ЭКСПОНЕНЦИАЛЬНЫЙ ЗАКОН

Наряду с нормальным распределением большое распространение имеет экспоненциальный (показательный) закон распределения, особенно в задачах управления надежностью [2].

Случайная величина x имеет показательный закон распределения с параметром λ, если ее плотность вероятности *f (x)* для *x> 0* имеет вид:

$$f(x) = \lambda e^{-\lambda x}. \qquad (7)$$

а закон распределения:

$$F(x) = 1 - e^{-\lambda x}.F(x) = 1 - e^{-\lambda x}. \qquad (8)$$

При этом среднее значение μ (математическое ожидание) определяется по формуле:

$$\mu = \frac{1}{\lambda}. \qquad (9)$$

Приведем пример. Если оборудование отказывает в среднем раз в 5 месяцев, то λ = 12/5 = 2,4, а распределение будет соответствовать графику на рис.6. Тогда вероятность того, что оборудование откажет в течение месяца, будет:

$$Q_1 = 1 - e^{-\lambda x} = 1 - e^{-2,4\cdot\frac{1}{12}} = 0,18 \qquad (10)$$

а за год:

$$Q_{год} = 1 - e^{-2,4\cdot 1} = 0,91\,. \qquad (11)$$

Применительно к тяговому подвижному составу принято брать распределение величины не во времени, а в пробеге. Тогда по оси абсцисс будет отложено не время, а километры (10 тыс. км, млн км и др.).

ВЫВОДЫ

По мнению автора, создание АСУНТ позволит на практике использовать математические и логические методы теории надежности и управления качеством в режиме on-line непосредственно на рабочих местах руководителей и специалистов железнодорожного транспорта. При этом «сложная математика» будет «зашита» в программу, и конечный пользователь системы сможет извлекать из накопленной статистики (по проблемам и инцидентам) всю интересующую его информацию в обработанном по всем правилам статистики виде.

Представленные материалы помогут получить на выходе конечного информационно-аналитического продукта возможность значительно повысить надежность тягового подвижного состава железных дорог России за счет реализации передовых научно-технических методов.

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RELIABILITY CRITERIA OF DIESEL-ELECTRIC LOCOMOTIVES

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ABSTRACT

In the article the author assesses the impact of current reform of Russian railways on locomotive complex, where dramatic changes occur. The most challenging of them is shifting locomotive park service functions to private service organizations. In line with the prevailing trends, the author describes his groundwork (block diagram and aspects of work) to create an Automatical system of locomotive set reliability control (ASUNT). Simultaneously, criteria important for system building of service maintenance and monitoring of technical state of rolling stock are justified. In the analysis mathematical techniques are used, theoretical and methodological materials, quality management standards are reflected.

ENGLISH SUMMARY

Background

Permanent and mandatory task of locomotive economy on railways is bringing technical indicators of traction rolling stock to specification requirements and reducing the number of failures, as well as reducing the time to eliminate them. The main technical tools for improving the coefficient of availability and reliability of locomotives are monitoring compliance with technology maintenance and repair, improvement *of logistics maintenance companies, monitoring of technical state of rolling stock by means of on-board and permanent-type diagnostics.*

Objective.

The purpose of the author is to demonstrate various aspects of creation of automated locomotives reliability control system with the use of mathematical approach and to justify relevant criteria, important for service maintenance and monitoring of rolling stock technical state.

Methods.

Introduction of methods of mathematical analysis and statistics in monitoring allows forming trends and using them to predict, with considerable accuracy, further development of this or that situation. In general, reliability control helps to combine the advantages of preventive maintenance system and the possibility of a rapid response to events by making fuller use of information obtained in the course of on-board diagnostics.

Results.

To control the reliability at JSC «Russian Railways» an information system of facilities failures accounting «KASANT» has been created. It uses the concept of «failure criterion» – feature or combination of features of violations of operable state of the object, set out in technical and (or) design documentation. Criticality of failure is defined as a set of features that characterize the consequences of failure. Violations of safety in train and shunting work have been classified earlier as train wrecks; accident; special cases of defects; cases of defects. Failure in accordance with State standard 27.002–89 refers to an event entailing violation of operable state of the object. There is a certain classification of failures – performance, production, design, degradation, etc., as well as categories of failures.

Depending on the consequences, failures are divided into categories:

1st category failure leads to delay of passenger or commuter train for 6 minutes or more, freight trains on station-to-station block (station) for 1 hour or more, or alleged violations of safety in train or shunting operations.

2nd category failure leads to a delay of freight trains on station-to-station block (station), with duration from 6 minutes to 1 hour, or when the impacts affected the performance indicators, except train delays relating to 1st category failures.

3d category failure does not lead to the consequences relating to 1st and 2nd category failures; failure accounting is made under automated locomotive sector control systems.

Failure criterion in the locomotive sector is any of the following events:

– Failure to comply with the train schedule (weight, speed);

– Restoration of operable state of the locomotive (its assembly units and parts) by locomotive crew in transit without disrupting train schedule;

– Need to perform unplanned maintenance;

– Excess of the established scope of work (restoration, replacement, adjustment) of any locomotive assembly unit during routine maintenance or repairs, causing excess of free time standard or complexity of repair locomotives, if this restoration, replacement and adjustment is not included in the scope of compulsory work. [3]

Using information from KASANT is desirable, but it should be noted that the notion of failure is not considered as a major indicator in the reliability control system, because it very inaccurately reflects its impact on the transportation process.

Therefore, basic indicators in locomotive economy reliability control system should be: technical readiness coefficient (TRC), lost train- hours, delay of trains, idle hours on different types of simple repairs, the cost of operable state restoration, etc.

To control the reliability of locomotives it is offered to apply standard ITIL (ISO20000), used in particular in the development of a unified system of monitoring and administration (USMA) of holding communication network (developer is JSC «Transset» from Nizhny Novgorod). As a software environment is used a set of programs of automated reliability control system in the locomotive sector (ASUT) (developer is JSC «Infocom») [4].

<u>Incident Management.</u> Each incident must be fixed by Unified monitoring system of locomotives technical state (UMST), which is created by TMH Service. Basing on the information of incident's lifecycle, an analysis of the causes is made, rooted system problems are detected and eliminated, to minimize the consequences of an incident.

<u>Problems Management.</u> It is performed in the automated reliability control system in the locomotive sector as statistical and analytical superstructure above incident management system. It is a set of algorithms that allow analyzing the data collected in the course of the incidents management.

It includes trends analysis and monitoring of known faults with the expectation of eliminating their sources in the long term. As for locomotives, it provides comprehensive factorial approach to incident information, identifying and eliminating neck stages and costly stages in technological process [1].

The author is involved in the development of automated reliability control system in the locomotive sector, which will be introduced in LLC «TMH–Service». The challenge is mathematical and algorithmic accompanying of the system, implementation of standards requirements of JSC «Russian Railways» in the field of quality and reliability, debugging information technology.

The underlying principle of the locomotive reliability control system is continuous improvement. This principle is fixed in the international quality standard ISO 9000, the national state standard R ISO 9000–2001, and functional strategy of quality and safety management of JSC «Russian Railways» [3].

Taking into account the problem of ASUNT creation and demonstrable progress of ASUZHT information systems (generic name for combined software used in railway transport, especially ASUT) the author developed a block diagram (Pic. 1) and the conceptual approach to the formation of ASUNT:

1. It is proposed to create local systems for monitoring the technical condition of locomotives with use of onboard microprocessors.

2. It is planned to develop together with «AVP Technology» preliminary design of ASUNT software – a unified system of monitoring the technical condition of locomotives (USMT), which will allow to implement reliability control using methodological approaches of ITIL and ISO20000 standards, as well as all standards of Russia and JSC «Russian Railways» in the field of reliability and quality of service maintenance.

3. It is planned to control reliability on the basis of information management system USMT in MDI mode. Its functionality is gradually developing, and its coverage is expanding.

4. On the information base of USMT, a system of statistical factor analysis is created with representation of the processed information in the form of tables and visual elements (graphs, histograms, etc.).

5. Debugging of automated workplaces is carried out for obtaining diagnostic data from microprocessor locomotives control systems (ARM ISU), the technology of interaction with automated diagnostic systems (ASTD) – microprocessor and computer, stationary and portable is created.

6. Used components are united into a single automated locomotives reliability control system. [5]

The method of Z-graphics is useful for monitoring trends in the process development at stage of projects efficiency analysis and identification the need for innovations. Pic. 2 shows an example of a Z- graph.

Graphical representation of information allows visually determining whether there are regularities. The main task of Z- graphs is to identify a trend. If there is a need, the range of variability at the end of the studied time period is assessed.

Values of indicators are different at different points of time, since any indicator is influenced by factors, varying in time. Differences are always present.

The range of variability reflects the extent to which, with high likelihood, there will be the value of moving sums and the total value of the index for the year if the system of factors, influencing an indicator, on the average will not change. Moreover, the likelihood that the moving sum value will lie above (below) the middle of this range is equal to 0.5. The probability of getting certain values, when approaching the limits of this range, decreases. In order to obtain with high probability values outside this range, the system of influencing factors should be amended. There are certain steps:

– To determine the min and max of the obtained data.

– To determine the arithmetic average with the formula (1); sample standard deviation with (2); the range of variability with (3) (where k is usually taken equal to 2).

Z-graph helps to track the dynamics of failures, including locomotive complex (Pic. 3) [6].

Besides Z-graphics, so-called normal law is applied.

Histograms can clearly demonstrate the nature of the distribution of the random variable; visually evaluate the representativeness of the sample. Histograms are useful at all stages of the data analysis.

At JSC «Russian Railways» core indicators are not checked on the law of the random variable (Pic. 4).

For a more precise analysis, raw data should be checked for compliance with one of the laws of the random variable. Central among them is a normal distribution or Gaussian distribution.

To estimate the parameter, not a single value x_i, but a sample of n values (sample size) should be taken. The average value of μ (mathematical expectation) is defined by the formula (4) [2].

Evaluation of index dispersion around the average value is estimated with rms deviation σ. See (5).

If the distribution is normal, then it will have the following distribution function of the random variable f (x). See (6).

Pic. 5 shows an example of statistical data obtained from the locomotive depot Tynda of Far Eastern traction Directorate 2011 by unplanned repairs of locomotives (due to faulty cylinder-piston group) 2TE10M series with diesel type 10D100.

Along with the normal distribution, a large spread has an exponential distribution law, especially in problems of reliability management [2].

The random variable x has exponential distribution law with parameter λ, if its probability density f (x) for x> 0 has the form (7) and the distribution law (8).

The average value of μ (mathematical expectation) is determined by the formula (9).

Conclusion.

According to the author, creation of ASUNT will make it possible to use in practice mathematical and logical methods of reliability theory and quality management in the on-line mode directly at the workplaces of managers and railway specialists. The «complex math» will be «sewn» into the program, and the end user of the system can remove from the accumulated statistics (on problems and incidents) all the interesting information in the processed, according to the rules of statistics, form.

Submitted materials will help to get at the output a final marketing product to significantly improve the reliability of traction rolling stock of railways of Russia through the implementation of advanced scientific and technical methods.

Keywords: railway, reliability of locomotives, locomotive economy, failure, technical readiness coefficient, monitoring, service maintenance.

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