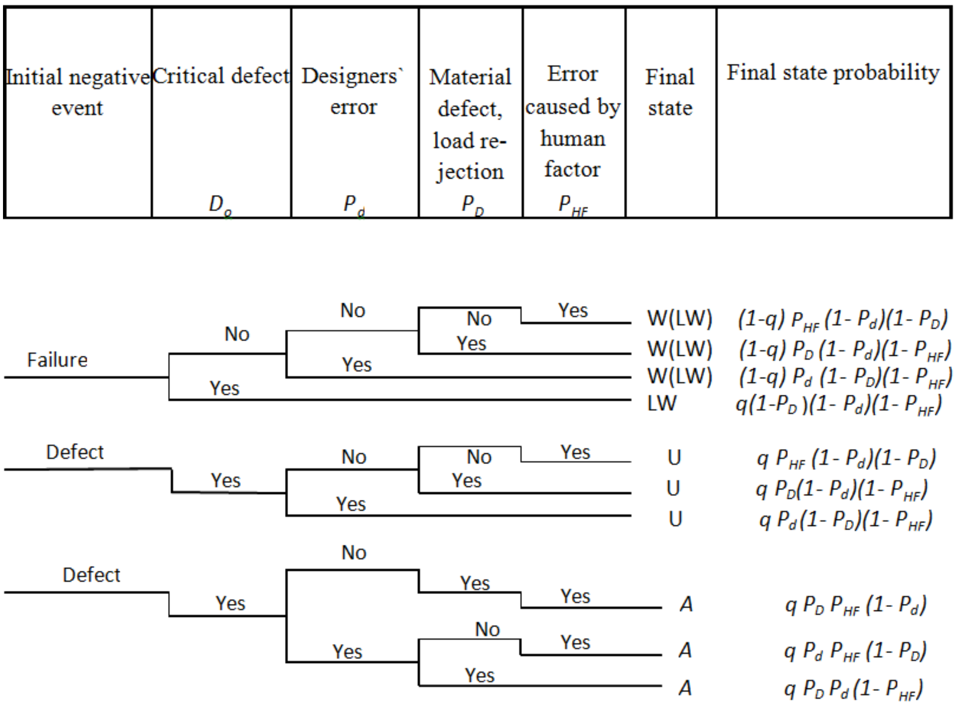

Fig. 4. Model of the situation development for the case of a critical defect of the freight car unit taking into account the human factor

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Originality and practical value

The proposed value of the failure probability, which is related to the human factor, is considered as a certain share of the overall probability of failure of the system «man – freight car». For this purpose, the significance coefficient of the human factor that affects the freight car reliability during the maintenance is introduced. For a qualitative assessment of risks one can take an interpretation of the Harrington's desirability function for the processes of freight car maintenance.

During maintenance and repair, it is proposed to introduce an indicator characterizing compliance with the technology of performing maintenance works for freight cars taking into account the human factor.

According to the developed model of situation development for the case of a critical defect it is possible to determine the border level of deficiency of the freight car unit due to the human factor for limiting the risk of accident or traffic event.

Conclusions

The complexity of modern technical systems increases the probability of errors. The human factor is often interpreted and used during examination of the causes of accidents and transport events that have caused human losses or material damage. On the basis of the conducted research it is possible to estimate the influence of the human factor on the maintenance and repair of freight cars.

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ВПЛИВ ЛЮДСЬКОГО ФАКТОРА НА ВИКОНАННЯ ТЕХНІЧНОГО ОБСЛУГОВУВАННЯ ТА РЕМОНТУ ВАНТАЖНИХ ВАГОНІВ

Мета. У науковій роботі необхідно: 1) дослідити показники й критерії оцінки врахування впливу людського фактора на безвідмовність вантажних вагонів; 2) теоретично описати ймовірнісну модель ролі людського фактора під час виконання технічного обслуговування й ремонту вантажних вагонів за технічним станом; 3) розглянути модель розвитку ситуації для випадку критичного дефекту вузла вантажного вагона з урахуванням людського фактора. **Методика.** Для досягнення поставленої мети дослідження були розглянуті методологічні підходи: 1) до оцінки показників надійності в системі «людина – вантажний вагон» під час виконання технічного обслуговування й ремонту; 2) до оцінки рівня безпеки руху в разі переходу з наявної системи технічного обслуговування й ремонту вантажних вагонів на систему за технічним станом. Описана модель розвитку ситуації для випадку критичного дефекту вузла вантажного вагона з урахуванням людського фактора. **Результати.** Наведено підхід до оцінки показників ризиків потенційних відмов вантажних вагонів. За показники взято ймовірність появи негативних подій (ризиків) і можливий економічний збиток від їх прояву. У розробленій моделі розвитку ситуації для випадку критичного дефекту вузла вантажного вагона з урахуванням людського фактора показано три можливі стани: працездатний та обмежено працездатний, непрацездатний і аварійний. Для кожного вихідного стану характерний розвиток подій, що пов’язаний із помилками проектувальників, із дефектами під час виготовлення деталей та вузлів, із людським фактором. **Наукова новизна.** Запропоновано величину ймовірності відмов, що пов’язана з людським фактором, розглядати як певну частку загальної імовірності відмов системи «людина – вантажний вагон». Наведена інтерпретація функції бажаності Харрінгтона для випадку застосування до вантажних вагонів. Під час проведення технічного обслуговування й ремонту запропоновано ввести показник, що характеризує дотримання технології використання робіт із технічного обслуговування вантажних вагонів з урахуванням людського фактора. **Практична значимість.** На основі проведеного дослідження можна оцінити вплив

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людського фактора на виконання технічного обслуговування та ремонту вантажних вагонів. За розробленою моделлю розвитку ситуації для випадку критичного дефекту можна визначити граничний рівень дефектності вузла вантажного вагона з урахуванням людського фактора для обмеження ризику аварії чи транспортної події.

Ключові слова: вантажний вагон; надійність; людський фактор; критичний дефект; технічне обслуговування; ремонт

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ВЛИЯНИЕ ЧЕЛОВЕЧЕСКОГО ФАКТОРА НА ВЫПОЛНЕНИЕ ТЕХНИЧЕСКОГО ОБСЛУЖИВАНИЯ И РЕМОНТА ГРУЗОВЫХ ВАГОНОВ

Цель. В научной работе необходимо: 1) исследовать показатели и критерии оценки учета влияния человеческого фактора на безотказность грузовых вагонов; 2) теоретически описать вероятностную модель роли человеческого фактора при выполнении технического обслуживания и ремонта грузовых вагонов по техническому состоянию; 3) рассмотреть модель развития ситуации для случая критического дефекта узла грузового вагона с учетом человеческого фактора. **Методика.** Для достижения поставленной цели исследования были рассмотрены методологические подходы: 1) к оценке показателей надежности в системе «человек – грузовой вагон» при выполнении технического обслуживания и ремонта; 2) к оценке уровня безопасности движения при переходе от действующей системы технического обслуживания и ремонта грузовых вагонов на систему по техническому состоянию. Описана модель развития ситуации для случая критического дефекта узла грузового вагона с учетом человеческого фактора. **Результаты.** Приведен подход к оценке показателей рисков потенциальных отказов грузовых вагонов. В качестве показателей приняты вероятность появления негативных событий (рисков) и возможный экономический ущерб от их проявления. В разработанной модели развития ситуации для случая критического дефекта узла грузового вагона с учетом человеческого фактора показаны три возможных состояния: работоспособное и ограничено работоспособное, неработоспособное и аварийное. Для каждого исходного состояния характерно развитие событий, связанное с ошибками проектировщиков, с дефектами при изготовлении деталей и узлов, с человеческим фактором. **Научная новизна**. Предложено величину вероятности отказов, связанных с человеческим фактором, рассматривать как определенную долю общей вероятности отказов системы «человек – грузовой вагон». Приведена интерпретация функции желательности Харрингтона для случая применения к грузовым вагонам. При проведении технического обслуживания и ремонта предложено ввести показатель, характеризующий соблюдение технологии проведения работ по техническому обслуживанию грузовых вагонов с учетом человеческого фактора. **Практическая значимость.** На основании проведенного исследования можно оценить влияние человеческого фактора на выполнение технического обслуживания и ремонта грузовых вагонов. По разработанной модели развития ситуации для случая критического дефекта можно определить предельный уровень дефектности узла грузового вагона с учетом человеческого фактора для ограничения риска аварии или транспортного происшествия.

Ключевые слова: грузовой вагон; надежность; человеческий фактор; критический дефект; техническое обслуживание; ремонт

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