Assessment of car engineering servicing quality based on failure information

Anna Makarova[1], *Nikolay* Zakharov[1*], *Georgy* Abakumov[1], and *Sergey* Elesin[1]

[1]Industrial University of Tyumen, 38, Volodarskogo St., Tyumen, 625000, Russia

Abstract. The article deals with the problem of assessing car engineering servicing quality, the relevance of which increases due to the increase in the level of motorization, risk of road accidents and environmental pollution. The existing methods of assessing car engineering servicing quality are considered. A new indicator for assessing engineering servicing quality is proposed, which is equal to the ratio of failure probability increments before and after engineering servicing. An example of calculation of the proposed indicator for a group of 867 Honda CR-V cars is presented.

1 Introduction

Road transport is an integral part of the transport system. Advantages over other types of transport determine its widespread use. The car fleet is growing rapidly. At the same time, a number of issues associated with its use are becoming more acute. The most urgent problems are environmental and road safety, as well as high operating costs.

Solution to these problems is closely related to providing the proper technical condition of the rolling stock. The most important element of car maintenance system is engineering servicing, designed to reduce the intensity of changes of technical condition parameters, as well as to prevent failures and malfunctions.

In practice, engineering servicing is not always carried out in time. Moreover, in some cases not all the operations specified by the technological process are performed. Some operations are carried out with violation of the technology and deviation of the parameters from the standards. The consequence is reliability indicators decrease in relation to potentially possible values [1, 2].

Thus, improving the quality of engineering servicing is an urgent problem. To solve it, a methodology for assessing engineering servicing quality and taking measures to eliminate flaws is necessary.

2 Research method

A large number of studies have been devoted to the issues of assessing maintenance quality in general and the quality of car engineering servicing in particular [3-6 et al.].

* Corresponding author: zakharov_ns@mail.ru

Engineering servicing quality is usually defined as a relative characteristic based on the comparison of a number of process indicators to a corresponding set of basic indicators. There are three main methods for assessing the quality level: complex, differential and mixed ones.

Each of these methods not only has certain advantages, but also a number of disadvantages. As a rule, a comprehensive assessment is obtained, which does not always correlate with the engineering servicing goals.

Therefore, in this paper, an attempt is made to develop an indicator that gives an integral assessment of engineering servicing quality, which is closely related to car reliability.

When developing a working hypothesis, the following axioms were formulated:

– after engineering servicing, the intensity of changes of technical condition parameters decreases, and this is manifested in decrease of failure probability density;

– as the operating time increases after the consequent engineering servicing, probability of failure increases.

The consequences of these axioms are the following:

- when engineering servicing is performed efficiently, the change of failure probability density at different parts of the cycle is significant;

- comparison of failure probability densities at the initial operating time after engineering servicing and at the operating time before the subsequent engineering servicing allows to evaluate the effect of engineering servicing numerically.

Piecewise approximation of failure probability dependence on operating time in the engineering servicing cycle by two straight lines is proposed on the segments from the beginning to the middle of the cycle and from the middle to the end of the cycle:

$$F(L) = a_1 L + a_0;\ . \tag{1}$$

$$(L) = b_1 L + b_0. \tag{2}$$

Here, a_1 and b_1 are physically similar to failure probability density. A hypothesis is proposed that engineering servicing quality can be estimated by indicator Q_{ES}:

$$Q_{ES} = b_1 / a_1. \tag{3}$$

3 Experimental research

To test the above assumption, an experiment was conducted. For this purpose, data on failures of a group of 867 Honda CR-V cars at a mileage of 0 to 30.000 km were obtained. In the considered time interval, m failures occurred in a group of N cars. Time to failure was equal to L_1, L_2, …, L_m. To solve the problem, empirical failure probabilities at the points L_1, L_2, …, L_m were calculated:

$$F(L_1) = 1/N;\ F(L_2) = \frac{2}{N};\ldots;F(L_1) = m/N. \tag{4}$$

In general form $F(L_i) = i/N$, where $i = 1 \ldots m$.

Based on the obtained data, a graph showing the change of failure probability by operating time was plotted (fig. 1).

The considered operating time interval is divided into two segments in accordance with the cycles, up to the first engineering servicing (fig. 2) and from the first engineering servicing to the second one (fig. 3).

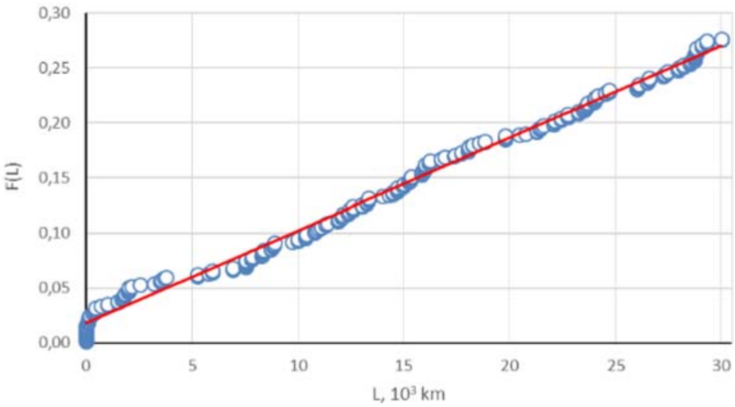

Fig. 1. Influence of operating time on failure probability on the segment of 0 ... 30.000 km

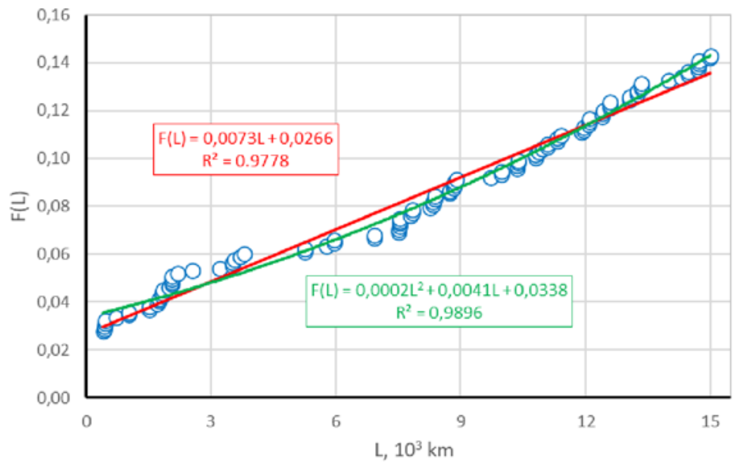

Fig. 2. Influence of operating time on failure probability on the segment of 0 … 15.000 km (the first engineering servicing cycle)

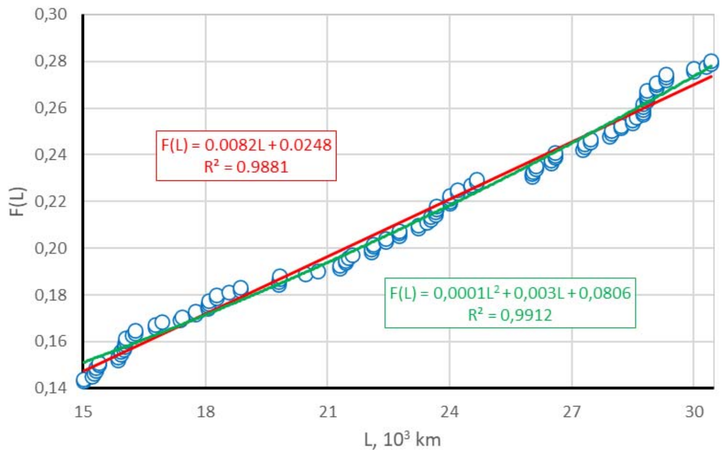

Fig. 3. Influence of operating time on failure probability on the segment of 15 … 30.000 km (the second engineering servicing cycle)

4 Results

To test the assumption that the failure rate decreases after engineering servicing and then increases again, linear trends were plotted on the graphs in fig. 2 and fig. 3. Then these graphs were rearranged in the coordinates "Operating time - deviation of failure probability from the trend" (fig. 4 and 5). The obtained values were approximated by a second-order polynomial.

For the first engineering servicing cycle, the correlation ratio was R=0.687, the probability of its significance, estimated by the Student's t-test, exceeds 0.99. For the second cycle, R=0.717, the probability of its significance also exceeds 0.99. This confirms the existence of the assumed regularity of failure probability changes in engineering servicing cycle.

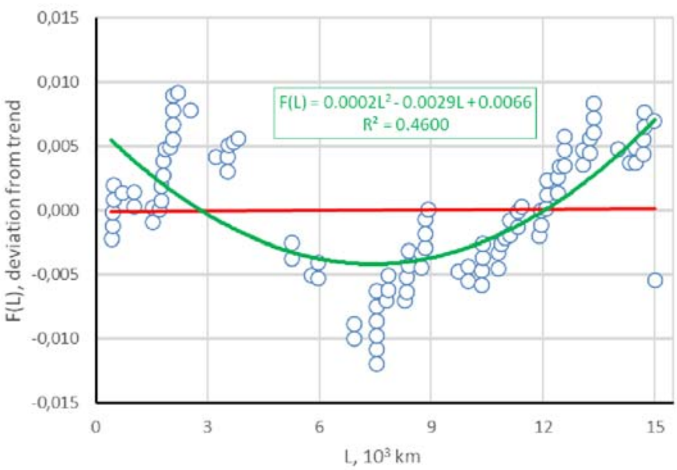

Fig. 4. Failure probability deviation from the trend on the segment of 0 … 15.000 km (the first engineering servicing cycle)

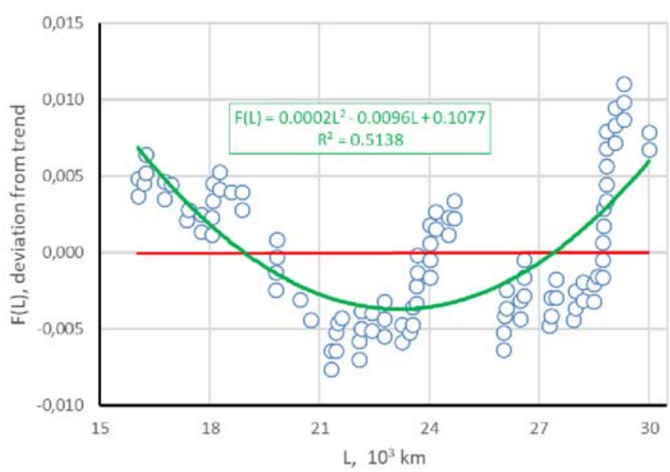

Fig. 5. Failure probability deviation from the trend on the segment of 15 … 30.000 km (the second engineering servicing cycle)

Based on the obtained data (fig. 6, 7), engineering servicing quality indicator is calculated Q_{ES}:

for the first engineering servicing cycle:

$$Q_{ES} = \frac{0.0092}{0.0062} = 1.484. \tag{5}$$

for the second engineering servicing cycle:

$$Q_{ES} = \frac{0.0091}{0.0073} = 1.247. \tag{6}$$

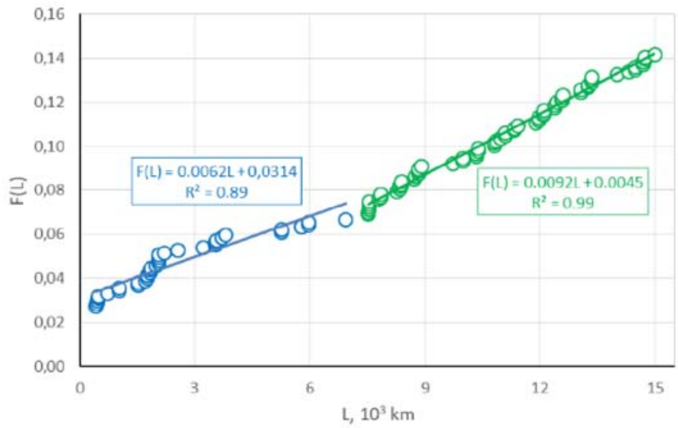

Fig. 6. Piecewise approximation of failure probability dependence on operating time in the first engineering servicing cycle by two straight lines

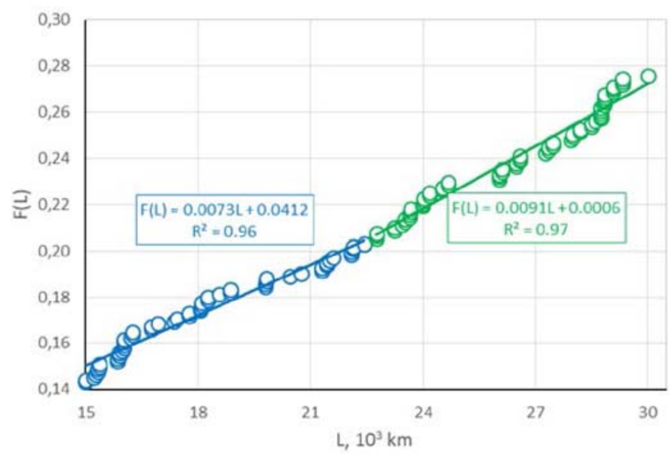

Fig. 7. Piecewise approximation of failure probability dependence on operating time in the second engineering servicing cycle by two straight lines

It is more correct to estimate the value of Q_{ES} according to failure probability dependence on operating time in the second half of the first engineering servicing cycle and in the first half of the second cycle (fig. 8):

$$Q_{ES} = \frac{0.0092}{0.0073} = 1.260. \tag{7}$$

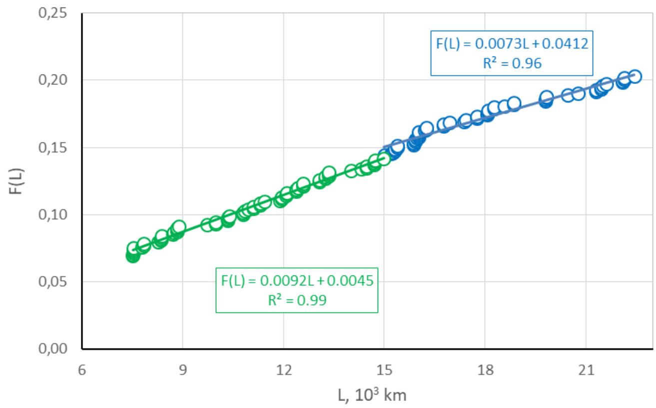

Fig. 8. Piecewise approximation of failure probability dependence on operating time in the second half of the first engineering servicing cycle and in the first half of the second engineering servicing cycle by two straight lines

Thus, the analysis of the obtained results confirmed the existence of the assumed regularities.

5 Conclusion

The performed studies allowed formulating the following conclusions:

- it was experimentally ascertained that failure probability density decreases after engineering servicing and rises with the increase in operating time;

– in the considered cases, the change of failure probability density at different parts of engineering servicing cycle is significant and varies from 1.26 to 1.48 times;

- it is shown that the ratio of failure probability densities at the operating time before the subsequent engineering servicing and at the initial operating time after engineering servicing allows to estimate the effect of engineering servicing numerically;

– for the practical use of the obtained results, it is necessary to conduct similar studies for cars of other brands and models, as well as to evaluate the correlation of the proposed indicator with similar ones, obtained using other methods of assessing engineering servicing quality.

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