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STATISTICAL ESTIMATION OF MEAN TIME TO FAILURE OF GONDOLA CARS BETWEEN REPAIRS

The paper presents the statistical processing of data on a car's time to failure. During the experiment it was found out that time to failure of such car units as wheel pairs, bodies and bogies complies with a normal distribution law. Numerical values of distribution parameters have been calculated.

Keywords: *reliability, mean time to failure (MTTF), freight car, distribution law.*

Provision of high efficiency and safety in use of freight cars is vital for the economy as it is one of the key directions of the country's economic development. Thus, for example, in the context of mass operations, even inconsiderable decrease of expenditures on a car's periodic repair can result in substantial saving of financial resources. And vice versa, in the context of high industrial competition, any albeit inconsiderable increase of such expenditures can lead to losing the inner and international market of transport services and, consequently, to substantial financial losses.

In order that a particular technical facility can be efficiently and safely used as intended, the system of technical maintenance has to permanently support it in good state available for operation. This process is usually called as management of a technical facility's state. One of the methodological provisions, which many research works are based on, is an assumption that if each technical facility's state is separately managed in an efficient way within the system of technical maintenance, the system of technical maintenance as a whole will be efficient.

The system of technical maintenance and repair of freight cars provide for the following types of periodic repairs and technical maintenance:

– technical maintenance en route TM (technical maintenance);
– actual decoupling repair in the volume of AR-1 (actual repair);
– actual decoupling repair in the volume of AR -2;
– depot repair DR;
– capital repair CR;
– capital repair with prolongation of lifetime CRP.

For freight cars one uses a combined criterion of periodicity of scheduled repairing, which takes into account the volume of works actually done by a car and calendar duration of its use from its construction or scheduled repair. At present for the main types of freight cars the resource between scheduled repairs is equal to 160 thousand km, and the calendar duration between repairs is 2 years.

A car is a complex system of interconnected units, parts and components. The longevity and efficiency of its use to much extent depends on the resource put during the designing and manufacturing of a car. In the process of use the imbedded resource is gradually spent –the efficiency of a car's operation decreases, tears and wears increase, corrosion and fatigue damages become stronger as the time goes.

The information about the technical state of a fleet (sample) of freight cars can go from data of commercial operation or bench testing. The most promising and efficient one is the first way of getting information. In the conditions of centralized accounting of cars by their numbers made by the Main Computing Centre (GVC), we can consider commercial operation itself as a kind of bench for testing the reliability of car constructions [1]. Therefore, results of such operational testing should be treated as feedback in management of the process of improving their constructions.

The methodology of calculating numerical parameters of the reliability of facilties based on statistical data about failures during testing or in operation assumes adopting one or another theoretical model of failures (function of time to failure distribution) and defining parameters of this distribution function. If the function of distribution is specified and the parameters of this function are defined, then we calculate all the required indices of the reliability of these facilities (mean time to failure, gamma-percentage operating time to failure, probability of failure-free operation for specified time to failure, residual resource).

According to GOST 27.002-89 [2], time to failure is the operating time of a facility from the start of operation till emergence of the first failure. Mean time to failure of a freight car has to be understood as the mathematical expectation of its time to failure from the moment of completion of scheduled repair (or construction) till the first decoupling of a car for actual repairing.

Mean time to failure of a freight car is an important parameter, which in its turn shows the quality level of scheduled repairs execution as well as the level of the operational reliability of a car on the whole and its separate construction elements. Naturally, the problem of defining the law of distribution of time to failure (identifying, so to say, the mathematical nature of a random value) of a car between repairs and its basic numerical characteristics is vital for the transport science as well as of interest for the industry.

It is the problem that the authors faced. At the of the Zabaykalsk railway the service of cars and the Zabaykalsk Institute of Railway Transport carried out an experiment for defining mean time to failure of freight cars. It helped to get a mass of data on numbers of failures and times to failure of cars till the first decoupling for actual repairing. The basic conditions of the experiment are presented below.

Condition 1. The plan of observations for reliability testing was adopted [NUN] – in compliance with which N of products has to be put under observation; observations are made till failure of all products; with emergence of failure, a failed product is not replaced by a new one.

Condition 2. As regards the type of rolling stock, gondola cars were chosen for under-control operation. 8645 gondola cars were put under observation.

Condition 3. As per elements of car construction, failures were divided into six groups: wheel pairs, box unit, bogies, automatic coupling device, breaking device, body and frames. Observations were made till the first decoupling of a freight car for actual repair after the scheduled overhaul.

The results of the experiment as per number of failures in relation to construction components are presented in Table 1.

Table 1. Number of failures of gondola cars as per construction elements

Failed unit	Number of failures	Sample share
Wheel pairs	1565	18%
Box unit	996	12%
Bogie	2421	28%
Automatic coupling device	240	3%
Braking equipment	462	5%
Body and frame	2961	34%
TOTAL	8645	100%

Table 1 shows that the biggest number of failures is recorded for wheel cars, bogies, body and frames. The obtained data were enough to do the approximation of the experimental data, to define a law of random value distribution and its numerical characteristics (Table 2).

Fig. 1 – 3 show the histograms of distribution of times to failure of gondola car elements as compared to theoretical

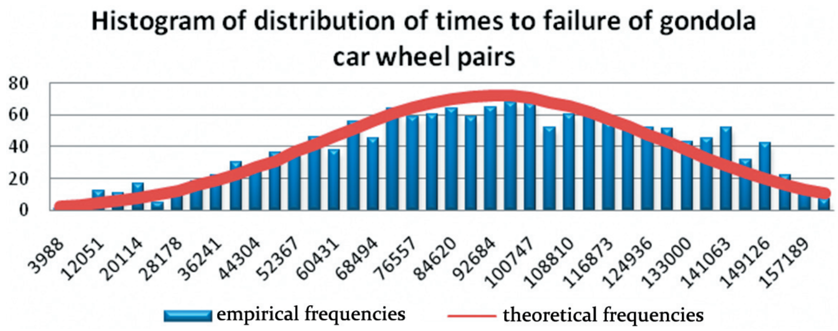

Fig. 1. Histogram of distribution of times to failure of gondola car wheel pairs

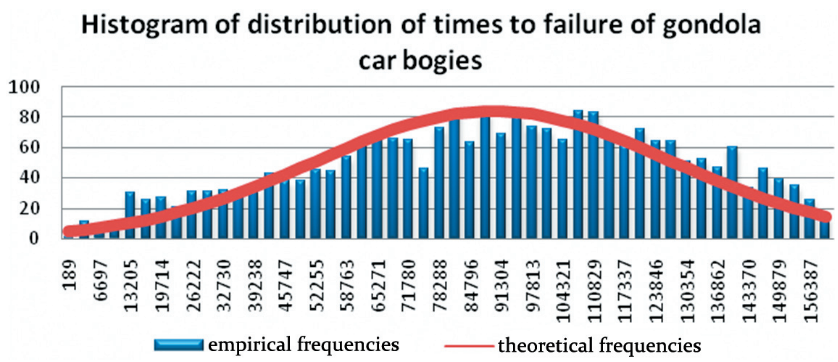

Fig. 2. Histogram of distribution of times to failure of gondola car bogies

Table 2. Results of fitting of times to failure of a gondola car to a normal distribution law

Title	Construction element			
	Wheels	Bogies	Body and frame	Car
Time to failure distribution law	Normal			
Density of probabilities	$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\bar{x})^2}{2\sigma^2}}$			
Distribution parameters (mathematical expectation, mean square deviation)	$\begin{cases} \bar{x} = 93072 \\ \sigma = 34904 \end{cases}$	$\begin{cases} \bar{x} = 89723 \\ \sigma = 37334 \end{cases}$	$\begin{cases} \bar{x} = 79890 \\ \sigma = 36605 \end{cases}$	$\begin{cases} \bar{x} = 84934 \\ \sigma = 38151 \end{cases}$

curves, which visualize the closeness of the distribution of experimental data to the a normal distribution law. The hypothesis that the distribution of time to failure of a car complies with a normal distribution law was confirmed during calculations by the Pearson criterion.

Due to a small number of car failures as regards automatic coupling and breaking equipment, as well as due to the specifics of box units repairing (possibility of making preliminary audits during scheduled repairs) it does not seem possible to identify a law of time to failure distribution for these construction elements, though data in this field is constantly being gathered. Yet it is statistically proven that on the whole time to failure for all the car construction elements also obeys to a normal distribution law (fig. 4).

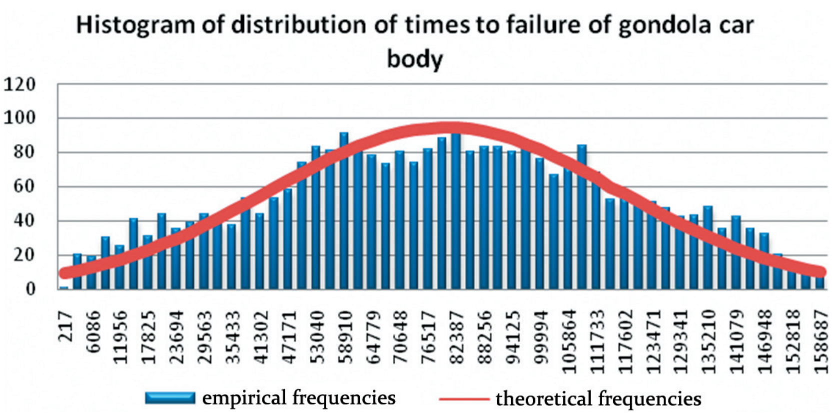

Fig. 3. Histogram of distribution of times to failure of gondola car body

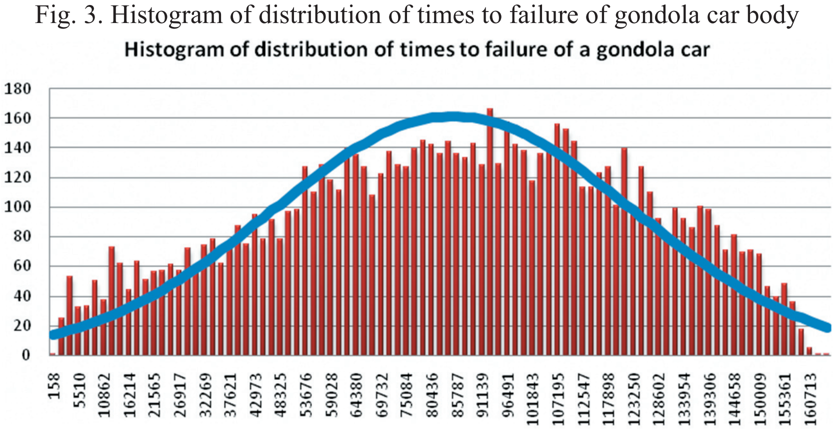

Fig. 4. Histogram of distribution of times to failure of a gondola car

Failure-free operation depends on a number of factors, some of them can be controlled and others are specified with some degree of uncertainty. Failure-free operation of a particular car depends on the quality of raw material and components, the achieved level of technology and the degree of technological process stability, the level of technological discipline, meeting all the requirements for intended use of a facility. The above listed factors influencing the availability of a car's components define its availability as a whole.

The research shows that time to failure has a substantial statistical dispersion. This dispersion serves as a kind of characteristic of technological culture and discipline as well as the achieved level of technology of repairing enterprises. The variance of time to the first failure can be reduced and its value can be increased by enhancing the quality of repairing, using advanced technologies, strictly observing the requirements of repairing documents, individual operational acceptance of each car after repair. Such approach is generally made for especially vital facilities (for example, aviation equipment).

The results of statistical calculations show that mean time to failure of a gondola car (as a whole) is equal to 84934 km at present. And as the practice shows, this event can be considered as practically reliable, i.e. as such that is due to happen. It should be also noted that the existing system of technical maintenance and repair as well as the quality level of scheduled repairs don't provide failure-free operation of rolling stock between repairs.

References

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