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# Assessment of the reliability of the locomotive based on statistical methods of quality management

**N K Kazantseva, E P Kharlamov, G A Tkachuk, T V Kazantseva**

Department of metrology, standardization and certification, Federal State Autonomous Educational Institution of Higher Education «Ural Federal University named after the first President of Russia B.N.Yeltsin», 620002, 19 Mira street, Ekaterinburg, Russia

**Abstract** The lack of reliability of the diesel locomotive operation leads to a decrease in the technical and economic efficiency of using the locomotive service of the enterprise. During the experiment which aimed at assessing the reliability of repair and maintenance of a diesel locomotive in one of the railway divisions of OJSC “Russian Railways”, it was found that the failures may be distributed by types of equipment, based on the failures for 12 months of 2017. Statistical quality management methods were used to identify the most problematic types of locomotive equipment and specific causes of failures.

## 1. Introduction

The quality of the technological equipment used is one of the most important criteria determining the stability of an enterprise, its image and economic efficiency of performance. Railway transport is of particular importance for the development of the Russian economy, since it provides transportation of passengers and cargo throughout the vast territory of Russia [10-12]. A diesel locomotive is an autonomous locomotive, which represents an important element of the process equipment used by “Russian Railways” JSC (JSC RZD).

## 2. The relevance and significance of the research

The performance of a diesel locomotive as a technical system designed for the haulage of train is assessed by many technical indicators: power, speed, traction effort, fuel and electricity consumption, oil consumption, as well as such an important operational indicator as the reliability of a diesel locomotive.

Insufficient reliability can lead to a decrease in the technical and economic efficiency of the entire locomotive service and an increase in the cost of transportation work, the need to perform unscheduled repairs because of failures of individual equipment, assemblies and parts of the locomotive.

From the point of view of the theory of reliability, any technical object (system, device, element) can be characterized by its properties, technical condition and adaptability to recovery after the loss of working capacity [1, 13, 18]. The industry standard OST 32.46-95 provides the definition for the concept of "reliability" in relation to locomotives. For diesel locomotives, the main required function is the performance of operational work (according to the regulated purpose) with those properties which are set by the specifications, while ensuring traffic safety [2, 14, 20].

It should be noted that the operating conditions of the traction rolling stock are constantly becoming more complicated depending on the tonnage rating and the overhaul life, which obliges JSC RZD to switch to locomotive maintenance, oriented towards reliability and safety. This approach is based on risk assessment and statistical methods of quality management [3, 17].

Safety and reliability measures of railway transport are regulated in such a way that the indicators of the accident rate of the infrastructure of JSC RZD should not exceed the established parameters of the Transport Strategy until 2030 [4, 15, 19].

Evaluation of the consequences of heavy traffic accidents on the railway revealed that the cause of accidents, collisions and derailments lies in the failures and defects that were not fixed and eliminated on time. Therefore, a method of forecasting and evaluating railway reliability is necessary to guarantee reliable operation of all equipment used on the railway.

## 3. Research design

In compliance with a comprehensive programme of the reorganization and development of national locomotive-car building, organization of repair and operation of passenger and freight rolling stock, a basic locomotive depot for repairing diesel locomotives in one of the JSC RZD divisions was determined. The main goal of this project is the organization of midlife and routine repair of diesel locomotives TR-3 based on the widespread introduction of mechanization and automation of technological processes, technical diagnostics and non-destructive testing tools, upgrading workplaces to modern sanitary and aesthetic requirements.

During the experiment on repair and maintenance of diesel locomotives, based on the results of diagnostics in the base locomotive depot, such developments as the KIPARIS intelligent industrial automated rheostat testing of diesel locomotives and the KASANT technical diagnostics system were used.

## 4. Theoretical part

Modern approaches to quality management imply the introduction of monitoring systems for the quality indicators of objects at all stages of the life cycle. There are various methods of quality control of objects, one of which is a statistical method. To analyze the results obtained using the KIPARIS test complex and the KASANT system of technical diagnostics, it is advisable to apply statistical methods of quality management methods. The random nature of the processes is due to the influence of a large number of different, sometimes insignificant, factors and conditions, as well as their interaction [5,6]. Considering the quality problem as a result of the malfunctioning of a certain system, one can attribute the changeability in functioning of the system to the effects of random factors and conditions and investigate this system using statistical methods [7, 16]. One of the statistical methods of quality management is the Pareto chart [8,9].

The Pareto chart is used in identifying the causes and factors affecting the effectiveness of quality management. Pareto showed that in most cases the inconsistencies and the losses associated with them arise from a relatively small number of reasons. This method is used when it is required to present the relative importance of all identified nonconformities in order to take priority measures to implement corrective actions and analyze their effectiveness. Pareto chart allows to identify the main reasons which are a starting point to improve the quality of the object.

## 5. Results

In the course of the work, the distribution of cases of failures which occurred in 2016 and 2017 was analysed. According to the data of the KASANT system, in 2017 there were 670 cases of failures of equipment of diesel locomotives, which exceed the number of cases for the same period of 2016.

Comprehensive data on the number and types of locomotive equipment failures is presented in Figure1.


**Figure 1.** Distribution of cases of failures occurred for 12 months by types of equipment of diesel locomotives.

It has been established that there was an increase in failures because of malfunctions of: diesel and auxiliary equipment - by 25 cases; electrical equipment — by 33 cases; on traction electric machines - by 5 cases; on the ventilation system - by 7 cases; for auxiliary electric machines - by 4 cases.

Using the Pareto chart, we identified the most significant failures of diesel locomotives. Figure 2 shows a diagram of the distribution of failures in 2017.

The Pareto chart, which characterizes the distribution of failures by equipment group, shows that diesel and electrical equipment, as well as traction electrical machines, are in the risk zone. These types of equipment are subject to more detailed analysis.

Let us consider in which nodes of diesel equipment a failure can occur: the diesel engine itself, the water system, auxiliary equipment, the oil system, the gas exhaust system, the fuel system, and the diesel regulator. Figure 3 clearly illustrates the distribution of failures by these types of equipment. As a result of the analysis of cases of failure of diesel locomotives due to malfunctions of diesel and auxiliary equipment, it was established that the main causes of failure of a diesel locomotive are malfunctions of the diesel and water systems.

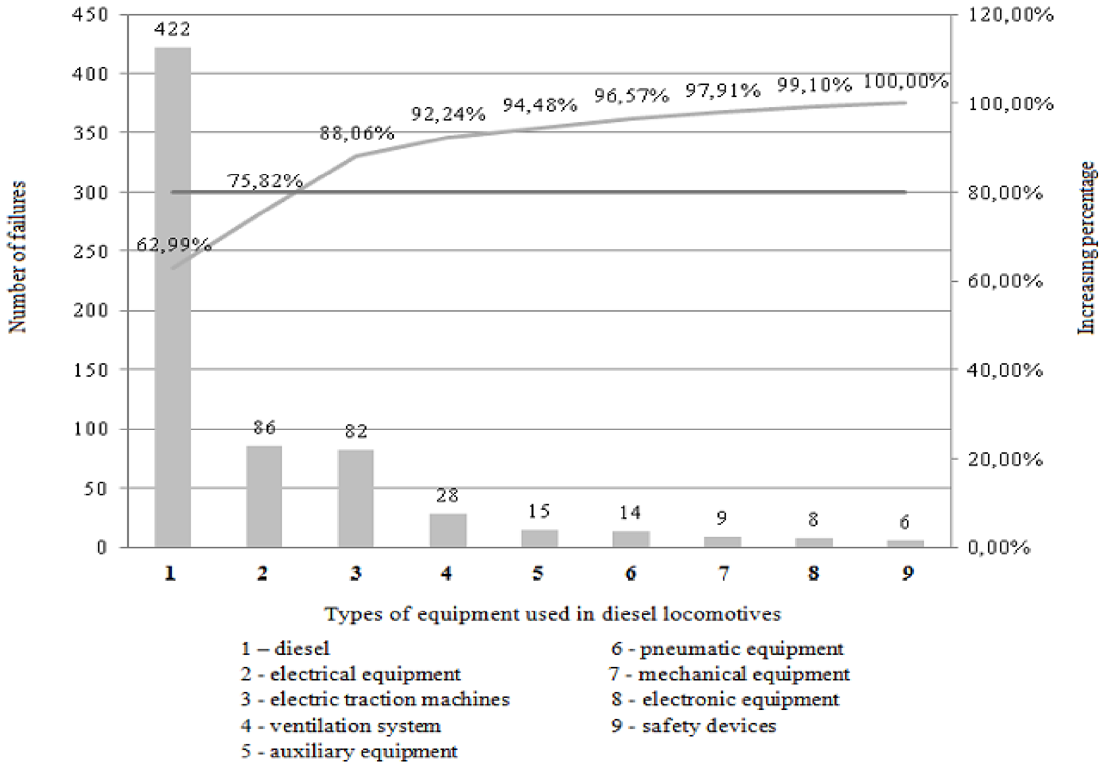


**Figure 2.** Distribution of cases of failures for 2017.

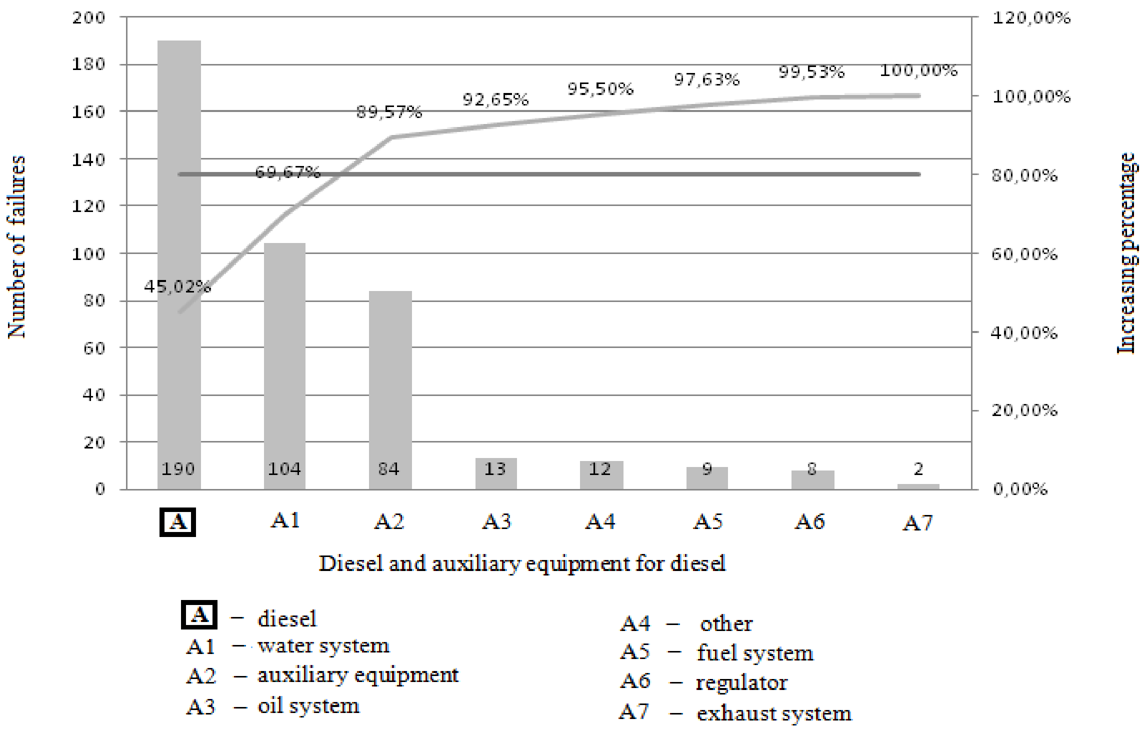


**Figure 3.** Pareto chart for the number of failures for diesel and auxiliary equipment

The next one is the analysis of malfunctions by diesel (Figure 4):

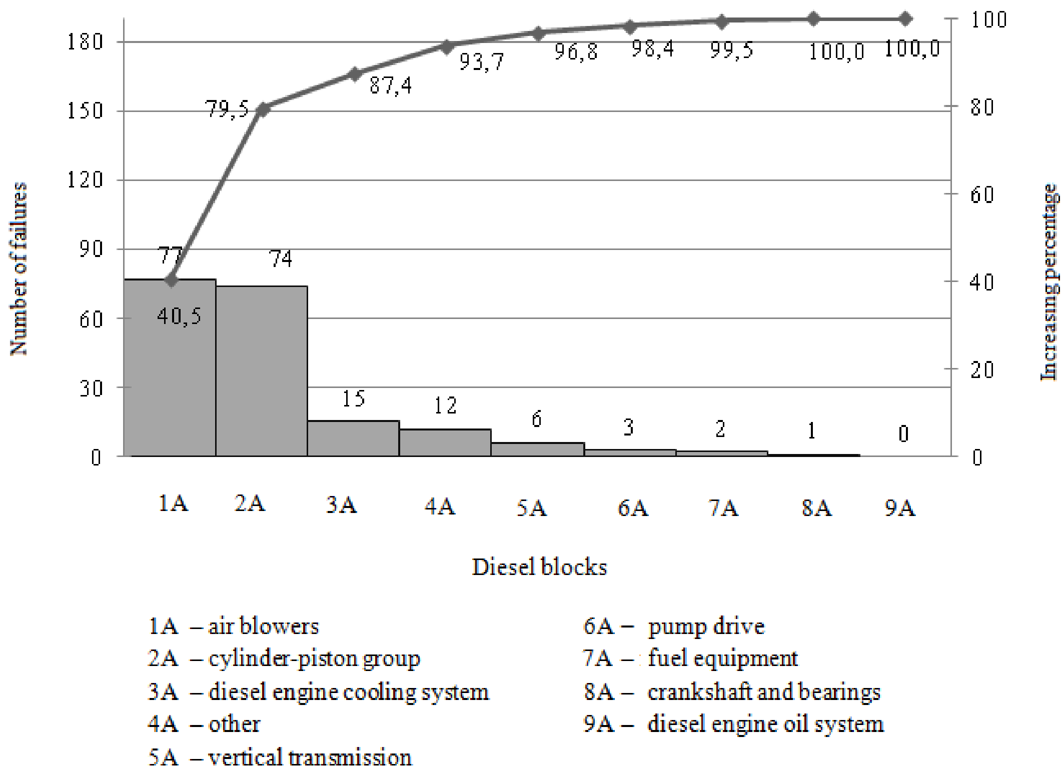


**Figure 4.** Pareto chart for the number of failures by diesel

During the analysis of diesel malfunction cases, it was established that the main cause of the malfunction is the failure of the diesel air blowers (77 cases - 40.5% of the total), as well as the cylinder-piston group of the diesel (74 cases - 38.9% of the total number of failures).

In the blower, there are two groups of failures: the failures of the turbocharger and the failures of the supercharger, which are distributed as follows: the turbocharger - 83.1 (64%), the supercharger - 13 (16.9%).

The main malfunction of the diesel blowers is the failure of the TK-34 turbochargers. In case of malfunction of this node, during the 12 months of the current year, 64 cases of failure or 83.1% of the total number of failures occurred.

As can be seen from the diagram, the main cause of failure of turbochargers is the loss of oil through the turbocharger (Figure 5). This caused 29 cases of failures or 45.3% of the total. However, there are such failures as the breakdown of the hull in 12 cases or 18.8% of the total number, surge in 5 cases or 7.8% of the total number in the risk zone, as well as coking of the nozzle in 8 cases or 7.8% of the total number.

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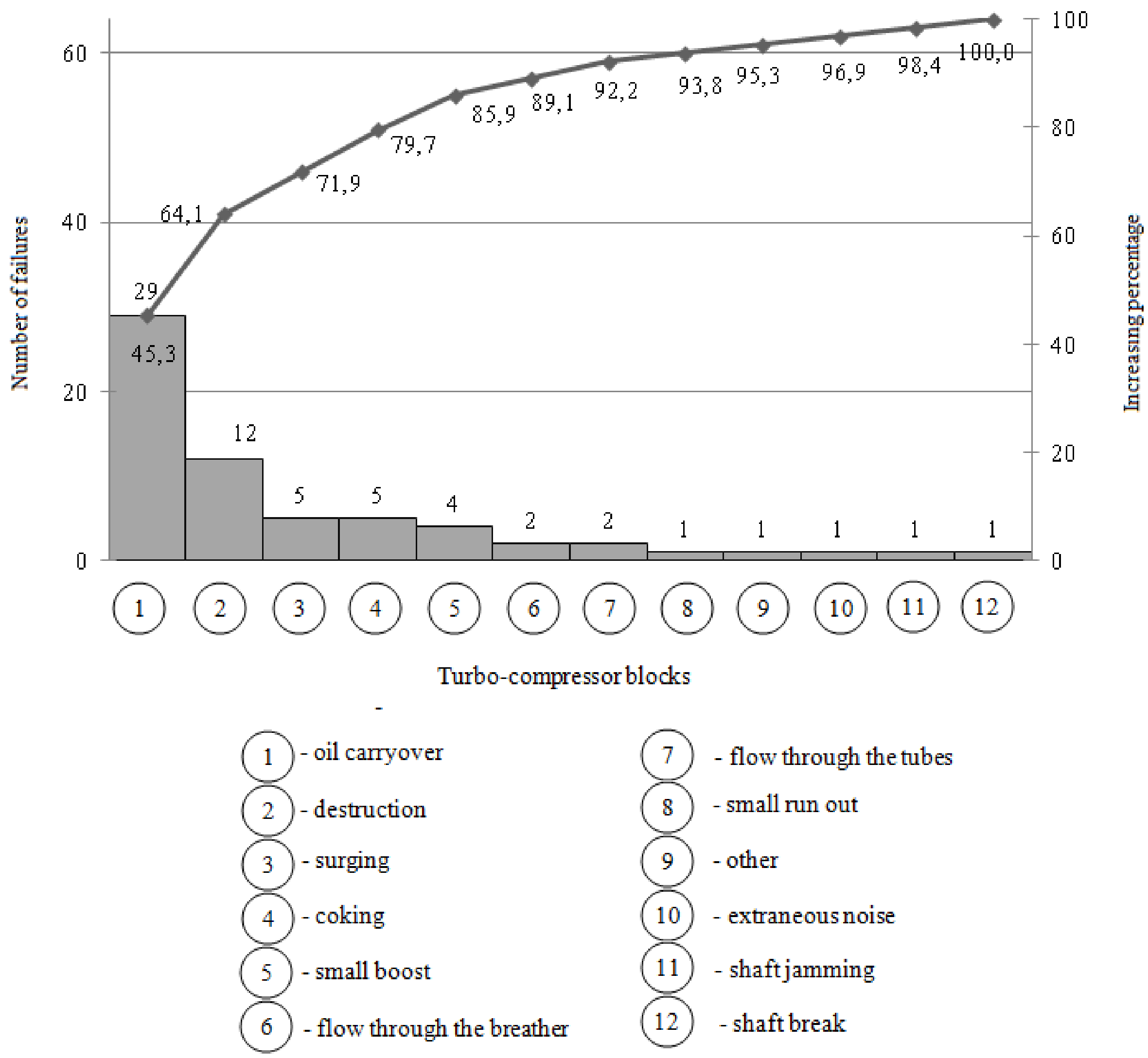


**Figure 5.** Pareto chart for the number of failures by turbo-compressor

## Conclusion

To assess the reliability of the diesel locomotive, a series of tests was carried out in the process of maintenance and technical maintenance using the special test complex KIPARIS and special diagnostic equipment KASANT. The obtained data were processed using factor analysis and a statistical method of quality control, i.e. Pareto chart.

It is established that the main causes of failure of a diesel locomotive are faults in diesel and water systems, in which the main causes of diesel engine failures and the diesel locomotive water system are turbo-compressor failures (64% of the failures). Failure of the turbocharger leads to a supercharger failure. The main reason for the failure of the turbocharger is oil carryover. After identifying the causes of failures in the base depot, an action plan was drawn up to improve reliability and reduce the number of failures of a diesel locomotive.

The statistical method of quality management used in this study allows not only to establish the number of failures in the locomotive units, but also to identify the primary causes of these failures.

## References

[1] Shishmarev V Yu 2010 Reliability of technical systems (Moscow: Academy Publishing House) p. 304
[2] OST 32 46-95 Traction rolling stock of railway transport. Reliability. Terms and Definitions. (In Russian)
[3] Kocherga V G 2012 Validity of diesel locomotives (Khabarovsk. DVGUPS Publishing House) p. 66
[4] Transport strategy of the Russian Federation for the period up to 2030 [Electronic resource] http://www.mintrans.ru/documents/3/1009 (In Russian)
[5] Williams J D, Woodall W H and Sullivan J H 2006 J. of Quality Technology 217 29
[6] Poltavskiy A V, Zhumabaeva A S, Ayzharikov K A, Pivkin A V and Telegin A M 2016 J. reliability and quality of complex systems 74 84
[7] Klyachkin V N and Karpunina I N 2018 J. reliability and quality of complex systems 35 42
[8] Kane M M, Ivanov B V and Koreshkov V N 2008 Systems, methods and tools of quality management. (St. Petersburg: Peter) p. 560
[9] Mikhailov M R 2002 J. Methods of quality management 36 9
[10] Braila N V, Khazieva K L & Staritcyna A A 2017 Results of technical inspection monitoring of the operation object. Magazine of Civil Engineering, 74(6), 70-77. doi:10.18720/MCE.74.7
[11] Klochkov, Y. (2018). Conflicts between quality management methods. Paper presented at the 2017 International Conference on Infocom Technologies and Unmanned Systems: Trends and Future Directions, ICTUS 2017, 2018-January 34-36. doi:10.1109/ICTUS.2017.8285970
[12] Evgrafov A N, Karazin V I & Petrov G N 2019 Analysis of the self-braking effect of linkage mechanisms doi:10.1007/978-3-030-11981-2_11
[13] Desyatirikov F A, Desyatirikova E N, Minakova O V, Akamsina N V & Mager V E 2019 Computer analysis of text tonality based on the JSM method. Paper presented at the Proceedings of the 2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, ElConRus 2019, 220-224. doi:10.1109/EIConRus.2019.8656847
[14] Khvatova T, Block M, Zhukov D & Lesko S 2016 How to measure trust: The percolation model applied to intra-organisational knowledge sharing networks. Journal of Knowledge Management, 20(5), 918-935. doi:10.1108/JKM-11-2015-0464
[15] Desyatirikova E N, Chernenkaya L V & Mager V E 2018 Method of calculating a priori reliability of elements of complex system. Paper presented at the 2018 International Russian Automation Conference, RusAutoCon 2018, doi:10.1109/RUSAUTOCON.2018.8501747
[16] Klochkov Y, Gazizulina A & Muralidharan K 2019 Lean six sigma for sustainable business practices: A case study and standardisation. International Journal for Quality Research, 13(1), 47-74. doi:10.24874/IJQR13.01-04
[17] Kozlovsky V N, Lysov V E, Ermakov V V, Antipov D V & Skripnuk D F 2019 Calculation and statistical experiment on the monte carlo method when assessing the stability of the technical characteristics of the automobile generator set in mass production. Paper presented at the Proceedings of the 2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, ElConRus 2019, 565-568. doi:10.1109/EIConRus.2019.8657034
[18] Kudriavtceva A 2019 SWOT-analysis of digital technologies for an industrial enterprise. IOP Conference Series: Materials Science and Engineering, 497 (1). DOI: 10.1088/1757-899X/497/1/012012
[19] Davliatova M, Brechko A, Lvova N, Sorokin M 2019 Enterprise functioning quality management under conditions of destructive program actions. IOP Conference Series: Materials Science and Engineering, 497 (1). DOI: 10.1088/1757-899X/497/1/012131
[20] Idrisova J I, Myasnikov V N, Uljanov A I, Belina N V 2018 Increasing the efficiency of labor protection in the enterprise. International Conference on Information Networking, 2018-January, pp. 586-588. DOI: 10.1109/ICOIN.2018.8343186