в виде последовательной структуры (рис.5):

Опираясь на метод путей и сечений, получаем выражение для определения безотказной работы буксового узла в наугад взятый момент времени [3]:

$$h(p)=\prod_{i=1}^{n} p_i =$$

$$[1-(1-p)_1(1-p_2)(1-p_3)(1-p_4)]$$

$$(1-(1-p_5)(1-p_6)$$

$$(1-p_7(1-p_{8..})p_9 p_{10} p_{11...} p_{34} p_{35} p_{36}.$$

ЗАКЛЮЧЕНИЕ

Показан метод моделирования надежности (построения дерева событий), позволяющий определить характер отказов буксового узла грузового вагона – их независимость и одновременная взаимосвязанность.

Этот способ реализует дедуктивный метод (причина – следствие), что наделяет его самыми серьезными возможностями при поиске корневых причин событий для статичных систем, поскольку дает наглядную и подробную схему взаимосвязей элементов конструкций и событий, влияющих на их надежность.

Рассмотренный алгоритм количественной оценки надежности буксового узла является доступным средством изучения важнейшей проблемы – количественного и качественного анализа системы. Выведенное соотношение для определения безотказной работы буксового узла позволяет увязать факторы ее влияния на показатели качества эксплуатации вагона. Продолжение исследований предполагает оптимизировать межремонтные пробеги в пределах определенного цикла; уточнить потребности в ремонте в течение интересующего срока с учетом критериев безопасности, которые зависят, в частности, от величины пробега между глубокими диагностиками

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RELIABILITY ANALYSIS OF THE JOURNAL-BOX: EVENT TREE CONSTRUCTION

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ABSTRACT

To work out measures related to improving safety, reliability and operating availability of cars, it is necessary to have a model that could be used in calculating the parameters of the MaR system (maintenance and repair). Special reliability index characterizing the probability of failure-free operation will be able to play its role in such a model. In the present article the author analyzes the causes of failures of freight cars axle equipment, shows an algorithm for constructing the tree of events that precede them, the transition from the tree-type structure of events description to the matrix one. Mathematically expressed rationale for determining failure-free operation of axle equipment was obtained with the help of paths and cross- sections method.

ENGLISH SUMMARY

Background and methods. *To achieve effective organization of maintenance and repair (MaR) of cars, reliability model, which could prove the system parameters and estimate the probability of failure-free operation, is required. However, obtaining such a model is a technical challenge, as the freight car axle equipment has rigidly interdependent elements. It is necessary to identify their connections, wherein in the system of two types: element-element and element-system. Event tree method in combination with the method of minimum cross-sections allows solving the problem.*

Objective. *The author's goal is to offer a model that can be used for calculating of parameters of maintenance and repair system concerning axle-related failures of rail cars.*

Results. *The author gives the data on causes of freight cars failures. 33% of failures occur in axle equipment (Pic.1). The main reasons are: (Pic. 2):*

- *weakening of the mechanical fastening – 22%;*
- *defects of bearings– 18%;*
- *damage to the rubber cushion – 18%;*
- *scoring of labyrinth rings – 18%*
- *wrong rollers in length and diameter – 8%;*
- *defects of lubricants (watering, polluting) – 4%;*
- *breaking of spacing ring – 4%*
- *wrong selection of bearings with radial clearance – 4%;*
- *crack in nylon separator – 4%.*

In the article the author focuses on the axle equipment with roller bearings.

$$\begin{pmatrix} A \\ B \\ C \\ D \\ E \\ F \\ G \end{pmatrix} \to \begin{pmatrix} 1,2,3,4 \\ B \\ C \\ D \\ E \\ F \\ G \end{pmatrix} \to \begin{pmatrix} 1,2,3,4 \\ 5,6,7,8 \\ C \\ D \\ E \\ F \\ G \end{pmatrix} \to \begin{pmatrix} 1,2,3,4 \\ 5,6,7,8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ D \\ E \\ F \\ G \end{pmatrix} \to \ldots \to \begin{pmatrix} 1,2,3,4 \\ 5,6,7,8 \\ 9 \\ 10 \\ 11 \\ 12 \\ 13 \\ 14 \\ 15 \\ 16 \\ 17 \\ 18 \\ 19 \\ 20 \\ \ldots \\ \ldots \\ \ldots \\ 36 \end{pmatrix} \quad (1)$$

Reliability means an ability of an object to keep through time within the established limits values of all parameters characterizing the readiness to carry out the functions required in set modes and conditions of application, maintenance, repair, storage and transportation. Moreover, reliability is a complex parameter, which includes failure-free operation, service life, maintainability, and persistence. Failure of an object is a random event, which means transition from operable to nonoperable state.

Operational condition of an object means its compliance with all requirements of technical and (or) design documentation. Faultfinding and restoring of axle equipment to working condition are carried out during maintenance and repair of cars.

The main problem for axle equipment is the fact that most of the elements are located within the housing, have zero testability during maintenance operation and can be diagnosed only in the depot. Bearings failures lead to a rapid dump of axle journal and derailment.

The author describes the procedure of facilitated reliability evaluation. In this process axle box is considered as a system of 21 series- parallel connected elements: axle box body, labyrinth ring, rear bearing, front bearing, main cover, 6 screws, 6 washers, inspection cover, rubber cushion, cup nut, locking plate. However, axle equipment belongs to the systems with a combined structure, i. e. it has subsystems with linked structure.

In systems with rigidly connected structure even slight variations in characteristics of individual elements may negatively affect the operable state of the whole system.

The author states that the event tree method is used for more in-depth analysis of the technical structure of the real technical system. He describes in detail the principle of event tree construction for description of axle box failures. Top event T is moment of rollers transition from rolling friction mode to sliding friction mode (with heating process, shift of the axle box etc.). (Pic. 3 shows top event dissolution). T event is controlled directly by the operator «OR», scheme coincides with the operation $\cup$. *By subsequent dissolution of A and B events (operator «AND»), the scheme coincides with the operation* $\cap$ *[3]. By considering each of the events A-G we'll obtain the scheme shown in Pic.4.*

List of indissoluble (elementary) events has a matrix structure. Top events and intermediate events are controlled by the operator «OR»(the columns in matrix), intermediate events are controlled by the operator «AND» (rows in the matrix, elementary events of intermediate events branches are enumerated) (1).

Eventually, there is a matrix with 36 rows (each is a minimum cross- section). It makes possible to represent an event tree as a chain structure (see Pic.5).

At the end the author, using the method of paths and cross-sections, gives a formula for axle equipment failure- free operation determination at a random moment:

$$h(p) = \prod_{i=1}^{n} p_i =$$
$$[1-(1-p)_1(1-p_2)(1-p_3)(1-p_4)]$$
$$(1-(1-p_5)(1-p_6))$$
$$(1-p_7(1-p_{8..})p_9 p_{10} p_{11...} p_{34} p_{35} p_{36}.$$

Conclusions

The described reliability modeling method (event tree construction) implements the deductive approach (cause – effect) that gives it the most serious opportunities in search for the root causes of events for static systems, since it provides a visual and detailed scheme of relationships of structural elements and events that affect their reliability.

Analyzed algorithm for quantitative assessment of axle equipment reliability is an available tool for studying the most important problem – the quantitative and qualitative analysis of the system. Derived relationship to determine axle equipment failure-free operation harmonizes its influence factors on cars performance index. Further research aims at overhaul life optimization within a certain cycle; specification of the needs for repairs during the period of interest, taking into account the criteria of safety, which depend, in particular, on the running distance between deep diagnostics.

Keywords: *railway, freight car, axle box, failure, reliability, event tree, method of paths and cross-sections.*

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