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Rational Lifetime of a Vehicle in Terms of Ensuring Security of Its Design

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Abstract

In recent years, automakers have been actively developing and implementing electronic active safety systems. These components and systems increase the vehicle safety, but complicate the design and increase the cost of maintaining it in good condition. Numerous theoretical studies have noted that the nature of the technical readiness coefficient changes during the time of operation exponentially, and by operational kilometers - linearly. The performed research allows concluding that the value of the realized technical readiness coefficient is determined by its minimum permissible value. The performed situational analysis suggests that the solution of the problem to ensure the lifetime of a vehicle, for example, according to the standards of safety features, requires optimization of solutions. This requires the formation of the multicriteria quality scorecards of the vehicle performance properties.

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Keywords: Road safety, optimization, vehicle, criterion, service life.

1. Introduction

In recent years, automakers have been actively developing and implementing electronic active safety systems. For example, the introduction of electronic stability control (ESC) brought the anti-brake system (ABS) to a new

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level of quality of providing security. There are data showing that the number of serious road accidents with one vehicle using the ESC system is reduced to 60%. In addition to ABS, the following systems are actively implemented: dynamic stability control, active cruise control, brake assist, blind spots monitoring systems, etc. Standard passive vehicle safety systems include bumpers absorbing energy on impact with an obstacle, cross bars in doors, pyrocartridges to open the hood and others. These units and systems increase the vehicle safety, but complicate the design and increase the cost of maintaining it in good condition [Kapustin (2015)].

The vehicle, being a high-risk unit, does not allow violations of regulations of its operation, leading to a reduction of road safety. To prevent the possibility of operating the unsafe vehicles, state agencies issue special regulations. For example, the European Commission has adopted a resolution stipulating that all vehicles produced since November 2014 should have the ESC system. The Russian GOST R 53480-2009 now has a term interpreting the article's limit state as a factor that does not allow further operation because of the risk, etc.

2. Main text

During operation, each vehicle reaches a performance limit by individual basic units, or completely. To maintain the operation safety of vehicle there are various strategies of recovering its serviceable condition or removing from line operation (S_1, S_2, S_3 … S_n). The company can decommission the vehicle after it reaches the limit state by any of the criteria (operational kilometers or service life in years). Repairing individual units, their technical parameters can be raised to the desired value. In each case, you need an analytical instrument that allows you to manage the process at the stage of vehicle operation. Numerous theoretical studies [Kapustin (2015), Kapustin (2016), Kuznetsov (1982)], etc. indicates that important properties of the vehicle (fuel efficiency, performance, reliability, road safety) change exponentially during the time of operation:

$$\mathrm{O}(t) = \mathrm{V}_0 \cdot e^{-\beta t}, \tag{1}$$

O(t) is indicator of operational properties of the vehicle; V_0 is indicator value at the beginning of operation; β is coefficient characterizing the change in O by vehicle operation time (vehicle aging intensity).

A similar change of the technical readiness coefficient of β (TRC) during vehicle operation is well described by the equation:

$$k^{TR}(t) = k_0^{TR} \cdot e^{-\beta t}, \tag{2}$$

where k_0^{TR} is technical readiness coefficient value at the beginning of operation.

We can determine the technical readiness coefficient of the vehicle by operational kilometers with the help of a linear function [Kramarenko et al. (1983)]:

$$k^{TR}(L) = 1 - \alpha L \tag{3}$$

where α is the parameter characterizing the dependency of TRC upon vehicle operational kilometers L.

Consider changing the dynamics of unit costs (RUR/1,000 km) for technical maintenance (TM) and running repair (RR) of the vehicle depending on operational kilometers. According to [Prudovsky (1990)], costs and TM and RR ($R_{TO\ and\ TR}$) increase exponentially and there is an analytic relationship between them and the technical readiness coefficient (k^{TR}). At the beginning of operation of the vehicle, costs of TM and RR TS R_0 are

$$R(t) = R_0 e^{\beta t}, \text{ RUR/1,000 km} \tag{4}$$

At the moment of decommissioning with operational kilometers of l_c, the costs for TM and RR R_c,

$$R_c = \frac{R_0 l_c}{k_{min}^{TR}}, \text{ RUR/1000 km} \tag{5}$$

Changes in the vehicle TRC for the period of operation depending on operational kilometers for several options are given in Fig. 1.